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Data, Informatics and Technology: An Inspiration for Improved Healthcare

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Joseph Liaskos
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IOS Press

DATA, INFORMATICS AND TECHNOLOGY: AN INSPIRATION FOR IMPROVED HEALTHCARE

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Data, Informatics and Technology: An Inspiration for Improved Healthcare

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Preface

The current volume presents the accepted papers of the ICIMTH (International Conference on Informatics, Management and Technology in Healthcare). The Organising Committee and the Scientific Programme Committee would like to present to the academic community the scientific outcomes of the ICIMTH 2018 Conference, which is being held from 6 to 8 July 2018 in Athens, Greece.

The ICIMTH 2018 Conference is the 16th Annual Conference in this series of scientific events, gathering scientists from all continents as well as from the hosting country in the field of Biomedical and Health Informatics.

The Conference is focusing on Improving Healthcare by the use of Data in Biomedical Informatics applications spanning the whole spectrum from Clinical Informatics, Health Informatics to Public Health Informatics as applied in the Healthcare domain. Considering that Management and organisational issues play an important role in the implementation phase of Biomedical Informatics applications, topics related to the above themes are also included as an integral part of the overall theme of the Conference. We are treating the field of Biomedical Informatics in a very broad framework, examining the research and applications outcomes of Informatics from cell to populations, including a number of Technologies such as Imaging, Sensors, and Biomedical Equipment and Management and Organisational aspects, such as legal and social issues and setting research priorities in Health Informatics. In essence, Data, Informatics and Technology inspires health professionals and informaticians to improve healthcare for the benefit of patients.

This volume incorporates only the full papers accepted for oral presentation and is published in the Studies in Health Technology and Informatics (HTI) book series which has the advantage of being indexed in some of the major indexing services, such as Medline and Scopus.

At the end of the deadline we had 130 submissions, from which after reviewing we have accepted 80 as full papers to be included in the volume proceedings.

The Editors would like to thank the Members of the Scientific Programme Committee, the Organising Committee, and all Reviewers, who have done a very professional, thorough and objective refereeing of the scientific work to produce a high quality publishing achievement for a successful scientific event.

Athens, 4.06.2018

The Editors,
Arie Hasman, Parisis Gallos, Joseph Liaskos, Mowafa S. Househ and John Mantas

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Automatic Detection of Depression by Using a Neural Network

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Abstract. Depression is the most common psychiatric disorder worldwide, which affects more than 300 million people. We aimed to detect depressed patients and healthy people automatically. We work on the PHQ-9 questionnaires and reduced it to a PHQ-5 questionnaires with a new cut-off value of 8 to detect depressed patients. We trained a Neural Network with 70% of our dataset. Then, the proposed classifier was tested with two datasets. The first one consists of 30% of PHQ-5 datasets, which could achieve 85.69%, 99.11% and 90.56% for accuracy, sensitivity and specificity respectively. The second test dataset consists of physical patient's parameters which recorded during a study in the Hanover Medical School. This classifier has shown good results in the detection of depression based on these two datasets.

Keywords. Depression, classification, neural network, Patient Health Questionnaire (PHQ)

1. Introduction

Specialists are only able to detect half of the patients with depression in primary care (especially old adults). As a result, almost 50% of patients do not receive any care [1]. Therefore, designing a quick and automated system is necessary for diagnosis of depressed patients [1]. Depression is one of the most uncommon psychological states that increases the likelihood of developing chronic diseases such as heart disease, obesity, diabetes, and in extreme cases of suicide. A patient with depression constantly feels frustrated and does not want to do routines daily works [2]. Mallikarjun et al. used EEG signals from 47 subjects with PHQ-9 (Patient Health Questionnaire) to predict depression. According to the PHQ results, the EEG signal could be categorized into two classes: depression and normal. The different features are used for support vector machine (SVM) classifier and accuracy of it is 75% [3]. Wahle et al. used the Mobile Sensing and Support (MOSS) app that extracted different features through Wi-Fi, accelerometer, GPS, and phone usage statistics. They used Random Forest and SVM classifier. These binary classifications have 60.1% and 50.9% accuracy, respectively according to the PHQ-9 with a cut-off value 11. It was considered to set PHQ-9≥11 as a depressive subject and PHQ-9<11 as a normal subject [4]. Jin et al. have been

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proposed a 2-level Poisson regression model to predict the PHQ-9 score. They used longitudinal data from Diabetes-Depression Care-management Adoption Trial. This method could be able to predict the presence of depression [5]. The purpose of our research is to investigate and implement the classification for the diagnosis of depression. Therefore, we present a 3-layer MLP neural network for automatic classification of depression by using PHQ questionnaire and also physical parameters of patients. Distinguish between the importance of different inputs is a tough challenge. The automatic calculation of the weights for different inputs was one of the reasons that we choose the neural network. During training the neural network, more important inputs receive more weight and have a more effective role in determining the output.

2. Methods

In this study, we examined the results of the PHQ questionnaire which reduced to five questions (PHQ-5) and also physical parameters which recorded by a SenseWear wristband. It is a multi-sensor system to record the physical parameters. This sensor is used to understand the impact of physical parameters performance on the diagnosis of depression. The five selected questions of the questionnaire correspond with individual physical features. The other questions explore the psychological dimension of the patient. We want to examine the impact of the five physical questions and their similarity with measured physical features for classification of the disease.

The PHQ is a self-administrated and very worthwhile questionnaire, which has a practical usage for diagnosis of mental disorders. This questionnaire has 9 questions with grade between 0 (not at all) to 3 (nearly every day). Most of the tested depressed patients had scores of 10 or more and healthy people had scores less than 10 with the PHQ questionnaire [6]. We used the US National Health and Nutrition Examination Surveys (NHANES) database from 2005 to 2016 to investigate the neural network classifier. NHANES is a cross-sectional observation study which was done by the National Center for Health Statistics [7]. 34963 individuals participated in NHANES from 2005 to 2016. 31213 questionnaires are valid with acceptable scores. We considered non acceptable scores as outliner and removed them from dataset. Our test dataset for physical parameters is a part of the data from the PREDICT Study which was done at the Mental Health Department of Hanover Medical School between 2013 to 2015. In this study, we had 14 patients suffering from depression with different severity. We measured their physical parameters by SenseWear sensor at the beginning and end of their hospitalization. The output of this device is a dataset with 27 features. We recorded physical parameters for 24-hours per day. The durations for the measurement phases are different for each patient. Therefore, we separated the datasets into 119 whole days. For preparation of the physical parameters dataset, we used the mean value of each feature during one day, so the effect of outliners was decreased by this pre-processing.

We trained our proposed neural network with the five selected questions of PHQ dataset. The important issue is to determine the appropriate cut-off value while the questionnaire is used with five questions. For this purpose, we investigated different cut-off values to realize, which of them fit to distinguish depressed and healthy individuals. We tested different cut-off values and observed that for different data, the accuracy of cut-off value 8 is more acceptable than the others.

In the next step, we used 30% of PHQ-5 datasets for testing the classifier and also physical parameters were used to find out relation between them and depression.

Whereas our classifier needs five features as input neurons, we selected the mean value of: physical activity, activity classification, sleeping, power consumption and metabolic equivalent parameters for each day. These features correspond well with the questions of PHQ-5 questionnaire.

A multilayer perceptron (MLP) is a feed forward artificial neural network which is used in this paper. MLP neural networks consist of at least three layers which in each node of hidden and output layers use a nonlinear activation function. This neural network uses back propagation technique as a supervised learning method for training. Our MLP network used the "trainlm" function as the train function and "radbas" and "tansig" functions as the transfer functions. We used 10-fold cross validation to evaluate the accuracy of the proposed method. It divided the training data into 10 approximately equal size parts. One of these parts was used as test data and the classifier was trained with the other parts. This method was done 10 times with different combination of data. Finally, the validity of the results is obtained from the ten-time accumulation. This accumulation, based on the algorithm, is evaluated on the validation.

Moreover, the physical parameters are used to test the proposed neural network. Our classifier is validated in terms of accuracy, specificity and sensitivity.

3. Results

The MLP neural network classifier was used to predict the depression for self-reported PHQ-5 dataset and also five selected physical parameters. The accuracy of PHQ-5 questionnaires with cut-off value 8 is about 85.69%, also sensitivity and specificity are 99.11% and 90.56% respectively. We can see that the elimination of four questions has not significantly reduced the performance of the neural network. It is still capable of separating two classes from each other with high precision. We can conclude that the questionnaire reduced to five questions is adequate to separate a depressed person from a healthy one. After achieving good results with the proposed classifier, we want to discover, which physical parameters of persons could be used as input features for neural network classifier. We therefore used five physical features which were recorded by SenseWear sensor. This classifier allocates all these data to depressed class. It is anticipated because these data were related to depressed patients with different severity. Table 1 shows the results of our classifier which was tested with two different datasets.

Table 1. Comparison of different algorithm to detect depressed patients

MLP Neural Network	Accuracy	Specificity	Sensitivity
PHQ-5 dataset	85.69%	99.11%	90.56%
Physical Parameters dataset	100%	100%	---

4. Discussion

We categorized the PHQ questionnaire dataset by using the 3-layer MLP neural network. We examined the impact of various questions in the questionnaire and also relation between different questions of PHQ questionnaire and physical parameters of SenseWearsens or. It can be considered the first five questions of PHQ questionnaire and five specific physical parameters have interdependence to each other.PHQ-5 questionnaire has sufficient and reliable ability to use for distinguishing depressed patients from other.

Meanwhile, the physical parameters: physical activity, activity classification, sleeping, power consumption, metabolic equivalent have high ability to use as criteria for distinction between healthy and depressed individuals. Physical features could be used for older people and depressed patients during therapy. We want to measure the impact of treatment cycles on them. Our limitations in this method are that we do not have the physical data from healthy persons or patients which occurred. If this kind of data were available, we could have a better conclusion for neural network classification. Moreover, we need to evaluate our results of PHQ-5 dataset with physicians.

We can improve our classifier to detect different severity of depression, but we need physical data related to each phase of depression. In addition, we can work on the time duration of data to find out the best time duration which be able to detect depressed patients. Moreover, our classifier has shown good results in detection of depression with these datasets. So, we can conclude and test an automatically classifier for depressed patients with a mixed dataset of self-administrated questionnaire and physical data, and also investigate the other machine learning methods. We would like to use neural network to identify which physical parameter has a significant impact on depression detection. Therefore, we can find out the unique feature which can help physician to diagnose depression disease.

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Concept for Sharing Distributed Personal Health Records with Blockchains

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Abstract. The characteristics of the "blockchain" technology and especially its decentralized nature lead to the notion of neutrality, censorship resistance, and absolute truths, which makes the concept interesting for many different domains, such as finance, supply chain management, or the energy sector – of course also for the healthcare area (eHealth). Blockchains also offer the possibility for well-known access points for a distributed system with easy to use and simple to integrate programming interfaces, which makes it interesting as a central point for electronic healthcare data exchange in a distributed environment. This paper presents a concept for integrating and sharing distributed personal healthcare records based on smart contracts implemented on an Ethereum blockchain.

Keywords. Personal health records, blockchain

1. Introduction

During the last decade there has been a big drive towards inter-organizational healthcare data exchange to improve quality of care for patients. Efforts for easing exchange of medical data are shown by several national initiatives, while European initiatives especially demonstrate an emphasis on cross-border exchange of such data [1]. Beside this health related data provided by the citizen him-/herself and stored in "personal health records" (PHRs) is expected to play a major role in future healthcare. Especially with the increasing number of mHealth applications for smart devices (e.g. smartphones), which often include data from personal health devices, the advantage in context of monitoring and self-management of chronic diseases is obvious. But unfortunately these apps and services have their own small "ecosystem" leading to an infrastructure with several isolated archives which need to be integrated and to be shared with medical professionals. This leads to challenges in integrating these data, implementing access control and provide an easily accessibly "entry point" [2,3].

In July 2016, the "Office of the National Coordinator (ONC) Tech Lab" in the US published a "Use of Blockchain in Health IT and Health-related Research" Ideation Challenge addressing potential use of blockchain technology in Health IT to address privacy, security, and scalability challenges of managing electronic health records and resources [4]. Possible use cases for blockchains in healthcare are for example creating and sharing secured and trusted health information, sharing consent (access control) information for health records, store audit log information for healthcare data access or billing and reimbursement.

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The aim of the work which results are presented in this paper was to show the possibility to design and implement an integration layer for sharing distributed personal health records using blockchain technology by providing the following functionalities:

- Register data from distributed PHR systems in a central registry
- Provide central access to single data sets
- Log access to data for audit purposes.

2. Material

In its original meaning, a blockchain can be described as a shared, append-only database that hat is constituted by many identical self-synchronizing copies on several distributed nodes connected over a peer-to-peer network. There is no centralized person/institution/body who/which has control over it and a consent algorithm ensures the consistency of the data stored on the chain. One of the core characteristics is that all users with access to a blockchain can read and write to a blockchain, but nobody can change transactions after they have been included in it, i.e. data written once to the blockchain can never be changed or deleted, because this would break the integrity of the chain. Thus, attempts to modify data are immediately detected [5]. This makes it for instance perfect for storing audit event information about health care data access.

Users are not known with their personal data but are represented by an address and are therefore anonymized [5].

Furthermore blockchain systems offer a simple programming interface for accessing the blockchain with read and write operations and are easily addressable over well-known nodes [5]. Therefore blockchains may act as a central integration layer for distributed systems.

The concept of blockchains was firstly described by a person known under the synonym “Satoshi Nakamoto” and was the basis for “Bitcoin” [6]. Bitcoin is a value transfer protocol and its capability is basically limited to just store transactions (transfer x coins from A to B). In further development of the blockchain technology Vitalik Buterin described a system implementing “Smart Contracts” (a theoretical concept from the 1990s [7]) and started a blockchain named “Ethereum” [8]. Smart contracts are pieces of code which can be stored and instantiated on a blockchain and used for arbitrary purposes. A smart contract can have functions and variables, whose values represent the state of the contract. This largely widens the functionality and offers the possibility for covering complex use-cases and enables the implementation of the required functionalities based on smart contracts.

3. Results

As blockchains are not designed to hold big amounts of data over the years, all healthcare records are stored “off-chain” and are only represented on the blockchain by smart contracts holding references to the original data. Figure 1 shows the set of smart contracts to implement the PHR integration layer which have been subsequently implemented with Ethereum’s program language “Solidity”.

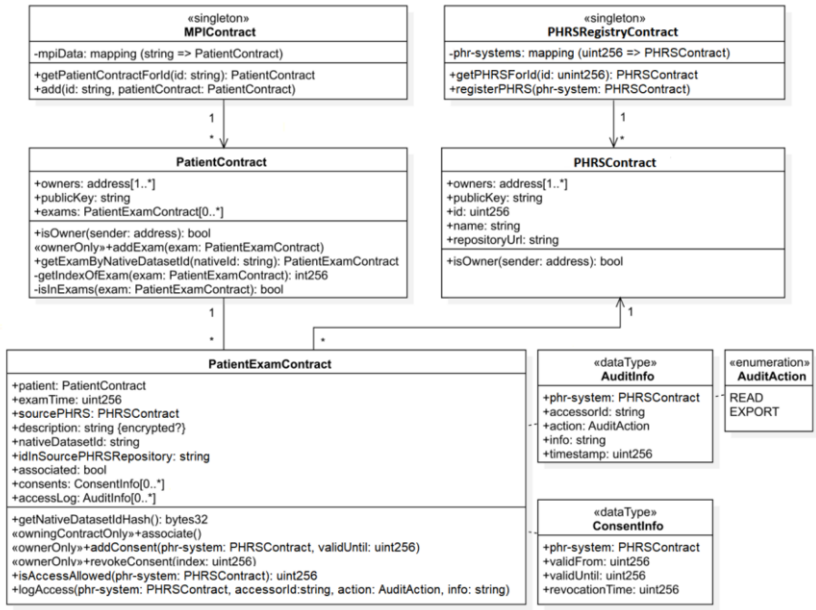

Figure 1. Basic Smart Contract Model

The center of the model is *PatientExamContract* which represents and is linked to a single piece of health information in a personal health record system. This contract is bound to a specific person by the *PatientContract* and to a PHR system storing the original health record by *PHRSContract*. While the *MPIContract*acts like a master patient index (MPI) and holds all known users (in form of their *PatientContract* representation) the *PHRSRegistryContract* represents a list off all participating PHR systems. In all contracts no human readable identifying information (like names) are stored to ensure anonymity.

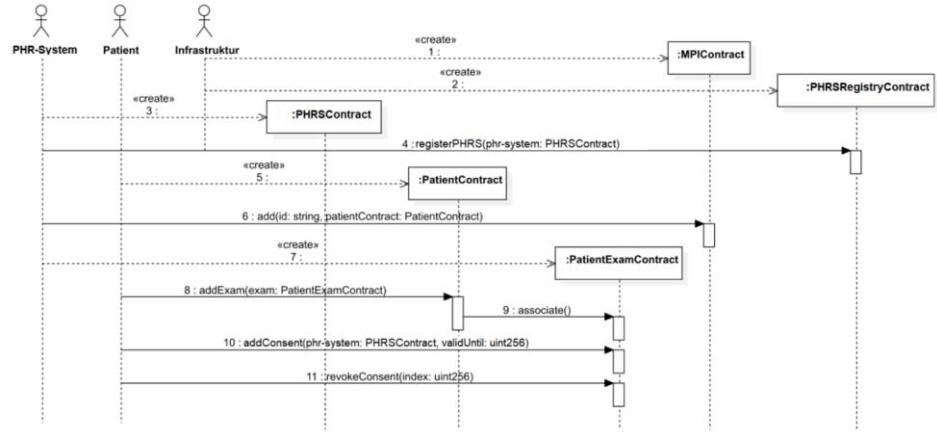

Figure 2. Sequence diagram

Figure 2 presents the sequences to provide the required functionalities. All participating persons as well as PHR systems enter the system by creating contracts representing them (*PatientContract* / *PHRSContract*) on the integration layer (steps 3 and 5). When a person wants to share some of his/her records he/she provides the blockchain address to the PHR system which is then able to create *PatientExamContract*s for healthcare records (step 7) and keep their addresses in its own database. In any case the record owner has to confirm the exam contract is his/hers (steps 8/9). Now the record can be shared with any other participant (person or system) known to the integration layer based on the blockchain address. Calling the add Consent() function adds an instance to the list of authorized users for a *PatientExamContract* (step 10), revoke consent removes it (step 11). Every access to the record can be logged by the PHR system by invoking the "logAccess" function in the appropriate *PatientExamContract*and by this creating and immutable audit event directly on the blockchain.

4. Discussion

The presented model is just a proof of concept regarding the technical feasibility of using blockchain technology for an integration layer for personal health records. There will be several organizational, usability, security and privacy challenges to overcome when it comes to an implementation of such a system under real world conditions.

Also an open issue is the type of blockchain to be utilized. Using a public blockchain will not be practical in the healthcare domain. Implementing a community blockchain raises the question about the consent mechanism to choose and the involved stakeholders.

At a last point it has to be mentioned, that a blockchain based integration layer does not contribute to making healthcare records and systems interoperable– i.e. for sharing records based on such a concept, interoperability standards such as HL7 FHIR would still be required.

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Towards Preventative Healthcare: A Review of Wearable and Mobile Applications

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Abstract. Wearable and mobile devices are now commonly used in our daily activities, giving users instant access to various information. One the one hand, wearable and mobile technologies are developing at a fast rate and have been increasingly ubiquitous. On the other hand, the potential of their application in health is yet to be fully explored. This paper attempts to sketch an overview of wearable and mobile applications in the healthcare domain. We first review how various wearable and mobile applications are being used to monitor and manage health conditions. Then how connections between physiological factors and psychological factors can help with disease prevention is presented. Finally, challenges and future directions for further developments of these emerging technologies in health are discussed.

Keywords. Healthcare, wearable and mobile devices, disease prevention.

1. Introduction

Wearable and mobile devices are now commonly used in our daily activities, giving users instant access to information and communication [1]. More specifically, the rapid developments and advances of technologies in low energy wireless communications, sensor miniaturization and data analysis in the cloud, have paved the way to innovation in digital health using wearable technology for improved health outcomes [2,3]. However, the potential of their application in health is yet to be fully explored. There are still many challenges to be addressed and more work to be done to make most use of these emerging technologies to achieve comfortableness, integration, functionality and fashion for their application in the healthcare domain [4,5]. Developing wearable solutions for healthcare is a broad research topic that involves knowledge across multiple research fields including electronic engineering, computer science, design, psychology, health and medical science. As a result, latest research developments on this topic are often reported in the literature of these very different fields. In this paper, we attempt to put the advances in these fields together. We first review how various wearable and mobile applications are being used to monitor and manage health conditions. We then present how detecting and measuring internal mental states and

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conditions such as cognitive load, stress, fatigue and anxiety is paving the way to a future of health focused disease prevention. Finally, we discuss some challenges and propose some future research directions.

2. Wearable and Mobile Applications for Monitoring and Management of Health Conditions

2.1. Technologies

Various wearable technologies have been built and introduced in the healthcare and fitness domains. These technologies range from consumer-driven devices, such as Apple Watch, Google Glass, to those developed specifically for certain applications, such as wrist-worn sensor for measuring the onset of seizures, a wearable for monitoring arrhythmias at homes [6]. Google has developed wrist-worn sensors for the continuous measures of pulse, activity and skin. Google Glass with built-in sensors has demonstrated the ability of collecting heart rate and respiratory rates. The Apple Watch biosensors can measure heart rate, balance, sleep pattern, gait, activity level, hearing and inhaler usage. Other commercial companies have developed wearable devices which can be used for heart-related monitoring (such as central aortic pressure) and brain-related monitoring (such as recording of the brain's electrical activities) [7].

In addition to wearable electronics, emerging biosensors have been explored to enhance the data collection, such as hand-held electrocardiograph monitors, body patches that capture physiological responses, and smart inhalers with Bluetooth capabilities [8]. These technologies provide measurements that can be used for short-term sampling in a clinical laboratory or long-term monitoring in a medical setting.

Smartphone applications (apps) have been used to couple with wearable devices and sensors to provide interfaces for visualization of measurement data, persuasive notifications and personalized digital interventions. In conjunction with the smartphone, additional personal data can be collected to provide insight into individuals' up-to-date activities and behavior [9]. Subjective questionnaires can be integrated with the tools that measure how the patients feel about their own conditions [8]. The joint use of wearable devices, apps and persuasive notifications supports the delivery of timely and tailored interventions to encourage behavior change. To better support clinical studies, Apple Research Kit (https://www.apple.com/au/researchkit/) has been developed to enable the easy creation of apps and platforms for different care needs and allow the measurement data to be collected efficiently for analysis.

2.2. Healthcare applications and impact

Wearable devices have been used to support personal fitness, self-monitoring of chronic diseases, self-management of cardiac rehabilitation, physical rehabilitation for surgeries and integrated care for mental health and cancer patients (e.g. [2,10]). Clinical trials and evaluation studies have been conducted to demonstrate the benefitsof new wearable technologies in healthcare. It has been shown that the data generated from wearable devices could potentially improve healthcare efficiency [11]. In addition, wearable devices enable clinicians to better deliver the care and monitor their patients' wellness. The use of wearable devices and smartphone-based programs can help to yield beneficial results in terms of patient engagement, uptake and adherence to care

programs [2]. Researchers have also explored user acceptance of wearable devices and associated healthcare apps. Positive results toward the adoption of the technologies have been demonstrated [12]. The perceived ease of use plays an important role in the adoption of healthcare wearable devices. Technology adoption in elderly also demonstrates that wearable and mobile devices allow them to live independently, safely and conveniently at their own homes as more and more seniors are connected to the digital world [4].

3. Wearables and Mobile Apps for the Prevention of Diseases

Internal mental states and conditions such as cognitive load, stress, fatigue and anxiety have a direct effect on our health and wellbeing and have the potential to help us shift from managing diseases to proactively preventing diseases. For example, as people experience stress too often and at a too elevated level, they eat and drink more, sleep less and socialize less. Chronic stress has also been shown to lead to increased inflammation and increased risk of cardiovascular and neuropsychiatric diseases. Stress causes changes in heart rate (HR) and heart rate variability (HRV) [13]. Empirical studies have been conducted demonstrating that HRV can be used as a biomarker of stress. Welltory (https://welltory.com/) is an example of wearable and mobile apps for the detection of stress using HRV data. Cognitive load is the total amount of effort imposed on working memory [14]. As people operate under high cognitive load, they make mistakes and forget things [15]. In a health context this could potentially translate into forgetting to take prescribed medication and/or taking the wrong one. Shi et al. [14] found that peaks of Galvanic Skin Response (GSR) data were significantly related to challenging tasks, indicating that GSR can be used as an objective indicator of cognitive load. Fatigue is a subjective feeling of tiredness and can have physical or mental consequences, or a combination of both. Research has found that physical fatigue causes changes in certain saliva peptides and that this salivary measure can be used as an objective biomarker index for fatigue [16]. SmartCap uses EEG data to detect a truck driver's fatigue (http://www.smartcaptech.com).

Anxiety is a medical condition caused by excessive and persistent worrying. It affects how we feel and behave and can cause physical symptoms such as changes in blood pressure. Tichon et al. [17] examined to what extent several physiological measures can be used to accurately reflect changes in anxiety in the context of flight simulation training and found that high perceived anxiety was correlated with increases in tonic muscle activation. The connections between psychological factors and physiological factors make wearable and mobile applications possible for disease prevention [3,18]. As a result, many applications have been developed for detecting physiological signals to measure psychological factors so that timely action can be taken when a person's health condition is showing alarming signals.

4. Discussions and Future Directions

The state-of-the-art wearable technology devices have been motivated by the actual needs in healthcare and the market. Factors, such as design, aesthetics and acceptability, are becoming important in the design of these technologies [6]. Comfort and usability need to be considered as the use can be difficult for some patient populations [8].

Furthermore, future wearable devices are expected to extend to a wider use in healthcare and the issue of privacy and security will need to be addressed. While wearable devices and biosensors can track specific behavioural characteristics for patient conditions, one of the big challenges is data analysis and translate the large amount of data into a meaningful way for intervention and care needs [11].

It should be noted that the review we presented here is mainly based on the literature that we collected from our past research. Therefore, it is only indicative. Future work should address how we improve and augment our ability to proactively manage our health and wellbeing [1,11]: 1) what is the role played by emotion, intention, motivation, cognitive load, fatigue and stress in proactive management of health? How might we support these factors using wearable and mobile computing? 2) how might we effectively influence behavioral changes for long term improvement of health and wellbeing outcomes? What are the factors that influence adherence to healthy life style? How might we address the adherence issue using wearable and mobile computing?

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Unmet Needs of Persons with Down Syndrome: How Assistive Technology and Game-Based Training May Fill the Gap

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Abstract. The use of new technology seems to be an important factor that contributes to the overall ability to adapt and achieve higher independence. Technologies using digital games have gained the great interest of the scientific community as there are many advantages for both effectiveness and benefits, physically and mentally, providing the opportunity for essential and enjoyable training. This study presents an important initial step utilizing the LLM Care service which focuses on the needs and challenges for the health and daily living of people with Down syndrome (DS) by applying new technology hardware and software. People with cognitive impairments, such as memory, attention and motivation problems may also benefit from this kind of cognitive support that assistive technology offers.

Keywords. Intellectual disabilities, Down Syndrome, healthcare, physical-cognitive training, quality of life, independent living, LLM Care, leisure activities

1. Introduction: Independent living of People with Down Syndrome

Down syndrome (DS) is one of the most well-known genetic disorders that occur due to the defective chromosome separation during fetal conception affecting the overall individuals' condition, such as physical, cognitive and psychosocial development [1]. It is one of chromosomal disorder that its average appearance is about 1 in 600/1000 birth (www.globaldownsyndrome.org). People with Down syndrome have a wide range of functional abilities associated with various sensory and motor damages, memory, knowledge and communication skills [2-3].

In recent years, the increasing trend of technological evolution is considered to have significant impact in improving the quality of health services. Considering that the poverty rate for people with intellectual disabilities is 70% higher than the average, it is easily understandable that there is an important need of easy-to-use systems development that aim at participation, employment, education and training, leading to quality of life improvement.

The use of new technology seems to be an important factor contributing to overall ability to adapt and achieve a higher independence. More specifically, the role of

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technology in learning environments is vital as there are few studies exploiting the use of digital games for learning purposes, known as "game-based learning". These technologies have gained interest in the scientific community, as there are many advantages in both efficacy and benefits for learning purposes [4-6]. In addition, the use of video games as a form of rehabilitation, incorporates fundamental elements of kinetic learning [7], while stimulating users to do the exercise by providing an intensive, meaningful and enjoyable training [8].

2. Rationale, aims and objectives

The aim of the current study is to present an important initial step by exploiting the LLM Care service focused on needs and challenges in health, social and daily living of people with Down Syndrome (DS). The LLM Care was initially exploited to provide the essential cognitive and physical training for improving cognitive and physical health of the elderly, improving at the same time theirs and their relatives' quality of life. LLM Care also expanded its services by searching innovative ways and exploiting the advantage of developing new innovations specialized for people with intellectual disabilities. Furthermore, the "Training Program for Improving Quality Of Life Through Inclusive Leisure for Persons With Down Syndrome", called DS Leisure Project will contribute to the improvement of their quality of life aiming at increasing the competences in terms of attitudes, skills and knowledge.

The study is conducted since 2016 by the Medical Physics Laboratory of the Aristotle University of Thessaloniki (http://medphys.med.auth.gr/) in collaboration with the Down Syndrome Association of Greece (https://www.down.gr/) and Nonprofit Organization "Spring Children" (http://tapaidiatisanoixis.gr). This procedure was equipped by medical practitioners who was sufficiently trained and certified to facilitate knowledge acquisition, improve decision making and skill coordination to provide appropriate training by engaging the users and delivering quality care.

3. A pipeline designed for supporting vulnerable people by exploiting Assistive Technologies

Assistive technology is designed to deliver health and social care services by supporting cognitive functioning, improving independence, and providing quality of life [9]. People with cognitive impairments, such as memory, attention and motivation problems may also benefit from this kind of cognitive support that assistive technology offers [10-11]. Barriers created by disability or impairment may be removed using this technology, as it can improve cognitive and motor skills through computational devices [11-13]. Through DISCOVER, training resources and additional support can be explored by encouraging personalized and collaborative learning (http://learn4care.gr/). In this direction, DS Leisure Project will be also useful as exploits high quality adapted learning materials tailored to the needs of Persons with Down Syndrome to acquire digital skills related to the use of Assistive Technologies (http://www.dsleisure.eu/).

In recent years, focus has been evolved to the quality of life including well-being, cognitive, physical, as well as emotional improvement in specific groups of people. It is worth mentioning that assistive technology may augment the quality of life of individuals with intellectual disabilities, and specially people with Down Syndrome

[14]. Assistive technology can improve communication and emotional skills, as well as daily living and other adaptive skills of people with neurodevelopment disorder [15].

Apart from expected benefits of computerized interventions that assistive technology offers, this approach achieves higher user's quality of life, good first training results on cognitive and physical condition and all the above achieved under a limited learning effect. Feedback regarding the usability, applicability and value will be provided by end users, professionals and involved stakeholders to determine a holistic patient-centered approach.

4. LLM Care Innovation

LLM Care service is defined as an integrated ICT platform which combines state-of-the-art mental exercises against cognitive deterioration with physical activity in the structure of an advanced ambient assisted living environment. This technological solution coincides with daily monitoring and helps to increase overall feeling of safety and self-confidence.

LLM Care service aims at providing the vital cognitive and physical training to the elderly people aged above 50, as well as vulnerable groups of people. It includes new technology hardware and software in order to improve or maintain the quality of their life [17]. It includes an integrated solution that has the advantage to combine independent living solutions with cognitive and physical training [18]. The whole system is based on recent research that claims the effectiveness of moto-sensory training on senior citizens with cognitive problems or mild dementia [19].

LLM Care exploits information technologies, services, and solutions, so as to deliver better health care services [16]. Taking into consideration the needs of professionals (increased knowledge, skills and collaboration), patients, carers (personalized care, care coordination and continuity of care) and medical students practice (experience and knowledge acquisition), the healthcare ecosystem (local level, cost-effectiveness and sustainable approach) should be easily adopted in order to cope with current and future changes by involving new groups of people [20].

5. Conclusions

LLM Care appears to be a vital tool, designed as a social ecosystem providing healthcare specialized for elderly and vulnerable populations. Moreover, DISCOVER is exploited to integrate digital technology into their everyday life using ICT tools, as well as DS Leisure that uses adapted learning materials and tools as support the effective use of Information and Communication Technologies (ICTs). The abovementioned combination may contribute to overall adaptability and higher independence as it focuses on the needs and challenges for the health and daily living of people with Down syndrome.

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LLM, namely, LLM Care which is a self-funded initiative at the Aristotle University of Thessaloniki (www.llmcare.gr).

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Risk Thresholds and Risk Classifications Pose Problems for Person-Centred Care

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Abstract. Classification of a continuous risk score into risk levels is common. However, while the absolute risk score is essential, it is arguably unethical to label anyone at 'high, moderate or low risk' of a serious event, simply because management based on a single criterion (e.g. avoiding the target condition) has been determined to be effective or cost-effective at a population level. Legally, mono-criterial risk labeling can inhibit the obtaining of a fully-informed, preference-based consent, since multiple considerations (various benefits and harms) matter to most individuals, not only the single criterion that is the basis of the provided risk category. These ethical and legal challenges can be met by preference-sensitive multi-criteria decision support tools. In this future vision paper, we demonstrate, at a conceptual proof-of-method level, how such decision support can and should be developed without reference to risk-level classifications. The statin decision is used as illustration, without any empirical claims.

Keywords. risk thresholds, risk classifications, person-centred decision support, Multi-Criteria Decision Analysis

1. Introduction

In their recent investigation of General Practitioner (GP)s statin prescribing for the primary prevention of Cardiac Vascular Disease (CVD), Robinson et al. found no upward 'blip' at either of the guideline thresholds placed on the New Zealand-adjusted Framingham CVD risk score [1]. However, in person-centred care, the case for using an absolute risk score in decision making, rather than managing on the basis of a threshold-based segmentation of the risk scale (e.g. into high, moderate or low risk), cannot rest on whether or not clinicians actually practice this way. To give their informed and preference-based consent to any test or treatment, the person must be informed about the harms and benefits of all the relevant options, with the magnitudes of those harms and benefits being assessed on the basis of their personal importance weights at or near the point of decision. While this requirement is rarely fully met today (except in surgery) it will be a prominent feature of the future we envisage and address in this vision paper. A key implication is that it will not be acceptable to focus on the single outcome proposed as the main criterion, e.g. CVD in the above case, Fracture in the bone health case, Breast cancer in an oncology case. The decision

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process must address the other criteria -considerations and things that matter to the person - equally as seriously and equally as analytically. When combined with the requirement for the individual to be able to weight those criteria explicitly and transparently, one is driven towards some form of multi-criteria analysis personalised decision support tool [2]. The need for a single-criterion, threshold-based guideline, based on average patients, becomes moot.

We can find no analytical basis for particular thresholds (e.g. 10%, 15%, 20%) and resulting risk characterisations – for most conditions - other than population level effectiveness and cost-effectiveness analyses. While appropriate at the policy level, this makes them inappropriate in person-centred care. It is unethical to tell someone they are at 'high, or moderate, or low risk' of a serious event simply because the standard management for the relevant risk range has, or has not, been determined to be cost-effective – or simply effective by some single criterion - at a population level. The Frax®-based guidelines in relation to primary prevention of fractures [3,4] and screening guidelines for most cancers are guilty of the same offence. From a wider perspective, risk classifications are just another way of clustering individuals to simplify guidelines and service provision. As a result, average group preferences are often used, inappropriately, in preference-sensitive individual decisions.

The argument against segmentations of risk measures is even stronger when it extends to basing management decisions solely on the individual's relative risk in a statistical distribution for a population. Hypertension provides a highly relevant example, where the typical risk classification includes defining the disease on the basis of systolic and diastolic blood pressure levels above 130/90 or 140/90. A disease called osteoporosis exists if (and only if) an individual's bone mineral density is 2.5 standard deviations below a group norm (that for a young white US female). Diabetes is a further example. All these statistical definitions infringe the individual's right to make a decision based on their individual absolute risk, as well as possibly being a major source of over diagnosis and overtreatment [5].

The aim of this paper is limited to providing proof of method, at a conceptual level, that decision support tools based on the technique of Multi-Criteria Decision Analysis (MCDA) can claim to meet both the ethical requirements for person-centred care and the legal requirements for consent. This is done - necessarily - without reference to any thresholds or classifications imposed on continuous risk measures. The example of a statin decision support tool is provided, but purely as illustration. It has no empirical claims to be a properly developed and validated tool.

2. Methods

The type of decision support tool we envisage becoming a familiar feature of the e-health future - because of their ability to meet these twin requirements - are based on MCDA. As noted in the recent ISPOR Task Force reports, MCDA methods are widely used in public-sector and private-sector decisions on transport, immigration, education, investment, environment, energy, and defence, and but the health care sector has been relatively slow to apply them [6,7].

The type of MCDA most compatible with ethical person-centred decision making and most able to ensure informed and preference-based consent is the value-based, compensatory model. This takes the form of a 'weighted-sum' model, which multiplies the personalised numerical ratings for the performance of each option on each criterion by the relative weight assigned to the criterion by the person, and then sums these weighted scores to get an overall preference-sensitive score for each option.

The performance ratings for all options on all criteria must be on the same continuous 0-1 (0 to 100%) scale and be personalised to the absolute risk of the individual concerned. Any segmented classification of an absolute risk for any criterion will undermine cross-criterial comparability and hence the coherence of the analysis.

3. Result

The illustration is of a multi-criterial personalised decision support tool for the statin decision: Should I go, or not go, to my general practitioner to discuss taking statins?

It shows how an overall opinion can be obtained from such a tool without any threshold-based risk classification and indeed that the tool requires the unclassified absolute risks to be input wherever these are relevant.

The statin decision support tool, built within the Annalisa implementation of MCDA [2], involves the person:

1. completing an online instrument to obtain an estimate of their personalised absolute risks of All-Cause and Cardiovascular Mortality in the next ten years
2. self-assessing their blood pressure and total cholesterol level, which are the two inputs required, along with age, sex and smoking status, to complete the online EuroSCORE-based instrument
3. self-rating the treatment burden of statins
4. assigning relative importance weights to four criteria (two 10 year mortalities, statin side effects and statin burden).

All these inputs are on continuous scales, albeit with different granularity, but without any threshold cut-offs. The tool is best understood by engaging with it. It is accessible at https://goo.gl/H7P51r.

The tool is derived directly from Støvring et al. [8] and purports only to translate the data in that study into multi-criteria decision support format as an illustrative proof of method. It adds two of the other criteria that would be needed in personalised tools - treatment side effects and treatment burden - and others maybe added in a fully-developed tool. We reiterate, its purpose here is purely illustrative, not empirical.

4. Discussion

Publicly accessible, multi-criteria analysis-based personal decision support tools are widely available to consumers in many areas of life. Which (UK), Tænk (Denmark), and Choice (Australia) are familiar examples of comparison services that support the decision as to which fridge, which vacation package, or which insurance package to obtain. While health decisions are undoubtedly more important, it is fallacious to assume that a different decision support structure is necessarily required here [9]. Deeper thinking about what goes into that structure, especially the criterion weightings and performance ratings, may be the route to higher quality 'tough' decisions.

A decision support tool (DST) is distinguished from an 'Information Support Tool' by (i) the structuring of the information it presents in decision-relevant form, and (ii) the elicitation of the person's preferences (criterion weights) at or near the point of decision, and (iii) the presentation of an algorithmic synthesis of the information and elicited preferences as scores for all the options included in the aided analysis. Some 'patient decision aids' (Option Grids, Mayo Cards) meet the first requirement, but do not satisfy the other two. They are also usually designed solely for use within clinical encounters and are available only through a health provider.

In conclusion, risk thresholds and classifications based on single criterion effectiveness and/or cost-effectiveness are inappropriate in person-centred care, even if possibly useful in policy-making and research. Personalised multi-criterial decision support tools avoid threshold-based risk classification and thereby facilitate the ethical and legal practice that will be demanded in the coming digital paradigm [10].

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Separating Risk Assessment from Risk Management Poses Legal and Ethical Problems in Person-Centred Care

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Abstract. Accelerating progress in screening technologies, e.g. genetic testing, means more individuals are facing the stressful decision of whether to request the test. Fully-informed and preference-based consent, as well as ethical practice, requires the full range of benefits and harms from any test or treatment to be identified and assessed from the individual's point of view. For both ethical and legal reasons, we see the decision on whether to undertake a genetic screening test being increasingly seen, in future, as calling for a personalised analysis of the full range of subsequent management options. The conventional dissociation of 'risk assessment' and 'risk management' phases is thereby ruled out. One way of addressing the resulting challenge is through personalised multi-criterial decision support tools. In this vision paper we provide conceptual proof of method of how such an interactive online tool could function. The polygenetic genetic screening decision is used, solely as illustration.

Keywords. risk assessment, risk management, person-centred decision support, breast cancer genetic screening

1. Introduction

While apparently innocent and attractive - "let's just do the test and see what it says and then decide what to do after we know the result" - this sequencing infringes the legal, ethical, and economic principle that no screening test (often called a 'risk assessment'), should be done unless the consequences of its possible results have been thought through. In many medical text books this is conveyed in statements such as 'A test should be done only if its results will affect patient management by causing the probability of disease to cross the treatment threshold'. As legally required, and as ethically expected in person-centred care, the decision on whether to undertake a screening test accordingly calls for an ex ante analysis of the full range of management (often called 'risk mitigation') options.

Failure to adhere to this best practice principle opens the person up to over diagnosis and overtreatment in a cascade of unnecessary tests and treatments -and their consequences. This is much less likely to occur if the decision had been addressed as one of multi-criterial risk management - or simply as making the best decision –from

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the initial starting point. Separating an initial risk assessment phase from a subsequent risk management phase (on the basis of a now known assessment) also interferes with the autonomy of the person. It biases their information processing, through focusing the decision making on the criteria measured in the risk assessment, often a single outcome such as risk of developing breast cancer. Whether or not to undertake a risk assessment should therefore embrace all the benefits and harms that matter to the person in the management decision, not only those addressed in the restricted risk assessment. Whether to have a risk assessment can therefore only be satisfactorily answered in the light of a full multi-criterial management analysis. This will enable the individual to give an informed and preference-based consent testing. The aim of this vision paper is to suggest how a 'perfected' informed consent [1]–might be met when, as we envisage, the future demands it. The method is Multi-Criteria Decision Analysis (MCDA). The result is a decision support tool which provides the conceptual proof of method which is a necessary condition for empirical development. The polygenetic test for breast cancer is used as the illustrative case [2].

2. Method

Multi-Criteria Decision Analysis is widely used in many public and private-sector decisions, but the health care sector has been relatively slow to adopt it [3]. The type of MCDA most compatible with ethical person-centred decision making, and most able to ensure informed and preference-based consent, is the value-based, compensatory model. This takes the form of a 'weighted-sum' model, which multiplies the personalised numerical ratings for the performance of each option on each criterion by the relative weight assigned to the criterion by the person, and then sums these weighted ratings to get an overall preference-sensitive score for each option.

AnMCDA-based Personalised Decision Support Tool (PDST) therefore involves determining and inputting:

- the relevant *criteria*, including the possible benefits and harms; these may be offered in a menu from which the person selects a subset at the point of engagement with the tool ('Pick Your Own')
- the available *options*; this list should be without provider censoring or filtering and including 'do nothing' and 'watchful waiting', as baseline and/or options
- the evidence-based- or, where necessary - expertise-based performance *ratings* for all options on all criteria, except those where the person is the expert, such as treatment burden, which they rate at engagement
- the person's characteristics (age, sex, etc.), which act as personalising modifiers of the performance ratings at the point of engagement

At engagement, the individual enters their weights for the included criteria and the full set of expected value scores for the options are displayed as the preference-sensitive opinion of the tool.

3. Results

A draft MCDA-based PDST for home use in the genetic screening decision for breast cancer is presented, as the conceptual proof of method necessary in advance of full

protocol and tool development. No empirical data are presented, since it is irrelevant for this purpose. The PDST is built within the Annalisa MCDA template [4], but the software choice is also irrelevant in this proof of method. The tool deals with two scenarios. In one, the person has already had a risk assessment, such as one based on family history, and their probability of breast cancer from this test is available. In the other, no such prior risk assessment has been done. The sequence, as the tool is engaged with, is as follows:

3.1. Management analysis for average risk

The person enters their criterion weightings and option burden ratings. Clicking next displays the full management MCDA which contains all possible options, without censoring or filtering apart from legal or biological restrictions. It is pre-populated with age- and sex- specific average population option ratings for all criteria, plus the newly-entered person's self-reported burden ratings for each option. The option scores generated are for a woman at average risk (e.g. 12.5%), but preference-sensitised. The illustration in Figure 1 has some possible options and criteria, and only default values.

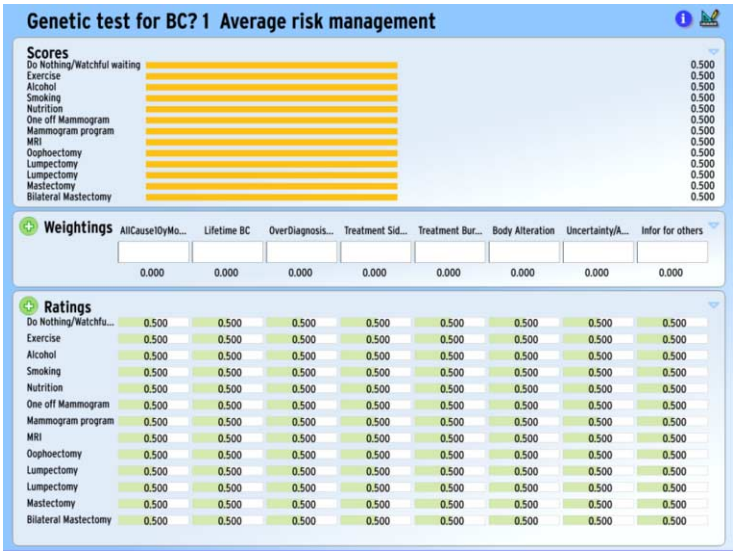

Figure 1. Screen from draft Breast Cancer genetic screening decision support tool (illustrative)

3.2. Management analysis for prior risk

A prior risk assessment, such as one based on familial risk, is available [5]. When the person enters this result into the tool, on clicking they can instantly seethe full adjusted management MCDA, using the weights they entered previously. If there is not a superior test available, such as a polygenetic one, the tool's decision support ends here.

3.3. Management analysis given range of possible risks from a polygenetic test

On clicking, the person sees the full management MCDA adjusted for their lowest possible polygenetic risk result. This will reflect the characteristics of the prior test if

they have had one, otherwise it will be the lowest for an average woman. On clicking again, the full management MCDA for their highest possible polygenetic risk appears.

3.4. The differences between all the option scores for the highest and lowest possible results are visually displayed.

This hypothetical exploration has determined, and displayed visually, the comparative management implications of three possible test results. The person can now make a fully informed and preference-based decision whether to go for the polygenetic test.

3.5. Management analysis after polygenetic test, if it has been undertaken

Person enters their result on receipt and immediately sees their final full management MCDA with the personalised opinion emerging from the PDST.

4. Discussion

An MCDA-based PDST can be used inter-mediatively, 'delivered' by a clinician in a shared decision making process to help the patient arrive at the best decision for the patient. In contrast, it can be used apomediatively ('direct-to-consumer') by the person in the community to help them decide for themselves, including whether to consult [6]. If they do so decide, the tool can be used inter-mediatively in the consultation. The purpose of an MCDA-based PDST is not to reduce decision conflict, anxiety, worry, or any of the many psychological effects of stressful decisions surrounding health. A proposed PDST, such as the current one, will make clear what is involved, and emphasise that consent to engage with it should only be given if the person feels able to cope with what they will meet. In this case it will be designed to support the person in seeking to make the best decision on whether to have a polygenetic test, doing so in the light of a full, preference-sensitive management analysis that meets the legal and ethical requirements we believe will characterise the future of healthcare.

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Blockchains in IHE-Based Networks

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Abstract. Introduction: Interoperability of health information systems is one of the key challenges of modern healthcare systems. A weak spot in this technology stack of interoperability protocols as defined by HL7 and IHE is cross affinity domain exchange of access control information and policies. In several industries the Blockchain technology had a major breakthrough. The goal of this paper is to elaborate how to exchange cross affinity domain access information enhancing well established IHE networks with block chain technology. Methods: Using literature analysis and research on current interoperability standards the state of the art of securely exchanging medical information was elaborated. We enhanced this system with the capabilities of the peer2peer based Blockchain network elaborating the workflows of exchanging the access control specific information. Results: We extended an IHE based affinity domain by adding a block chain ledger to the deployment. This ledger is fed with XACML based policies which are propagated through the peer2peer based system. Using the Blockchain protocol other affinity domains are informed of the change and can retrieve the information. Acting as an additional source of policies and consents the policy decision point is capable of querying this network and building a decision based on the retrieved information.

Keywords. Electronic Health Record, Blockchain, Access Control System

1. Introduction

Interoperability is one of the key aspects in establishing continuity of care across healthcare enterprises. IHE (Integrating the Healthcare Enterprises) is an industry initiative is successfully developing industry standards to connect these isolated information silos and is adapted all over the world [1]. This connections is done by building electronic health records (EHR) based on Cross-Enterprise Document Sharing (XDS.b) Affinity Domains [2,3]. EHR systems are already productive and populated with massive amounts of patients and data giving their users an overall information about the patient's health condition.

Containing large amount of sensitive data EHR systems are required to have a modern and reliable security and access control concepts in place. Current IT system access control related standards and profiles such as SAML or IHE XUA ("Cross-

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Enterprise User Assertion") are strong and have been successful in support of securely sharing information between pre-identified users assigned to roles and organizations. The IHE XUA profile implements XACML (eXtensible Access Control Markup Language [4]) policies to describe consents and access rules for roles within an organization [5]. However, managing access rights of single users across XDS Affinity Domain borders is currently not fully addressed by existing standards.

Use cases describing individual ownership or access rights to valuable digital assets are not restricted to the healthcare system. The financial markets has witnessed a new technology with the emergence of digital currencies transacted via the Bitcoin application [6]. Bitcoin is built upon by a technology called Blockchain, a decentralized, peer-2-peer based information distribution network. Blockchain creates a decentralized digital and public record of transactions between identified entities in a secure, byzantine-proof [7], tamper and unchangeable manner [8].

The goal of this work is to suggest an architecture that enhances existing modern and well-approved interoperability standard based networks with the unique technical aspects and benefits of the Blockchain technology.

2. Methods

The approach to this topic was split into two separate phases. While the first was focusing on gaining knowledge and understanding current paradigms, workflows and resulting limitations the latter one aimed on elaborating architectures and workflows to compensate those.

In a first step we analyzed the current state of the art. The analysis was split focusing on three areas of research: Capabilities and limitations of current XDS based EHR and interoperability enabling standards to exchange medical information between institutions, software products, and Affinity Domain borders, overview of Blockchain and knowledge about the technology as it is used in its most prominent use case of digital currencies, current state of development of using Blockchain technology in the area of access control systems in medical IT systems. This was done by searching PubMed and the ACM Digital Library. We used keyword searches for "Blockchain", "Blockchain access control", "block chain ehr" and "block chain ihe". We did not apply any date restrictions since the technology is just emerging and the number of search results was limited.

Using the information gained in the first step the core components of which an IHE XUA/XUA++ compliant access control system consists of were identified. As a second step the communication flow between the components was analyzed. The resulting diagram was afterwards extended with components, workflows and transactions needed to establish communication flow with Blockchain networks.

3. Results

In the first step of our analysis we could confirm that the current IHE technology stack is capable of managing access to document entities securely in a flexible manner, which was validated analyzing productive projects in the scope of the national wide Austrian EHR project ELGA or region Midt in Denmark. Documents are exchanged using IHE-XDS and the access rules are defined in Oasis XACML policies describing

rights and restrictions as part of a role based access control system [4]. The architecture outlined by the framework is addressed in RFC 2904 [9].

Using this markup language, it is possible to formulate policies and rights targeting single users by coding it into the subject's element of the XACML policy. However, it remains an open question, how this information can be transported the access control system of a second affinity domain. To enforce access permissions as close as possible to the data it is necessary to exchange the policies between the different IHE affinity domains.

To overcome this problem, we evaluated a cross-affinity domain peer-2-peer network using Blockchain technology to store user specific policies or restrictions. While approving the access rights the Policy Decision Point (PDP) consults the Policy Repository (PR) and additionally retrieves the policies assigned to the user's public key from the Blockchain Ledger Network assigned to the affinity domain. To retrieve the public key corresponding to the User-ID submitted in the Security Token the Healthcare Provider Directory (HPD) is queried. HPD is an IHE integration profile that supports the management of healthcare provider information in a directory structure with a certain scheme[10]. The profile supports federation of HPD based directories aggregating the search result from all known XDS Affinity Domains into one search result. Based on this result the PDP is able to build the query request to the ledger network and receive all policies that are associated with the public key of the requester. The access rights of the requesting user result in the superset of the rights granted by the policies retrieved from the PR and the policies retrieved from the Blockchain network. Since all policies are automatically distributed within the Blockchain network, all ledgers are at a certain point aware of all available personalized XACML policies. This allows the requested affinity domain to enforce policies originally declared in the requesting affinity domain.

If the document is registered and shared directly with certain users, the policy can be generated and added to the distributed Ledger network at time of generation. The policy itself is structured as defined by [4] in the major sections of Subject, Resource, Actions and Environment. In the scope of this paper Subject and Resource are from prior importance. The first one is expected to contain the ID of the user that access should be granted to the document. The ID must match the ID that is associated in the HPD with the user to whose public key the policy was added in the Blockchain.

Based on this concept, we expect to establish an exchange personalized policies across IHE XDS Affinity Domain boarders. Therefore, we can overcome the limitation of processing and issuing only within the scope of the own affinity domain and are able to enforce policies defined in another domain.

4. Discussion and Conclusion

Starting from the goal of extending an IHE XDS based EHR system with Blockchain technology we have used the distributed ledger architecture as an additional source of XACML policies. These policies are used to describe personalized access rules such as giving a single person access to a specific document. The described system exchanges these policies in a private Blockchain using a distributed peer-to-peer architecture. This concept is also possible to define access control rules across affinity domain borders if the user can be uniquely identified in one of the known IHE HPD Directories.

Therefore, it was shown that IHE based EHR systems can benefit from the new possibilities created by the combination with the technology offered by Blockchains.

However there also emerged new open questions that must be covered in further research. A major challenge that must be tackled is the resolution of possibly conflicting policies. Since we allow the introduction of services retrieved from several policy sources there is no guarantee that the XACML policies are conflict free. The easiest possibility to resolve this problem is apply the rule of the "first applicable", however this might lead to unexpected and undesirable results. Therefore, it must be regarded as an important future topic.

Another open topic is how to efficiently integrate the notification possibilities from the distributed ledger architecture. Since policies change the availability of documents for a certain user, the user must effectively be notified about this change.

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Advantages of Modular Hybrid Network Communication on Clinical Wards

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Abstract. The ever-increasing flood of information, especially in the medical-clinical field, inter alia due to the increase of data-intensive mobile/wearable devices, is one of the biggest challenges of medical informatics. In this work different possibilities of the integration of wearable devices on the example of the development of a fall prevention system are presented and classified. We started with a commercial off-the-shelf one-on-one system (Shimmer/Arduino) using a Bluetooth connection, integrated via nurse call system as Human-Machine-Interface. During the evaluation of the system we mentioned several new requirements and optimization possibilities. Thus, we adjusted the hardware-software-system; the near-field communication was realized by IEEE802.15.4, we replaced commercial off-the-shelf devices with highly-specialized open hardware in-house developments and we transferred the nurse call integration by setting up our own network and integrating this into an existing (wireless) local area network. With this development, the energy-efficient, simple and intuitive mechanisms of proximity communication via IEEE802.15.4 can be combined with the benefits broadband functionalities, e.g. of Wi-Fi, with both worlds benefits and the compensation of some disadvantages.

Keywords. health-enabled tech, wireless network communication, clinical support

1. Introduction and Motivation

With proceeding digitalisation and increasing information overload, especially in the medical-clinical sector, it is important to coordinate and structure the communication among devices wisely. The increasing usage of the IoT (Internet of Things) in various forms, the implementation of parallel data network and sensor data, which generate a large amount of data, is the daily routine at clinical wards. The impact of mobile devices was already evident in 2010, when for the first time more devices were connected to the internet, than there are people on the planet [1].
Thus, more and more wearable devices are used in medical applications. They have to store and process data, as well as communicate with each other and their users, without interfering other devices (see [2]). Therefore, a suitable integration into the existing infrastructure is required. The work of the last ten years shows, that IEEE802.15.4/Zigbee is the mainly used protocol for this challenge [2,3].

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Mobile devices are subject to various requirements of the clinical daily routine, such as hygiene, weight, comfort, durability and robustness, so it is not easy to fulfil the technical requirements, especially the realisation of the communication. The tech. requirements include a highly reliable, low latency and loss-free transmission of the data. It is important to pay close attention to the protocols used by the devices for communication, which occupy frequencies and channels and interfere the sending process of other devices. Zigbee is considered as an appropriate solution for the communication problem.

Because of the high falling risk and the related serious injuries of geriatric patients, which can result in grave consequences and medical costs, we designed in several iterations a fall prevention system in different architectures to recognize an attempt to leave the bed.

This work presents different forms of the realisation of a network by reference to an own fall prevention system.

2. Method

In the first study in 2011 we decided to pair each sensor with a base station that was connected to the nurse call system at bedside. We designed the base station using an Arduino with an Atmel ATmega168 microcontroller unit (MCU) and a Bluegiga WT11 Bluetooth (BT) module (see Fig. 1 - A). If regular messages from the sensor are missing or the sensor detects a rising attempt, it triggers an alarm and the base station activates the nurse call. Technically, the number of base station–sensor pairs is not limited. For each patient, one pair, that can easily be connected to the nurse call system at bedside, is needed [4].

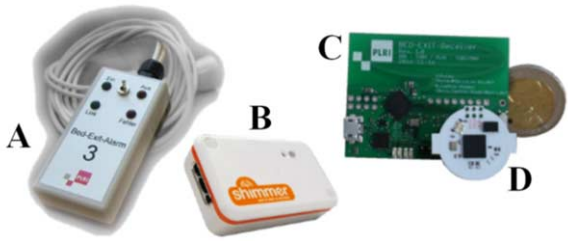

Figure 1. Image of the first base (A) and Shimmer sensor wearable (B), one new relay node (C) and the INBED (Inexpensive Node for Bed-Exit-Detection) sensor wearable (D)

For the patient side we chose the Shimmer sensor system as shown in Fig. 1 (B). These commercial off-the-shelf systems is equipped with a BT module that allows wireless communication. Making use of the BT, a variety of receivers can be used to integrate the new modality into the clinic's system. Porting the algorithms to the hardware was straightforward. The Shimmer provides enough resources, making it possible to detect additional states of the patient. After some lab condition tests, we selected an elderly, female patient on the geriatric ward to verify the performance. In an interview, the patient reported that the sensor did not bother her at all. She did not feel constricted in any way. Moreover, the staff was open and interested in the technology [4]. With results from the first study and gathered data and information, we developed a more specialized version of a fall prevention system to cover some of the new requirements and unmentioned challenges. The INBED (Inexpensive Node for Bed-Exit-Detection)

system is a modular prototype, developed by the TU Braunschweig with strong support by clinical partners. The core unit of the system is a small, affordable wireless sensor board, the INBED wearable (see - D), based on an Atmel ATmega2564rfr2 MCU combined with a Bosch BMX055 micro-electro-mechanical systems (MEMS). The general functionality of the system is illustrated separate from system component [5].

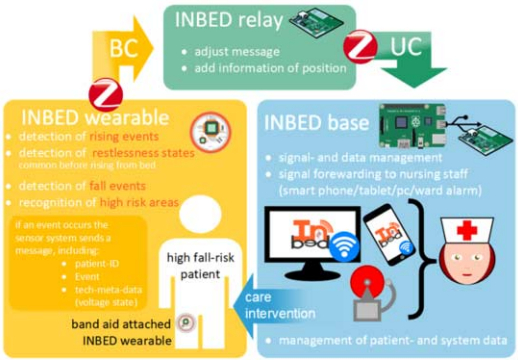

Figure 2. Model of the overall function of the INBED system

The patient wearable detects, among others, rising attempts and sends a signal to the nursing staff immediately. Besides the wearable, the developed system contains several components like relay nodes (equal to wearable setup – see Fig. 1 - C) and a signal processing base station (Raspberry Pi) to create a modular communication network [5]. Articles from the past 10 years show a widespread use of IEEE802.15.4/Zigbee-based communication in small range personal area networks and for sensor communication [2,6]. We also use this protocol for the mobile and relay part. The INBED wearable broadcasts (BC) generated messages to the network, via IEEE802.15.4, which are forwarded (UC, unicast), also by this standard, from the relay nodes to the base station, which triggers the alarm. At message receipt by a corresponding recipient, the message is amended, in that the message status is adapted and the following data are added; the receiver assignment and the receiver distance.

The alarm is displayed (optically, acoustically and/or haptically) on the user interfaces (hardware-enhanced mobile phone) and the terminals. If the message is received by the base station, the contained data will be stored in a web application database which provides the information. Furthermore, the base station uses IP calls to communicate to mobile nursing staff devices within the ward internal Wi-Fi and create versioned RSA encrypted backups every 24h on a PLRI server.

3. Results and Discussion

The first bed-exit system (Fig. 1 - A/B) is defined by its intuitive short-range one-on-one BT communication of the portable sensor system (Shimmer) to the base station, that triggers an alarm via nurse call. The unidirectional communication via the already installed, analogue and functional nurse call system allows only alarm triggering and not the data transmission in a wider context, e.g. further live evaluation purpose.

The use of the established BT communication of Shimmer and base station is primarily useful and appropriate, but also has disadvantages. Thus, the widespread usage can lead to interferences of bundled BT devices among each other. Furthermore,

depending on the BT components a rather short transmission distance can also be problematic. In addition, a one-on-one connection can be an issue; if the receiver fails, one Shimmer/patient remains unmonitored, but on the other hand only one per outgoing receiver. Due to the selected setup, the BT communication is seen as a black box, so that the energy efficiency per se is questionable, which correlates with the rather short battery life of the wearable device. This may can be fixed by BT low energy setup. The connection via the present nurse call system also involves pit falls. So, a manufacturer-specific interface can be an issue, e.g. with high licensing costs. Furthermore, the fact that the nursing staff can not differentiate between a fall and other requests results in high stress of the staff. However, through this connection setup, no other devices are needed.

The follow-up system (INBED, Fig. 1 - C/D), consists of commercial off-the-shelf components on open hardware (HW) design. This enables short-range comm. via its own modular, simple and highly energy-efficient IEEE802.15.4 network and is therefore largely independent of the given communication infrastructure. Its own network also provides additional side-effect functions, such as indoor tracking or risk area detection. Due to the bidirectional connection, an adjustment of threshold values as well as reprogramming during operation is possible. The use of the IEEE802.15.4 network also offers the possibility of adapting the radio band to avoid overlaps and interferences (e.g. 784 MHz, 868 MHz, 915 MHz). Although this reduces the data rate from 250 Kbit/s to min. 20 Kbit/s, but for this application this wouldn't be a disadvantage. The resulted communication infrastructure is adaptive and thus robust against link failures or relay node outages. The network is structured as a tree with the base station as root node, relay nodes as intermediate nodes and the INBED wearables as leaf nodes while the HW-enhanced mobile devices for the nursing staff can join the tree at any point to stop occurring alerts, when near at alarming patient device [5]. By adapting a star architecture, a reduction of the required HW/costs/efforts can be achieved. Implementing a peer-to-peer architecture would increase it again, as would reliability and robustness of the network. Both must be weighed against each other. By the final hybrid approach, the advantages of Zigbee in the area of short-range comm., e.g. energy-efficiency, as well as the benefits of larger bandwidth and supra-regional communication with wide area network (WAN) or Wi-Fi via the base station can be used. By implementing WAN communication within a demilitarized zone, comprehensive security is ensured.

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Deploying Cloud Computing in the Greek Healthcare System: A Modern Development Proposal Incorporating Clinical and Laboratory Data

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Abstract. Cloud computing is a reality in most business sectors. Hospitals have been more reluctant to adopt cloud technology due to strict data security regulations. Cloud could provide economies of scale reducing Information Technology spending in the Greek state-owned hospitals, while giving the opportunity to the hospitals to upgrade their profile offering web-based services. We propose a simple, robust and easy to apply approach for the Greek hospitals, focusing on clinical and laboratory data in order to move to the cloud environment. To the best of our knowledge, there is no other study regarding the adoption of cloud infrastructure in the Greek hospital sector. This innovative method could transform the business model of the hospitals.

Keywords. Cloud computing, Hospital, Application, Infrastructure, Data

1. Introduction

Cloud computing represents a hot topic in the Information Technology (IT) industry. Many companies adopt cloud computing in order to reduce IT spending using a "pay as you grow strategy". On the other hand, major cloud providers such as Amazon, Microsoft and Google offer a plethora of services in order to meet customer needs. Strict regulations of patient data both in the USA (HIPAA) and in Europe (GDPR) have prevented hospitals and other healthcare providers from moving data to the cloud. In fact, big healthcare providers such as big hospitals and laboratories have established a private cloud in their premises to keep the increasing amount of data. There are three

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kinds of data kept in the healthcare data centers: 1) patient data (Electronic Medical Record, EMR), 2) business data (patient billing data, supplier data, etc.) and 3) general-purpose data (emails, documents, file server data, etc.) [1,2]. Unstructured data comprise a fourth category, which is difficult to digitize and usually involves the adoption of Enterprise Content Management Systems (ECM). Moving to cloud is a task requiring thorough design while every organization follows its own path. Main approaches include Software as a Service (SaaS), Platform as a Service (PaaS), Infrastructure as a Service (IaaS), Private Cloud, Public Cloud, and Hybrid Cloud [3]. Greek public hospitals have followed the trend of the Greek public and private sector, being reluctant to incorporate cloud services in the core operations, particularly due to the sensitive nature of the stored data. Greece will lag behind other countries in the adoption of the cloud services, but this delay may offer the opportunity to avoid mistakes and follow the best practices. In this study, we propose a novel approach not presented in the literature so far, for the transition of the Greek public sector hospitals to the cloud era. This approach is based on the Greek reality. This approach is at the initial stages and has not been implemented yet. Although best practices from abroad must be taken under consideration, the local conditions in Greece differ significantly from those in the USA, UK, New Zealand, Taiwan, etc. [4,5]. Attikon General University Hospital will be used as a reference point.

2. Methods

Attikon University Hospital is a tertiary teaching hospital of the Medical School of the University of Athens and the main public healthcare provider in Western Attica. Established in 2003, its IT infrastructure includes the Hospital Information System (HIS) that spans all the major hospital clinical and laboratory departments [6]. It is based on the MedISys product by Med.IS [7]. According to the official company web site [7], MedISys does not have a cloud version and SaaS is not included in the services provided by Med.IS. Attikon software infrastructure includes corporate applications (Payroll, ERP) as well as system applications such as email. The hospital has an in-house IT Department [8]. Following Greece financial meltdown and the corresponding austerity programs imposed upon it by its creditors [9], financial pressure has also been put upon the hospital budgets. Therefore, from a Government perspective, Greek public hospitals face the challenge to serve an ever-increasing number of patients with scarce resources both human and financial. Thus, achieving economies of scale is of vital importance. Lack of human and financial resources affects all departments including the IT Department. Cloud computing could provide a way to facilitate the business needs with a reduced budget. The steps for a successful implementation are shown in Figure1.

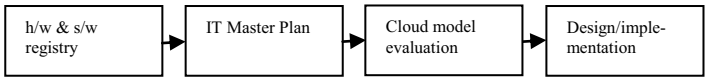

Figure 1. Simple Cloud implementation flowchart

Creation of a hardware and software/application registry: The registry (typically Excel files) will include the necessary detail both for the hardware as well as the software/applications including hypervisors and the infrastructure currently in use and is not going to be out of operation in the upcoming time. Details will indicatively

include Product name, version, date of purchase, date of upgrade and number of users. They will also include infrastructure that is about to be delivered to the Hospital in the coming 6 months. The registry should be as complete as possible.

Development of IT Master Plan and Documentation of Legal and other obligations: A brief master plan will be developed giving the projected expenditure of the IT Department for the next two years, as this has been included in the Hospital budget (if possible). Following the previous step, the target is to solidly create the necessary gap analysis scenario. The IT master plan will follow the business needs as stated by the Hospital management. At the end of this step, the IT needs for the next 24 months (in terms of quantity and budget) will be clear. The timeline of the IT investment will also be delivered. In cooperation with the Legal department and all other involved Departments, the constraints/limitations imposed by law or other regulations (e.g. GDPR) that affect the IT strategy, will be documented and included in the IT Master Plan. GDPR in particular is expected to affect significantly all the health sector [10,11]. The IT Department will include the GDPR guide and recommendations which have been finalized by the Hospital. The implementation of GDPR may impose certain restrictions, i.e. it may be required that data owned by the hospital will be stored in data centers located inside the EU or the country itself.

Evaluation of cloud model and providers: In the US healthcare sector, cloud utilization grew to 35% [12]. SaaS is the most popular choice [12]. IaaS has now been employed as well. SaaS requires that the vendor offers a cloud version of the application, in contrast to MedISys. The most obvious path is to initially transfer the mailboxes to the cloud. This strategy is followed by many organizations including banks, healthcare businesses, etc. Email contains sensitive information but does not include information such as medical and HR records. A second step is to transfer clinical and laboratory data to the cloud, facilitating the development of web services towards doctors and patients via a strict sign-on process. These data may include patient records, main symptoms and diagnoses, data from the Hematology and Clinical Chemistry laboratories (blood count, coagulation), etc. Major cloud providers in the healthcare sector include Amazon AWS [13], Microsoft Azure [14] and Google [15]. Local providers are also an option [16]. At the end of this step, the business case and the benefits for the transition to cloud will be established [3]. **Development of a detailed design path-implementation:** For an inexperienced customer, moving to the cloud should be done in close cooperation with a reliable technology partner. The partner will design all the detailed steps and tasks until the migration to the cloud. The detailed design is necessary in order to achieve the required economies of scale. Cloud is a “pay as you grow” approach [4] bringing scalability and financial benefits if used appropriately. The design should take into consideration issues such as security, integration with the existing and out of cloud infrastructure and management of the cloud environment from the IT Department [3]. It should also include detailed project management and time scheduling. It is the final and most critical sub-step, including the implementation of the cloud transition as well as the training of the IT Department personnel.

3. Results and Discussion

In this study, we present a four-step methodology for the adoption of cloud computing from the Greek hospitals. To the best of our knowledge, there is no other publication

regarding the adoption of cloud infrastructure in the Greek hospital sector. This is an innovative and simple approach targeting healthcare organizations with limited resources. This is why the cloud methodology developed here, is adapted to the reality faced by Greek hospitals, in order to move to the next phase of the upgrade of the IT infrastructure. This kind of technology upgrade takes place every 7-10 years in the Greek public sector (hospitals included), mainly due to financing and resource limitations. Although every hospital is a different organization, a centralized approach that includes many hospitals can also be used and will introduce economies of scale. Due to the lack of in-house expertise, an external partner should be involved. There are many cloud providers available. Amazon, Microsoft and Google are global players, but G-cloud with 11000 vCPUs, 35TB RAM and 325 TB Storage [16] may also be considered. G-cloud by ΚτΠΑΕis state-owned and offers IaaS services to all government organizations [16]. Cloud has been adopted by Hospitals from the USA to Taiwan [5,17] with tangible benefits if designed appropriately. As a future goal, cloud may also facilitate the provision of web-based services both to the medical staff as well as the patients/customers of the hospitals.

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A Computer-Based Speech Sound Disorder Screening System Architecture

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Abstract. This paper reviews several architectures of Computer-Based Speech Therapy (CBST) systems and solutions and describes an architecture for an Entropy-Based Sound Speech Disorder (SSD) Screening System aimed at by our research project. The proposed architecture and data flow scenario aim to provide a fully-automated Entropy-based SSD Screening System, to be connected with CBSTs and to be used as a research infrastructure for further refinement of the objectives of our research project.

Keywords. Speech Processing, Screening, Speech Sound Disorder, Computer-based Speech Therapy Tools, Gamification

1. Introduction

The field of (early) detection of Speech Sound Disorders (SSDs) using computerized tools has not reached its full potential in accordance with the available technological possibilities.

Neuroscience [1] describes the circuit supporting articulate speech as comprising a first stage where the acoustic signal is received by the temporal lobes and it activates the primary and association auditory areas in both brain hemispheres. Specialized centers in the left hemisphere select the phonetic segment corresponding to the word out of the sound wave and trim off the phoneme pronunciation variations. In a third stage words are identified by referring to the stored lexical codes while in the final stage semantic libraries disciplined by morphosyntactic rules are accessed and the mental representations of the words (notions) are generated. Our assumption is that an automated SSD screening system attempting to assess the intricate neurobiological mechanisms involved in articulate speech should look for validation in the anatomical patterns (both in terms of architecture and logical sequence/data flow) or risk failure to deliver consistent results.

The main steps taken by an automated SSD Screening system are: audio signal recording, pre-processing (analog to digital conversion, signal length adaptation/signal segmentation), processing (feature extraction, calculations/comparison to a standard), results display.

This paper's objective is to review the architecture of the existing systems/solutions and to propose an architecture for the Entropy-based SSD Screening System aimed at by our research project.

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2. Review of several CBST Architectures

Many existing Computer-Based Speech Therapy Tools (CBSTs) focus mainly on therapy and less on the detection stage and often include a screening module which is not fully automated or only partially automated. Paper [2] provides a description of the architecture of an integrated therapy system that has a "*Complex Examination*" module as the starting point in the data flow diagram. This module comprises anamnesis, a cognitive examination, a personality examination and additional analyses besides the speech examination component which is meant to detect general (hearing, voice, vocabulary and grammar related) issues, articulation issues and pronunciation issues. The scores achieved are then fed into an Expert System which is meant to assist SLPs making therapeutic suggestions. *Comunica* framework [3] consists of 3 computer-aided speech therapy tools: *PreLingua* (pre-language stage), *Vocaliza* (mostly articulatory, but also semantic and syntactic levels) and *Cuéntame* (pragmatic level of language) designed mainly for SLPs in Spain and Latin America. *Vocaliza* proposes an architecture which consists of a configuration interface where the SLP can create user profiles and which stores acoustic information for the creation of user-dependent acoustic models, of Augmentative and Alternative Communication (AAC) systems. Gamification is used extensively, which renders the *Comunica* framework highly interactive and motivating for the users. *ISLand* [4] is an intelligent system based on data mining techniques (clustering) and ludic activities, designed to support the language development of children from 4 to 5 years. The architecture includes an access interface for the various users (children, teachers and parents who may reach it from a smartphone, a tablet, web or desktop), an Information Management layer which stores users' data, and a Decision-Making Support layer, containing the modules for Statistical Validation, Monitoring and Reports, Therapy Session Planning and a Knowledge Database. Paper [5] describes an online Speech Therapy application for English speaking children aged 5 to 12. The application comprises 3 main systems: the Server, the Game (*Kimbee*) and the Therapist Portal. The Speech Processing sub-system of the Game is designed to access the speech processing library CMU Sphinx via a JavaScript port and perform audio recognition of a target word in the browser, without server assistance.

3. Software Architecture Proposal

In pursuit of the research thread discussed in [6] (processing algorithm flowchart shown in Figure 1 below), our next objective is to develop an integrated system that would allow the management of the SLPs, of the screening subjects, of the audio samples and of the analysis algorithms, with an automated processing of the audio recordings and presentation of the results (isometric diagram).

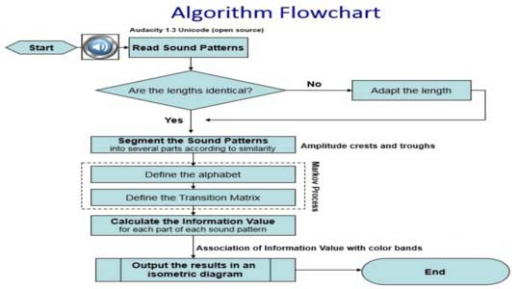

Figure 1. Algorithm Flowchart

The system architecture proposal presented in Figure 2 below contains 7 modules: 3 modules grouped in Cloud and 4 modules interfacing with the Cloud set. The first module in Cloud is an ASP.Net Server application. This application will contain the dashboard used by the operator (SLP) to create new subjects and the option of visualization of the isometric diagram (results) of every single subject screening test. The application will also provide statistics of the target population by different criteria of interest (for instance: gender, age, geographic coordinates). The ASP.Net application provides access to the database (second module) containing the related tables holding

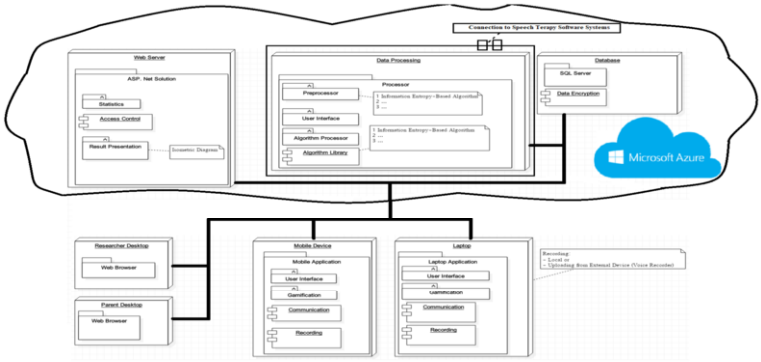

Figure 2. SSD Screening System Architecture

data on the subjects/operators and data that are fed into the algorithm(s) used to perform the screening. All the data will be stored in an SQL server and the personal data will be encrypted to ensure data confidentiality. The module, "*Data Processing*" contains a data pre-processing (audio signal adaptation) subsystem, a user (researcher/SLP) interface where subject data are analyzed, a data processing subsystem and an algorithm library that grants the entire set flexibility, i.e. the possibility to insert other algorithms. The other 4 modules make up the audio signal acquisition set and allow the users to access the Cloud interface on different levels (researcher/SLP/Assistant/parent). The Researcher Desktop module allows the researcher to access the ASP.Net application and the data processing module in order to analyze the relevant data. Parents have access to the ASP.Net application through the Parent module. The Mobile Device and Laptop modules consist in a mobile, respectively, laptop application made up of 2 subsystems: User Interface (for the acquisition of the audio signal) and Gamification (meant to offer motivation to the subject, i.e. eliminate the psychological stress). The *Recording* and *Communication* modules allow the user to record the audio signal and to send it in digital form to the Cloud. It is important to highlight the possibility to connect the entire screening system

described above to speech therapy software systems. Below we make a description of the system usage scenario. After logging into the system, the SLP creates new subjects in the database who will take the screening test. The audio signal is acquired by running the mobile (smartphone/laptop) audio recording application, which consists in a game-based assessment. Subsequently the audio files are sent to the database, in a blob. The name of the audio file will be made up of the unique code of the operator (SLP) who created the new subject, the unique code of the subject and the recording ID (increment). It is important to indicate that every unique code, both of the subjects and of the operators, will be generated via an algorithm to protect personal data. The audio signal is processed following the Information Entropy-based algorithm (or other algorithms selected by the researcher). After the processing the results of every subject may be accessed by the SLP, by the researcher or by the subject's parent through the specific applications (SLP, Researcher or Parent Desktop). Unlike parents, who may only view the results of their own child/children, and the operator (SLP), who may only view the results of his/her own subjects, the researcher can visualize the results of all the subjects so as to be able to use the proposed architecture as a research infrastructure (compare different algorithms, generate (macro)-statistics, fine-tune algorithms).

4. Conclusions

The architecture and the scenario described above, bring the advantages of a rigorous centralization (archiving) of data/results, of a dramatic reduction of the massive paperwork load required to collect data in the traditional (pen & paper) fashion and to display the results and of the access to statistics by different levels of interest by the SLP and to the research infrastructure by the researcher. Most SLPs are no computer wizards, ergo the need for an intuitive user-friendly interface. Our system is under development. The infrastructure described above will form the basis of a system to be used in current practice, providing considerable help to SLPs in their activity. Future work will focus on improving modularity (add new algorithms and interface screening system with other therapy and/or ongoing progress-assessment modules), mobility (mobile devices for remote/rural areas), solution cost and time-efficiency (cloud storage), subject motivation (gamification) and data confidentiality (data encryption).

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Hand Rehabilitation Using a 3D Environment and Leap Motion Device

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Abstract. The paper presents a 3D healthcare informatics support for Hand Rehabilitation after injury. As a novelty, the application uses the Leap Motion sensor for patient's gestures recognition, and videos to illustrate to the users the hand exercise to perform. The implemented application provides feedback to users regarding the correctness of the performed recovery gestures/exercises. The data related to hand rehabilitation is saved in a database and offers to the Medical Rehabilitation Experts the possibility to monitor the patients in a more consistent manner. To assess the efficiency and accuracy of the application the application will be tested following a usability plan.

Keywords. Leap Motion, gestures, hand rehabilitation, 3D environment

1. Introduction

Using new gesture-based technologies in medical recovery after injury is more and more present. Existing devices that recognize hand gestures, such as Leap Motion [1] or devices that recognize gestures made by the entire body such as Microsoft Kinect [2], assist users to ease off recovery after injury of different body parts. Literature describes applications based on gamification using the Leap Motion sensor for hand rehabilitation [3]. These applications use the gamification concept when users play games that assist rehabilitation. Other research studies target the feasibility of using the Leap Motion gesture-based sensor to monitor the physiotherapy activity in cases of wrist fractures [4]. The Microsoft Kinect device is used in the rehabilitation field in certain research studies aimed to improve the users' correct posture on a chair in front of the computer by different age categories [5], referring to the entire body. A concept more and more frequently used in medical rehabilitation is Virtual Reality (VR). There are studies in which VR is present for controlling pain to increase the pain tolerance level [6,7]. Patients are asked to perform certain actions using VR environments to alleviate the pain. VR is also used to improve the motor function in patients who suffered a stroke [8]. This paper's objective is to present a 3D Desktop application, based on the Leap Motion technology, to assist the users in medical hand rehabilitation. The application uses the Leap Motion technology, for observing hand gestures. Our work creating the application -HandRec, aids users in the process of hand rehabilitation. The user has available a library of videos showing how to perform the recovery gestures. Once the recovery gesture has been performed, the application will give

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feedback to the user indicating whether the specific gestures were correctly performed or not, as a new method to assess the performed exercise.

2. Methods and Tools

Being a 3D application, we naturally developed it using the Unity editor version 5.6.To ensure connection between the Leap Motion sensor and its software we used a Software Development Kit (SDK) package provided by the Leap Motion development team. The rehabilitation support was implemented in the application with the assistance of two virtual hands. The 2 hands were programmed to imitate the user's hand gestures. The application is using C# language and C# scripts. The design of the HandRec application implied 3 modules, the users having to perform a recovery exercise for each module. Each exercise must be repeated 10 times. Each recovery exercise is shown in a video played continuously while the user is performing the rehabilitation gesture/exercise.

2.1. Module 1

The first module is dedicated to the fist closing and opening exercise. First, the user observes the correct way to perform this exercise in a video. Then, using the Leap Motion virtual hands, the user performs the recovery gesture 10 times. Each time the user performs the gesture he/she receives a feedback indicating whether the gesture was performed correctly or not, shown in green and red above the image (Figure 1).

Figure 1. Gesture interaction, Module 1

The correctness of the gesture performance is verified using an algorithm that checks the distance from the fingers to the hollow of the hand when the hand is closed and the opening angle of the hand when opening the hand. To be considered a correct hand closing and opening gesture, for the closing hand gesture the distance range was set: [0.2; 0] unities in the Unity virtual space, while for the hand opening angle, a [170;180] degree range was set in the Unity virtual space. If these distance and angle ranges are not complying with the performed gesture, this will be counted as incorrect. It is important to point out that we chose the distance and angle ranges in as much as when it comes to gestures, we may consider that gestures are an abstract thing, which differ from person to person.

2.2. Module 2

The exercise in Module 2 is designed for the wrist. The application plays for the patient a video showing how he/she must perform the exercise. The user/patient performs the

gesture shown in the exercise. The Leap Motion sensor detects the implemented gesture and, in reply, displays on the left/right side whether the gesture has been correctly performed. The application verifies whether the wrist recovery gesture is performed correctly. If the user manages to rotate the hand so that the thumb rotates from the initial position to the final position and backward within a [170; 190] degree angle range, then the gesture will be counted as correct. If the user has not succeeded in rotating the thumb from the initial position to the final position and backward within the specified angle range, then the gesture will be counted as incorrect. Basically, by this gesture the user is instructed to rotate the hand to show the hollow of the hand, then backward, while the hand is in a horizontal position.

2.3. Module 3

This is the most complex model since the user is instructed to perform a hand catching and dropping gesture of a spherical object from an initial position to a final position and backward. The catching and dropping gesture is implemented on 3 fingers of the hand: the thumb, the index and the middle finger. The patient has to perform this gesture as shown in the video illustrating how it should be performed. To create this gesture we implemented a C# script for the Leap Motion software. The gesture was created in a similar manner to the one in which a catching gesture was implemented in other related solutions. In this case, the gesture only requires 3 fingers and not the whole. If the 3D object that has to be moved from the initial position to the final position and backward is between the thumb and the index finger + the middle finger at an optimal distance range [0.02; 0.12], then the object will stick to the thumb and the user will be able to move it to the final position and backward, until the user no longer has his/her fingers within the optimal distance range. To create the 3D Leap Motion gestures used in the recovery application (one for each module), we had to include 3 Dynamic-link library (.dll) files provided by Leap Motion in the application. Thus, various libraries could be accessed in the C# scripts that made up the recovery gestures. Creating the three recovery gestures for each of the 3 modules required testing of several 3D optimal distance ranges between the coordinates of the virtual fingers of the hand used for the interaction and other coordinates (coordinates of the palm). To compute these distances, we used the standard formula for distances between two points in a 3D space:

$$d(P_1,P_2)=\sqrt{((x_2-x_1)^2+(y_2-y_1)^2+(z_2-z_1)^2)} \quad (1)$$

Where: $P_1(x_1,y_1,z_1)$ – are the coordinates of the first point in the 3D space;

$P_2(x_2,y_2,z_2)$ – are the coordinates of the second point in the 3D space.

The other computations to create the three recovery gestures refer to the determination of the optimal angle ranges that must be reached to ensure the functionality of the Leap Motion gestures.

2.4. MySQL Database

A MySQL database was created to monitor the evolution of each patient/user in the hand rehabilitation process using this new developed application. A table was created with the users and the number of exercises performed correctly or incorrectly per each module. The database also stores the distances and the incorrect angles reached by the user while performing the recovery gestures, so that they could be given advice by the authorized specialists (physicians or nurses) on how to improve the percentage of

correct performance of each exercise. All the data saved in the database help the authorized specialists to monitor the evolution of the medical recovery of the users' hand. For the connection to this database we created *two* scripts, a C# script and a PHP script. The PHP script connects the Unity editor to the MySQL database while the C# script accesses. The created application is under test and is tracked PHP script via a series of database connection-specific methods and classes.

3. Discussions and Conclusions

The novelty of this application is the interactive way recovery is done, but also the generation of an automated reply with respect to the fashion in which the recovery exercise has been performed. Assisting or replacing the nurses – in cases where the patients can perform the rehabilitation at home – results in less overwork and lowers the costs. HandRec application is easy to use, does not require heavy training, it guides the patients and offers them feedback. The 3D display manner of the mock up helps the patient to more easily relate to the real exercise and correct it better. Our application has an advantage over existing applications [3,4]: an illustration of gesture performance via videos, but also the display of automated feedback regarding of the number of correctly performed recovery gestures. To observe if the application's recovery gestures work correctly the application was used by a group of 3 people who did not need hand recovery. Thus, a maximum gesture performance score was obtained for each user, which confirmed that the implemented gesture works correctly. HandRec application it will be tests by group of 20 patients who need hand rehabilitation after injury. The application will be tested according to a test plan. The test plan will include the patients' consent and the permission granted to us to use the data from the database (the numeric values resulting from the translation of the real-life positions, when the gesture is performed, into virtual positions within the 3D space of the application) to enhance the recovery gestures. The application will be also extended adding new recovery gestures for new modules in cooperation with rehabilitation specialists [9].

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An Approach for Dynamic Vital Parameter Monitoring – Prototype Development

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Abstract. The alpine space is characterized with rural regions, often hard to reach for mobile care. As part of the EU-funded INTESI project, a mobile platform for vital sign self-monitoring for patients who receive mobile care was developed. Based on a thorough analysis of user requirements and available technology a platform was established, that integrates several Bluetooth low energy devices for measuring vital signs. The developed VITAMO app further enables clients and nurses to easily govern measurements and jointly take control of a client's health during the care process. In addition, the system supports the communication of clients and nurses electronically. The internal data structure adheres to current healthcare standards e.g. FHIR and offers easy interfaces for future applications. The complete system was applied in a pilot study and got formally evaluated.

Keywords. Mobile Health, Telemedicine, Vital Signs.

1. Introduction

An increasing life expectancy and the wish of the elderly to live an autonomous life at home challenges health care. In Austria, the number of persons who received mobile care increased from 123.000 in 2011 to 147.000 in 2016 which is an increase of nearly 20% in 5 years [1]. This general trend is also observable in regions of the alpine space which is characterized by rural and often hard to reach locations with sparse population. Many of these regions require long distances to travel and are sometimes even isolated due to weather conditions especially during the winter time. This is a major challenge for the mobile care organizations in these regions. With the proliferation and success of modern information and communication technology (ICT), it is likely that mobile care could also profit from these developments. The EU-funded Interreg Alpine Space project "Integrated territorial Strategies for Services of General Interest" (INTESI) – apart from other goals – aimed to investigate the potentials of ICT to support mobile care in rural regions in one of its subprojects. The subproject was not only technically focused but involved clients, nurses, nursing scientist and health information scientists. Thus in a first step a regional nursing profile of a selected test-region was developed, nurses' needs and processes were identified and potential technologies were evaluated. In order to proof the concepts, a digital healthcare diary

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was developed, deployed and later evaluated. The basic idea behind the diary was, to allow clients to self-measure vital signs including blood pressure, pulse, body weight, activity level and blood glucose, which could be remotely monitored by the nurses. The diary also included functionalities for communication and reminders. The prototype was tested by the regional mobile care organization [2] in the district of Reutte, Tyrol, Austria from November 2017 to March 2018. The following paper is focused on the technical part of the pilot study and introduces the methods and results of the prototype implementation which is realized as a Bluetooth and LTE connected mobile platform.

2. Methods and Tools

The implementation of the system was created leveraging iterative and agile software development processes. Issue-tracking, documentation, deployment organization and overall project was managed by using a local GitLab instance. The version control tool Git [3] was used for collaboration Visual Studio Code as the open source editor and development environment. The DevOps approach was followed throughout the development process [4]. A two-tier deployment model with continuous integration was chosen with a staging platform that mirrored the production environment for testing and analysis. Deployment was automated using sophisticated modular tooling and leveraging containerization by Docker [5]. A component-based design of the platform was chosen to stay modular and achieve a dynamic software system, which can be dynamically adapted to different users' needs. The digital health diary required a framework supporting different platforms including mobile devices. After evaluation of existing open source technologies, the node.js based framework Meteor.js [6] was chosen. Meteor.js supports Full Stack JavaScript development with a strong focus on prototyping. The framework uses modern technologies like ES6, connected-client reactive applications and comes along with a set of tools like build-tools or packages. The Front-end Framework React was utilized with Meteor.js to enable component-based design for each UI element. Our idea was to develop the platform as a web app used for tablets and desktop PCs all in the direction of progressive web apps, which are known to be reliable, fast and engaging. For data visualization of the measurements the framework plotly.js [7] was integrated with React. Apache Cordova was used, which allows to natively run a web app on a mobile platform (usually IOS or Android) by utilizing WebView as a wrapped browser on the device. Due to this approach, native features like Bluetooth, cameras and all other sensors of the smartphone or tablet can be easily accessed through web-based JavaScript interfaces. As the project required to reach patients in rural areas where cable internet may not be available, a tablet with mobile internet connectivity was used as mediator between measurement devices and server. The tablet device is generally independent from the web-based implementation, though the project focused on Android operating system (version 7), as the Bluetooth connection for the BLE (Bluetooth low energy) devices was solely realized on the Android platform in this project. Vendors for suitable BLE Devices were gathered in the project's previous steps. The prototype included one vendor for the tablets, one vendor for blood pressure device, weight scale device and blood glucose device and one vendor for a fitness tracker wrist band (FT). All devices support BLE (version 4.0) where venders offered a text-based Bluetooth specification document for its connectivity. The Bluetooth interface was developed using the Android SDK incorporating the interface for Cordova. Unit tests for each component as well as

integration tests for the app were executed continuously during development. Further a minimal JavaScript Cordova testing app was developed separately.

3. Results: VITAMO Platform

Based on the requirements, the platform VITAMO was developed, which consists of tablets that are connected to Bluetooth LE devices for vital parameter measurements body weight (incl. additional body composition values), blood pressure (incl. heart rate), activity (incl. sleep activity) and blood glucose. The components are depicted in Figure 1. The tablet is connected with a self-hosted central server (through mobile internet) and automatically synchronizes the measured values. The Distributed Data Protocol (DDP) solves the problem to update all related clients whenever data of one client changes. The nurses are then able to view the measurements through the web interface. The resulting application uses the same code for patients, nurses and administrators. The Server, the web client and the mobile app share the same codebase and are compatible with each other. As Meteor.js is usually using web sockets for its data synchronization, a continuous internet connection is necessary. However, due to the use of Cordova on the mobile app, the system is able to overcome interim disconnections without any data loss, as the app is able to resume after disconnection automatically. Utilizing web sockets, the latency of the communication is reduced compared to traditional REST-APIs. As Meteor supports MongoDB, a document-oriented database, the data elements were modeled as document-oriented structures according to the evolving FHIR-standard [8]. Elements like heart rate were modeled FHIR-Observation resources. The final user interface with the dashboard for the latest measurements is depicted in Figure 2. The activity level provides information about the past 24 hours including sleep activity. The navigation guides through detail views with plots and measurement tables of each item. The nurses' view contains extra functionality like switching to the patient table that displays all patients and its last measurements.

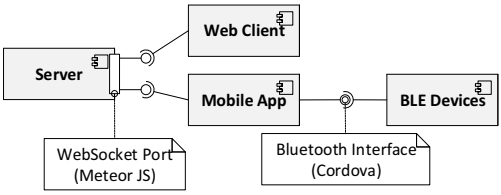

Figure 1. Components of the VITAMO system.

Figure 2. Screenshot of final app on a tablet.

Reminders can be set by a nurse for each patient. Further, telephone calls can be established between patients and nurse (coordination center) which was accomplished using the recent WebRTC 1.0 standard [9] as well as normal voice calls as fallback. Admin users have rights to generate/edit patients and pair new BLE devices for the patients. BLE is continuously listening on the tablet for near devices and when a registered device is found in the BLE advertisements a connection is automatically established. Values are sent immediately after measurement, except the FT, which is advertising continuously and a tablet-triggered pull of past 24 hours' values happens every 30 minutes if the FT is within reach. In case of transfer error, the values are saved on the devices and resend when a new measurement occurred.

4. Discussion and Conclusions

The agile software development approach allowed to dynamically react to requirements that came up during the testing phase. The feedback was continuously used for further prototype changes. A big advantage of using a solely web-based application was given through the easy distribution of updates as the server automatically provides the (meteor related) changes without any further tasks needed (even on tablets). Due to the same code base of the system for all users and underlying platforms (tablet, PC) the user experience kept the same for all users, which helped e.g. when the nurses needed to explain something to the patients through phone. The use of plotly.js enabled flexible configuration of plots, where tablets got a function-reduced plot for the mobile app and web-client got the full set of features, i.e. data range specification, zoom functionality and print functions. The FHIR-based organization of internal data-structures offers future proof data interfaces. The use of consumer-wearable devices is a limitation but as stated in [10] such devices show a high interdevice reliability. Using the BLE standard is a balanced type of communication respecting to aspects like range, cost, power, speed, etc. in comparison to others [11]. Telemonitoring is known to reduce cost and enables living independently for elderly people [12]. Comparing the system design and the design of the field test with the state of the art in mHealth research [13], our system is advanced in its use of enabling mobile technologies and its adaptive and dynamic approach. The prototype got tested in the field with real mobile care receiving patients. Each patient got a tablet with LTE mobile internet and the BLE vital sign devices for measurements. Using new web technologies (e.g. Meteor.js) enabled us to develop a comprehensive multi-platform app including Bluetooth very efficiently. The focus was set on usability, so we tried to realize the requirements as much as possible without any or just very few user interaction (e.g. automatic measurement transmission). VITAMO offers real-time data exchange, FHIR-conformity, no further user interaction (patients just do familiar vital sign measurement procedures) and works out-of-the-box and everywhere with mobile internet.

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Matching Ontologies to HL7 FHIR Towards Their Syntactic and Semantic Similarity

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Abstract. Current medical systems need to be able to communicate complex and detailed medical data securely and efficiently. However, the quantity of available healthcare data is rising rapidly, far exceeding the capacity to deliver personal or public health benefits from analyzing this data. Thus, a substantial overhaul of methodology is required to address the real complexity of health. This can be achieved by constructing medical domain ontologies for representing medical terminologies, considered to be a difficult task, requiring a profound analysis of the structure and the concepts of medical terminologies. In this paper, a mechanism is presented for constructing healthcare ontologies, while matching them to HL7 FHIR Resources ontologies both in terms of syntactic and semantic similarity, in order to understand their nature and translate them into a common standard to improve the quality of patient care, research, and health service management.

Keywords. Healthcare interoperability, ontologies, ontology matching, HL7 FHIR

1. Introduction

The promise of a global standard for healthcare records is still years away, as medical information systems need to be able to communicate complex and detailed medical data securely and efficiently [1]. This can be achieved by constructing medical domain ontologies for representing medical terminology systems, in terms of a group of medical concepts, linked together based on their relationships [2], supporting the indispensable integration of knowledge and data [3]. Using ontologies in the healthcare domain is obviously a difficult task and requires a profound analysis of the structure and the concepts of medical terminologies. What is more, multi-site healthcare provisioning and research require healthcare data to be restructured into a common format and standard terminologies, linked to other data sources. The latter is currently delivered through the HL7 FHIR standard [4], which is widely adopted to achieve interoperability and improve the quality and safety of patient care, research, and health service management [5]. It seems that achieving healthcare interoperability is a challenging task, which however can be possible through the translation of healthcare data into ontologies. Hence, in this paper a mechanism is presented for constructing healthcare ontologies, while matching them to HL7 FHIR Resources ontologies which are built through the FHIR Linked Data Module [6]. Apart from the ontology creation, ontology matching will be performed both in terms of syntactic and semantics, in order to reduce the semantic gap between different overlapping representations of the same

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domain, and finally match ontologies of multiple or even unknown medical standards into the HL7 FHIR resources.

This paper is organized as follows. Section 1 presents the current methodology for creating and matching healthcare ontologies into HL7 FHIR resources, while Section 2 provides the results that were collected after the validation of the mechanism. To this end, Section 3 is discussing our conclusions and plans.

2. Methodology

The current approach has the ability to identify the similarities that exist between the different HL7 FHIR resources and the ontologies that have been created from the different healthcare related datasets. Fig. 1 represents the architecture of the developed mechanism, while the ontology creation and matching stages are presented below.

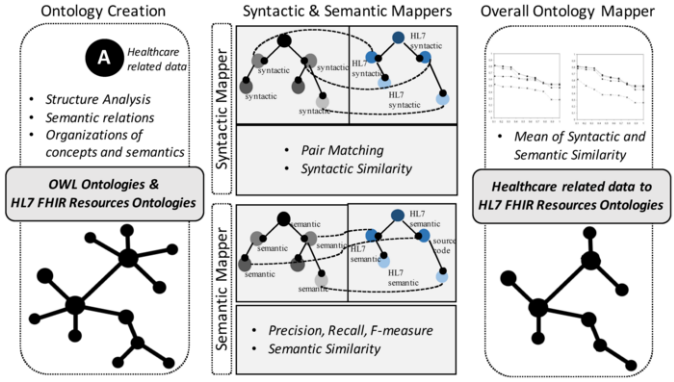

Figure 1. Architecture of the Ontology Creation and Matching process.

Ontology Creation: The *Ontology Creation* method presents an automatic way of obtaining an initial organization of concepts from any structured documents:

1) In the1st step, datasets are prepared for obtaining concepts through the analysis of their structure to verify the elements that can be considered as concepts in the ontology.
2) In the 2nd step, the semantic relations for each one of the ontologies that will be created are obtained, referring to the properties, axioms and constraints.
3) In the 3rd step, the organization of the concept and semantic relations takes place, which are organized in ontologies that are stored in files encoded in OWL language.

Syntactic Mapper: The *Syntactic Mapper* provides a way for matching and identifying the syntactical similarity between two different ontologies, based on their structural form.

1) In the 1st step, the syntactical representation of the ontologies to their upper-case characters takes place, which are then split up into different character pairs.
2) In the 2ndstep, the checking of the character pairs takes place, in order to identify which characters can be found in both split strings, and pair the two ontologies.
3) In the 3rdstep, the identification of the probability of resemblance according to *Equation 1* takes place. Shortly, the structural similarity between two ontologiesS1 and S2, is twice the number of character pairs that are common to both strings, divided by the sum of the number of character pairs that are identified.

$$Similarity\ (S1,S2) = \frac{2*|character\_pairs(C1) \cap character\_pairs(C2)|}{|characters(C1)|+|characters\ (C2)|} \quad (1)$$

Semantic Mapper: The *Semantic Mapper* provides the means for matching the different ontologies, according to their semantical meaning:

1) In the 1st step, the name similarity that exists between the ontologies is identified by utilizing neighborhood similarity [7] to combine similarities of different attributes.
2) In the 2nd step, the structural similarity that exists between the ontologies is calculated in the case that both ontologies have common members or relationships.
3) In the 3rd step, the instance similarity is measured through examining the instances of data from the two ontologies.

By the time that these three steps are performed for each different ontology, the calculation of the final results' precision (*Equation 2*), recall (*Equation 3*), and finally the harmonic mean (*F-measure*) (Equation 4) – semantic similarity, takes place.

$$\text{precision} = \frac{|\{\text{relevant data}\} \cap \{\text{retrieved data}\}|}{|\{\text{retrieved data}\}|} \quad (2) \qquad \text{recall} = \frac{|\{\text{relevant data}\} \cap \{\text{retrieved data}\}|}{|\{\text{relevant data}\}|} \quad (3) \qquad F = \frac{2*\text{precision}*\text{recal}}{\text{precision}+\text{recall}} \quad (4)$$

Overall Ontology Mapper: The *Overall Ontology Mapper* method merges the results of the mechanisms, and identifies the related to theHL7 FHIR resources ontologies:

1) In the 1st step, the Overall Ontology Mapper queries through the calculated metrics, and provides a mean between the Syntactical Similarity and the F-measure.
2) In the 2nd step, the final identification of the ontologies of the healthcare related data and the HL7 FHIR resourcesoccurs.

3. Validation Results

The use case exploits a healthcare dataset structured in*JSON*format, derived from BioAssist's platform [8], consisting of *238 different measurements* of the heart rate of a specific patient, measured every *5 minutes* on the *2017-02-20.*

- The results of the*Ontology Creation*, *Syntactic*, *Semantic*, and *OverallOntology Mapper*are depicted in Figure2, Table 1, 2 and 3 accordingly.


```
"observation": [
    {
        "id": 487608034419000,
        "ObservationSystem": "urn:ietf:rfc:3986",
        "ObservationIdentifier": "487608034356000:487608034419000",
        "statusIndicator": "preliminary",
        "category": "vital-signs",
        "sub-category": "Heart rate",
        "dateOfMeasurement": "2017-02-20T18:27:14.000Z",
        "patient": {
            "identifier": 1279,
            "name": "Anonymized Patient"
            },
        "measuredValue": "81 bpm",
        "practitioner": {
            "identifier": 1279,
            "name": "Anonymized Patient"
            }
    },
```


Figure 2. Use case dataset instance.

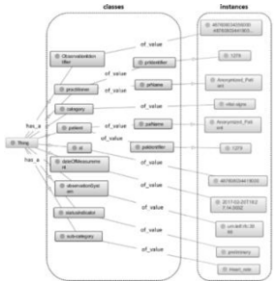

Figure 3. Ontologies of the dataset.

Table 1. Results of the Syntactic Mapper

Use Case Dataset	HL7Similarity (top 1)	HL7Similarity (top 2)
ObservationIdentifier	Observation.id – 98%	DiagnosticReport.id – 76%
category	DiagnosticReport.category – 50%	Observation.category – 50%
patient	Patient – 85%	Observation.subject – 13%

Table 2. Results of the Semantic Mapper

Use Case Dataset	HL7 Similarity (top 1)	HL7 Similarity (top 2)
ObservationIdentifier	Observation.id – 99%	DiagnosticReport.id – 0.5%
category	DiagnosticReport.category – 2%	Observation.category – 94%
patient	Patient – 1%	Observation.subject – 98%

Table 3. Results of the Overall Ontology Mapper

Use Case Dataset	HL7 Similarity (top 1)	HL7 Similarity (top 2)
ObservationIdentifier	Observation.id – 98.5%	DiagnosticReport.id – 38.25%
category	DiagnosticReport.category – 26%	Observation.category – 72%
patient	Patient – 43%	Observation.subject – 55.5%

4. Discussion

Through Table 3 it is clear that in order to identify and match an ontology with a different ontology, both syntactical and semantical matchings have to be performed. In more details, through Table 1, Table 2 and Table 3 it can be seen that despite the fact that an ontology has been syntactically mapped to an ontology due to its syntactic form, the same ontology has been semantically mapped to a different ontology due to its semantic meaning (e.g. *category* has 50% syntactical matching with *DiagnosticReport.category*, whereas it has 2% semantical matching). Consequently, we are not able to create patterns mentioning that in the case that an ontology matches either syntactically or semantically with a specific ontology, then it has an exact match with it. Currently, we are working on the evaluation of the proposed approach with different ontology matching techniques, since having a formal representation of these matchings will be useful for extending our approach. Furthermore, we will continue evaluating the proposed framework with multiple datasets, of various medical standards and formats, including formats of unknown nature.

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Home-Based Training Support for Stroke Patients Using the Leap Motion and StandInExercise Stand

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Abstract. Rehabilitation aims at brain rewiring through intensive practice following brain injury. This paper presents a new supportive mechanism that will be used to isolate wrist movement and in combination to the use of serious games, to act as a motivational tool to improve adherence during home-based practice. The paper describes the proposed methodology employed to carry out the home-based programme while leap motion is used to monitor and evaluate these exercises.

Keywords. Rehabilitation, Technology, User-feedback, Gamification

1. Introduction

Stroke is one of the leading causes of disability in adults with increasing epidemiological rates every year [1]. Rehabilitation after stroke requires many hours of therapy at the clinic but perhaps the most important element is the actual practice from the patient while being at home [2]. Upper limb rehabilitation is more demanding compared to lower limbs [3]. However, the brain has been shown to have the capacity of structural changes that lead to functional modifications; specific conditions need to be satisfied though, the most important of all being the intensive practice. Adherence has always been an issue therapists have had to deal with, especially when practice takes place at home without the therapist's presence. Leap Motion offers a marker-less, low cost, portable device for measuring wrist, hand and finger movements in real-time. Previous research has shown the device has a high variability and relatively low accuracy in the measurements of joint angle. However, it is hypothesized this could be improved through greater control of the positioning of the limb relative to the device. This preliminary study has two aims: 1. To investigate the feasibility of using the Leap Motion as part of a home-based upper limb rehabilitation programme, through the use of a gamified computer environment. Feasibility will be tested using quantitative and qualitative approaches. 2. To investigate whether relative positioning between the limb and the sensor can improve accuracy of joint angle measurements, using the StandInExercise mechanism. This device will specifically allow measurement of wrist

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movements. While the study focusses on neuro-rehabilitation, there is also scope for the findings to be applied to areas of orthopedic rehabilitation.

2. StandInExercise Apparatus

The purpose of the stand is to keep the arm as stable as possible while the wrist moves freely up/down, clockwise and anti-clockwise. This will eliminate possible unwanted movements resulting in false readings from the Leap motion device. As illustrated in Figure 1(a), the stand has a variable height as well as variable length to accommodate different sizes of arms. The wrist must be positioned at a certain height from the Leap Motion device located on a table - see Figure 1(b). The wrist is able to move freely allowing some flexibility during the exercise. The ball head base allows the stand to be fixed at different angles with respect to X, Y and Z axis (pitch, yaw, roll). The stand doesn't require any external power, thus keeping its design, complexity of its use and costs to the minimum. The leap motion device is connected to a computer that collects the data for further analysis.

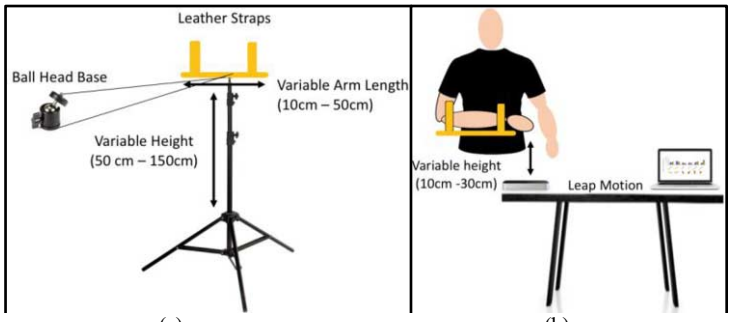

Figure 1. (a) StandInExercise Specification and (b) Arm fixed at a particular height / angle – Wrist moves freely while distance from Leap Motion is fixed

3. Serious Games

Recent studies indicate that patients lacked motivation when they had to repeat a series of exercises in order to get better [4-8] and [9-12]. With the use of challenging / entertaining games (known as *serious games*), a patient's motivation can increase as the exercise becomes interesting and fun. Serious games are defined as the (digital) games used for purposes other than mere entertainment applied to a broad spectrum of application areas, e.g. military, government, educational, corporate, healthcare [9]. Such games enable patients to experience virtual environments and conditions that are impossible in the real world for various reasons such as safety, cost, time, etc. [12]. A framework of rehabilitative serious games has been developed and demonstrated using a Leap Motion controlled navigation game [13-15]. To make the process of physical recovery / exercise more exciting, a simple game for wrist exercises will be introduced. Moreover, the data from the Leap Motion can be used to measure range of motion and time spent completing the exercises. Other examples in the literature using this

approach can be found in [16]. In this study, we plan to evaluate the use of a Leap Motion game-based set up with stroke survivors.

4. Leap Motion Detection – Current Problems

Previous work [17] has investigated the accuracy of Leap Motion when participants performed wrist physiotherapy exercises. In particular, the exercises used following a wrist fracture were implemented by healthy participants, which involved flexion-extension, pronation-supination and radial-ulnar deviation. Movements were captured in parallel with a magnetic motion capture system (Polhemus Liberty) which provided the "gold-standard" reference measures. Joint angles were measured in the three movement planes described above by both the Leap Motion and Liberty systems. We found significant differences between radial, pronation and supination movements, with supination in particular showing a large error. Excluding supination, we found an average error of 28%. While this inaccuracy is inappropriate for clinical assessment, we suggested that the device, being low cost and unobtrusive is ideal for providing home-based guidance and feedback. In the previous study, an arm rest was used but there was no specific control over arm/hand placement relative to the sensor. In this study we have produced a more controlled limb support mechanism which we expect will reduce variability in the Leap Motion measures.

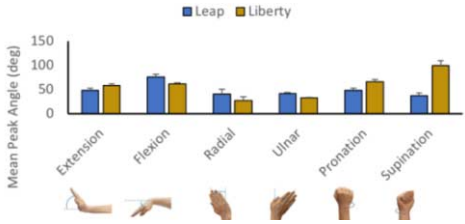

Figure 2. Results from study comparing joint angle measures captured by Leap Motion (Blue) versus Polhemus Liberty (Gold) for a range of wrist exercises. Values are mean peak angles, errors bars show standard error.

5. Proposed Evaluation on patients' views

A convenient sample of 10-15 stroke patients will be used in this preliminary study. Patients will be included if they are able to actively extend their wrist for a minimum of 5º.Exclusion criteria will include epilepsy or medication/ co-morbidities that might affect the patient's ability to participate. Patients will be expected to play a rehabilitative computer game using their affected upper limb, while being in their home environment. The computer game will be connected to the Leap Motion device and the StandInExercise Apparatus, as described above. Sessions will be repeated 5 days/week (excluding weekends) for a total daily duration of 30 minutes. Patients will be trained on how to use the game and will be supervised once or twice per week by an occupational therapist. The wrist movements targeted will include flexion, extension, ulnar deviation and radial deviation. The overall intervention will last for 3 weeks. Data will be collected on joint range of motion, time and duration of use over the intervention. To investigate the optimal hemiplegic limb positioning during exercise and explore whether use of Leap Motion can be beneficial towards better adherence

during home-based rehabilitation programmes, patients' views will be investigated via questionnaires completed on a weekly basis, followed by a final interview at the end of the intervention.

6. Conclusions

The proposed StandInExercise system is based on a low-cost leap motion technology and might be a promising approach towards better patient adherence during home-based rehabilitation programmes. In this study we will specifically target flexion, extension, ulnar and radial deviation of the wrist. Literature indicates that Leap Motion can be accurate enough to use for these specific movements and along with a serious game, this might be a meaningful rehabilitative tool.

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Clinical Data Warehouse Query and Learning Tool Using a Human-Centered Participatory Design Process

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Abstract. BMI Investigator (BMII) is an interactive web-based tool with a learning knowledge base, which provides a way for researchers to query structured, unstructured, genomic and image data contained in a data warehouse. We demonstrate how development of an efficient, usable, and learnable web interface for a diverse group of research stakeholders benefits from an iterative human-centered participatory design process utilizing a team of clinicians, students, programmers, and informatics experts.

Keywords. human factors, participatory design. healthcare, data warehouse

1. Introduction

In the medical domain, health researchers interact with digital information systems every day. Ensuring the delivery of safe and ethical research with secondary clinical data can be a complex process. This process needs to take into account the ability of researchers to not only interact efficiently with healthcare tools, but also be able to easily use them for their intended purpose. In order to make research more accessible to stakeholders with diverse technological and research skills, namely clinical informatics fellows, residents, medical students, medical researchers, and biomedical informatics graduate students, an interactive web-based tool that facilitates rapid exploratory retrospective studies was created with a searchable knowledge base for educational purposes and support. Biomedical Informatics Investigator (BMII) allows the user to query clinical information from a database of electronic health records. However, across the design, implementation, and evaluation of tools like BMII, challenges can arise if there is a failure to understand and engage end-users in technology adoption and use in context [1-3]. Participatory design bridges the relationship between stakeholders' tacit knowledge and researchers' analytic knowledge to engage end-users in the design of better products [4,5]. To develop BMII into an effective, efficient, and learnable web interface for its intended diverse group of stakeholders, an iterative human-centered design process using participatory design was undertaken.

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2. Methods

BMII allows one query to rapidly access both structured and unstructured data from the electronic health record (EHR).Structured components are transformed into relevant database coding schemes and placed in relational tables in OMOP common data model format. Unstructured notes and reports are coded using the High Throughput Phenotyping Natural Language Processing (HTP-NLP) scheme, producing SNOMED-CT annotated text stored in a graph database and Berkeley DBs [6]. Diagnoses, procedures, demographics, and laboratory values can be queried from different sections of the EHR. Additional data types including medical images and genetic data are currently being added to BMII with relevant searchable parameters. In the development of the BMII web-interface, human-centered design principles using participatory design, an iterative development process that relies on feedback from stakeholders at all stages, were implemented (ISO 9241-210:2010) [7]. These standards stress that solutions and commentary from users should be able to be fed back into the design process early in the development process [7]. Treating stakeholders as co-designers of the interface, a multi-disciplinary team was created consisting of five clinical fellows, a PhD candidate and statistician, programmers, and natural language processing (NLP) expert. To encompass a diverse representation of typical stakeholders, the cohort of clinical fellows had varying degrees of computer science knowledge and medical backgrounds (internist, pathologist, pediatrician, surgeon, and anesthesiologist). The project followed the iterative design process defined by Turner et al. and Spinuzzi, with the following three phases: design, implementation, and evaluation [1,4]. Team members were given continual access to the prototype at all stages, and a bug/issue tracking system using GitHub was implemented to facilitate feedback for the tool. A series of collaborative design sessions involving team members were held. Field notes were dictated and coded to give theoretical insights on the positive and negative components of the design. Session notes were hosted on the Github and available to all team members. Initial design and implementation were done by the principle investigator, who is a clinician, researcher, and NLP expert, and a programmer. The evaluation stage, which incorporated the full participatory design team, featured structured questionnaires to assess researchers' needs and the usability of the tool for research queries. Stakeholders were asked to participate in simulations using BMII to query case studies to reveal challenges in the design, usability, and functionality of the web interface for each of the clinician team members. After analysis of outcomes from the initial design, mock-ups of the new web-interface incorporating key outcomes and analysis from current well-known interfaces, were distributed and analyzed by the group. Additional design aspects and tools built in to the web interface following the second iteration were shown to team members by the programmers, who then elicited further analysis and feedback. In parallel with the second design, a third design iteration began with a focus on using the query tool as a research education tool for a diverse group of stakeholders beyond clinical informatics fellows based on stakeholders' evaluation of the mock-ups and current implementations. Educational systems for medical students, residents, clinical fellows, and biomedical informatics graduate students were assessed and key factors of research design for secondary use of clinical data were abstracted from these systems. A semi-structured questionnaire was distributed to biomedical informatics medical students, clinical fellows, and biomedical informatics graduate students assessing their knowledge prior to affiliation with the program and aspects of informatics education that could be enhanced through a

learning querying tool. Using this information, implementation began on the use of a help-desk and knowledge base to disseminate pertinent clinical informatics research to the end-user.

3. Results

The first design prototype of the web interface allowed the user to create compound Boolean queries using SNOMED-CT concept codes or descriptions and demographic variables. The user was able to choose a variety of inclusion/exclusion criteria and queries could be saved, imported and joined (Figure 1). During the first design evaluation, stakeholders primarily produced case studies involving identifying cohorts with certain medications, diagnoses, and demographic restrictions (i.e. morphologic subtypes of non-small cell lung cancer broken down by age and gender, comparison of treatment rates for depression in white and non-white pregnant women). During the case simulation on diabetes, stakeholders stated "the measure of HbA1c has an upper level of 9.5, but in BMI investigator the scope for entering a range for blood levels is missing" and it was not intuitive on how to "use or select lab values or cut-off values for lab values." In addition, for a case study of cases with ADHD between 70 and 100 years old, one stakeholder used the visualization function and realized that the chart gave counts instead of percentages, stating "raw numbers tell me scale, but visualization should tell me proportion." Key requirements addressed in the collaborative design sessions and case simulations for web-interface modifications were improved visual representation, case counts including proportion of the population, easier navigation, reproducibility of past searches, and data transparency. These requirements were fed back into the iterative design process to produce mock-ups (Figure 1).

Figure 1. Iterative Design 1 Working Prototype (left); Example of a Mock-up (right)

For the second design, mock-ups were created based on frequently used research query tools using Pencil Project. The stakeholders agreed that clinical researchers' familiarity with these tools would make the learning curve and usability easier. In addition, constructing an interface incorporating social media and widely used application designs was discussed. The team decided that the goals of the tool would benefit from the simple design aspects of research tools, such as Medline and PubMed, over applications that host variable data uses. In Figure 1 (right), you can see familiar research tool aspects, such as query list, query builder, and a 'Filter By' demographics, values, and time. Stakeholders evaluated the Figure 1 mock-up with 80% of fellows suggesting a help-desk icon linking to a knowledge query database of frequently asked questions. The stakeholders liked the search bar, which would allow the system to decide whether a code, concept description, or synonym was inserted.

For design 3, the semi-structured questionnaire had a response rate of 78.6% (11 of 14). The majority of responders (90.8%) had been involved in the Department of Biomedical Informatics for at least six months. At the beginning of their training, 90.9% rated 3 or less on a 5-point Likert scale with 1 being 'not at all familiar' and 5 being 'familiar' for knowledge of research design methodology, and 72.7% were 'not at all familiar' with ontology or terminology. After analysis of the survey and learning objectives, stakeholders valued learning statistical analysis, research methodology, the creation of structured query language queries for data research, and the concepts of terminology and ontology. These learning objectives and frequently asked questions will be hosted on the searchable knowledge base with links to articles, learning materials, and Jupyter notebooks.

4. Conclusion

A participatory design process can avoid some of the complications related to poor health research interface design by incorporating key stakeholder opinions early in the process. A creative secondary purpose of the tool emerged from this process: to provide a knowledge base and support center for key clinical informatics training objectives, such as research methodology, programming, and ontology. (8) Future work includes testing this comprehensive knowledge base on the user population, since stakeholders all target population types. The findings in the stakeholder questionnaire and design sessions allowed us to build a BMII that is able to provide stakeholders with efficient, effective, and useful methods for querying a data warehouse and needed clinical informatics knowledge.

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Gamifying Motion Control Assessments Using Leap Motion Controller

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Abstract. In rehabilitation, exergames and serious games are widely usedin order to motivate patients in the therapeutic procedure. Patients are asked to modify their incorrect motor patterns or reinforce the proper ones through activity rather than exercise. Interactive applications as such, can have a huge impact on a patient's motivation making repetitive physical exercises into pleasant experiences, thus maximizing the gains of therapy. In this paper we present the design and implementation of a serious game platform based on virtual 3D game environment and leap motion controller for interaction. For each session, achieved goals and response to stimuli is recorded and analyzed. Preliminary analysis results from evaluating the game with healthy subjects are encouraging.

Keywords. Serious games, motion assessment, rehabilitation, leap motion

1. Introduction

In the field of neurorehabilitation, serious games and exergames are becoming popular. These are games of serious purpose that combine virtual reality with physical exercise [1]. They are widely employed as tools for the treatment of patients with motion difficulties, of neurological or myoskeletal cause [2], offering the possibility to execute a series of repetitive and functional movements efficiently [3], in a less monotonous and boring way [4]. Implementing the therapeutic exercise in a game environment, following an interactive scenario with goals, results in attracting the patient's interest and increases the adherence in the therapeutic procedure while at home. This is feasible with a prior learning process, along with the guidance of the therapist.These serious games applications include the use of biosensors (accelerometry, ECG) and cameras (e.g. Microsoft Kinect, Leap Motion Controller), via dedicated APIs. They also include immersive interfaces, and user-computer interaction means, beyond the classical mouse, keyboard, and screen, which give the impression that the user acts inside the game environment, and translate the actual movements into actions in the virtual world.Within this context, we present a novel serious gaming platform for motion rehabilitation. The proposed gaming approach addresses the need for alternative rehabilitation solutions that can be delivered anywhere with the use of modern

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exergaming technologies. An important aspect is the ability to use the platform at home, in unsupervised environment, while the progress and adherence can be monitored remotely via objective measures. Potential end-users of the system are a) individuals with motion disorders, b) physiotherapists and rehabilitation experts, rehab labs or institutions, who wish to add this service in their infrastructure.

2. Methods and Tools

In order to properly design and develop the serious gaming platform for motion rehabilitation the following requirements were defined.

- *Interaction through physical movement detected with biosensors.* The core interaction with the system must be performed using modern and intuitive HCI interfaces to allow replication of the actual physical movements that we need to restore/improve.
- *Movement associated with therapeutic - rehabilitation process and entertainment.* The games of the platform must be entertaining by using 3D virtual environment and by providing real-time feedback and goals that the user must achieve.
- *Support of both supervised use and unsupervised use.* The overall setup must be non-complicated to allow the use not only in a controlled environment but also in the users' home after a few demonstrating minutes at the lab/clinic.
- *Low cost infrastructure.* The platform must rely on low cost consumer-based hardware. The use of medical specialized devices and high-end hardware must be avoided.
- *Monitoring of response via stored activity data.* The platform must store acquired data in a format that can be analyzed. While analysis and visualization tools can be performed out of the game using proper analysis tools.

Based on the above requirements we have chosen Leap Motion controller as the interface to use for the interaction between the user and the games. Leap Motion Controller is a motion sensor based on IR cameras with high accuracy in a bounded scope, it tracks with high detail the hand and individual finger movement. Also,it is a consumer device available at low cost and it is easy to install and setup. The software development was based on Unity3D. Unity3D is a popular game development platform, a powerful platform with numerous options and embedded functionalities and it also offers an easy learning curve and fast prototyping.

2.1. Description of Functionality and Implementation Details

The motion. The game metaphor is based on the metaphor of a virtual object, the motion of which follows the actual motion of the user's hand. An airplane was selected as the virtual object - avatar. The goal was to repeat specific movements as many times as possible, without any confusion for the patient, which lead to the selection of an infinite-length path as the avatar field of action. Actually, the avatar is static in Z axis (back-front), and the impression of movement is given by the relative movement of the

background towards the avatar. This offers better control over the medically defined movements.

The targets and the scores. While static on the Z axis, the avatar must move and rotate in the XY plane, in order to pass through 'gates' appearing in steady rate at different parts of the screen. This guides the hand motion and rotation, and generally the motion control of the hand. This control is assessed by a game score, based on the gates that were successfully passed.

Customization. The game is extensible and customizable. The system parameters are: a) window size: depends on the hardware, b) gate appearance rate: defined by the clinical expert, c) Gate appearance position: currently positioned on a 3x3 grid and d) rotation angle sensitivity: tailored to the patient and expected results

In Unity 3d the whole implementation is organized in *scenes*, viewed by the user. The basic components are the *Game Objects* (GOs). The *prefabs* are predefined GOs with known characteristics (rotation, scale, meshes), that build a scene. In the specific game, these are a) Airplane avatar whose motion reflects the actual hand motion, b) the gates - waypoints, and c) the terrain that makes the infinite path. A certain number of prefabs is constructed that alternate each other and give the impression of the infinite spanning path. Certain scripts handle filtering and storing the output of each session. In the prototype as session output is defined the trajectory of a patient's hand movement throughout a session, saved as a signal and a list with all the gates and their corresponding attributes. The objective of saving these data is to monitor a patient's condition and derive information regarding his performance and his overall improvement after a set of therapeutic sessions. The aforementioned design and development has taken place in an agile manner, in short design-develop-test iterations, and in a multidisciplinary collaboration. In each cycle there was a series of tests with experts and healthy individuals that gave us insights and feedback as what were major drawbacks that they detected though the game sessions

3. Results

The platform was designed to be simple and intuitive in use, yet not lacking in functionality. As the loading of the game completes, a "Menu" scene follows that gives the candidate user three options: start the game, change the parameters or quit. The airplane can be moved across x and y axis and rotate around z axis (optional). The gates move towards the avatar of the player and the game's objective is to guide the airplane inside these rectangular objects. The user or his appointed clinician can adjust the speed of the gates and their distance between them. This determines how fast the user will need to react in the game. There is also the parameter for ending one session that may be a time limit or a specific score to reach. (Figure. 1)

Figure 1. Hand's movement (visualizer) translation into game movement

The graph below is an attempt to visualize how the patient's hand moved during one game session in accordance with the waypoints. It may be presented as a line plot, but in reality, it is a consolidated figure of the (x, y) positions of the airplane avatar in chronological order. This sequence of motion points and gate-objects is available in each session for further analysis, and actually constitutes the basis for the creation of quantitative metrics for comparisons, of rehabilitation progress among others. The platform has been tested so far on healthy individuals, whose data were used to produce the above figures. They provided positive feedback and a number of detailed observations about motion handling of the avatar and the general functionality of the serious game. There was also a successful test with one patient for feasibility purposes, but the results were premature to be interpreted as an actual evaluation of the system.

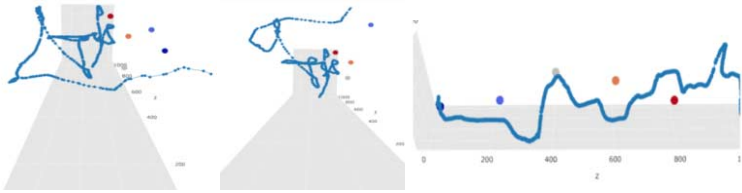

Figure 2. Reconstructed visualization of the actual hand movement and the position of the presented waypoints, Z-axis corresponds to game time.

4. Future Steps and Conclusion

In the previous sections we presented the rationale and the implementation of a serious gaming platform for motion rehabilitation. The implemented prototype game developed on Unity3D gaming platform leverages Leap Motion controller to interact with the user's hand and proposes how to organize the goal setting, customization and scoring for the serious gaming purposes. At the moment, this framework is limited to a specific range of motions and game paradigms. Since initial results seem promising, future steps include a small-scale study involving patients with problems on the motion control of upper limbs, that will possibly reveal any limitations. Also, further analysis of the recorded data will provide additional insights on the game's effects on the disease and the analysis modules. Processing data from each session, will be performed in almost real-time conditions to provide detailed feedback to the patient as fast as possible. Another scenario that must be investigated is the synchronous acquisition of additional signals (e.g Electromyography, EMG) to examine the correlation between stimulus and actual motion in patients and in healthy subjects, and extend accuracy to a wider range of movements.

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UMOD: A Device for Monitoring Postoperative Urination

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Abstract. A Urine Monitoring Device (UMOD) has been designed and implemented for monitoring postoperative urination. This device has been created primarily to assist nurses and doctors monitor patients during their postoperative and recovery period. Furthermore, to reduce the burden of the nursing staff required to regularly monitor and empty the urine bags saving them precious time. The device consists of a stand and a load cell where the urine bag is attached. The stand is light and can easily move shall the patient require to move. An ESP Wi-Fi microprocessor module is used to calculate the rate of flow of urine in real time, identify and ignore any false readings due to accidental movements of the urine bag using an accelerometer and transmit the readings to a server / cloud through the local Wi-Fi.

Keywords. Monitoring, Urine, Postoperative Urination, Fluids, Medical treatment

1. Introduction

The number of different medical related conditions treated on a daily basis in hospitals is enormous, requiring constant attention fromhospital staff, resulting in pressure, tension and in some cases mistakes. Rapid changes in medical technologies together with changing practice pattern of doctors can be employed to improve the time spent by nurses and doctors. Development of such technologies is the way forward towards a more effective and accurate healthcare system. This has become even more apparent given that there is high demand for increased productivity despite financial reductions. As stated in [1], "Expensive technology is a bargain if it can improve quality of life, preserve economic productivity and prevent the high cost of disability". This paper presents how a prototype of a low-cost Urine Monitoring Device (UMOD) has been developed and how this can be used for patients fitted with a urine catheter. The device has been designed to provide constant, real-time information about the rate of flow of urine in the bag. The rate of flow of urine is particularly useful to the medical staff given that there are many illnesses related to the urine system such as chronic kidney disease, bladder diseases, urine system pathologies, etc. UMOD can be used to monitor the patients' ability to urinate postoperatively given that there are numerous factors that can influence this ability such as (a) age, (b) gender, (c) a previous history of bladder problems, (d) type and duration of surgery and anesthesia, (e) drugs, and (f)

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intravenous fluids [1]. In such cases, our device can be used to provide useful information to the doctors regarding the frequency and the volume of urine flowing out of the body of the patient.

2. Proposed Low-Cost Urine Monitoring Device

The objective of developing a low-cost urine monitoring device is to facilitate the mass deployment of such devices in hospitals in order to collect useful information from patients suffering from urinary related diseases and support their postoperative treatment. Also, to reduce the burden of the nursing staff to check the urine bags at frequent time intervals by alerting the nurse station with the help of an alarm system so that a suitable action can be taken. Furthermore, to intergrade these devices to a healthcare system. In 2014 Abraham Otero et.al. designed and built a similar device capable of automatically monitoring of urine output [3]. The device provided minute by minute measures and it could generate alarms that warned of deviations from therapeutic goals. Their device had a single-chamber container holding 90ml. The urine ended up in the vessel through a tube attached to the catheter and outside it had a capacitive sensor. This capacitive sensor was used to measure urine levels in the container. So, when this pot was filled, it was emptied automatically without the need of electricity. To do this, however, their device used magnetic forces to prevent activation of the dispenser until it is almost full. In addition, BIOMETRIX built a device called URIMETRIX for measuring the urine output and calculates the volume of urine every time the patient urinates and then dispose the urine in a bag [4]. This allows closer monitoring of the patients given that it is possible to measure the ratio of urine density compared with water density and provide information on the kidney's ability to concentrate urine. URIMETRIX includes high level urine meters, Foley catheters with temperature sensor and intra-abdominal pressure sets with accurate pressure transducer monitoring. UMOD features a much simpler and lower-cost mechanism where the weight of the catheter's bag is constantly measured and any increase / decrease on the weight of the urine bag is timely recorded. No special urine bags are required nor tubes. Assuming an average urine specific gravity at 1.020[5], it is possible to calculate the quantity of urine flowing into the bag in milliliters. Nevertheless, for some conditions, there is high urine specific gravity, such as in the cases of volume loss (dehydration, vomiting, diarrhea, fever), hepatorenal syndrome, heart failure, renal artery stenosis, shock syndrome of inappropriate antidiuretic hormone. For some other conditions such as diabetes insipidus, renal failure, pyelonephritis, glomerulonephritis, psychogenic polydipsia, malignant hypertension there is low urine specific gravity. In such cases using a urinary specific gravity measurement is a routine part of urinalysis. Nevertheless, this exceeds the scope of UMOD given that it is designed to provide readings assuming an average urine density thus making it applicable for conditions that do not affect the urine specific gravity and simple monitoring of postoperative urination is critical for the patient's recovery [5].

UMOD System Requirements: The Urine Monitoring Device was designed based on a set of requirements provided by nurses and doctors. More specifically, the UMOD's cost had to be kept as low as possible to support the mass deployment such devices around a hospital. UMOD should be light in order to be easy to move. It should constantly measure the weight of the urine bag (ignoring the actual weight of the bag) and transmit the data to a local server / cloud for further processing. Furthermore,

UMOD should be easy to set up for users (primarily nursing staff) with no particular ICT skills. Furthermore, the device should also be capable of ignoring any sort of accidental movements of the urine bag. The device should also be fixed either on the side of the bed or on a separate floor stand given that some patients might wish / have to move out of their bed. The device allows nursing staff to easily empty the urine bag.

UMOD Hardware / Software Design and Operation: Operation of UMOD is based on a load-cell that constantly measures the weight of the bag and transmits the readings to a local server / cloud running a database to keep track of each patient urination (time, weight / volume). More specifically, the device is using an ESP (Wi-Fi) microprocessor module which is connected to a load cell. The load cell is used to measure the weight of the urine bag and it can provide readings up to 2kg. The analogue signal from the load-cell is amplified and then received by the ESP where it is then transmitted through the Wi-Fi to a local server or cloud. The load cell is attached on the stand that is to be situated next to the patient's bed. A hook connected on the load cell allows the urine bag to be attached. Using the readings recorded in the local server / cloud, it is possible to calculate the rate of flow of urine per hour assuming an average urine specific gravity of 1.020 (). These readings can be particularly useful for checking the frequency and quantity of urination of a patient after an operation. Finally, an LCD screen is connected to UMOD where someone can see the current reading of the urine weight (kg). UMOD is set to ignore the weight of the empty urine bag, thus providing readings only of the content of the bag. UMOD is also facilitated with an accelerometer in order to record potential movements of the urine bag. The accelerometer has been (externally) attached near the end of the urine bag (see **Figure 1** and **Figure 2**).

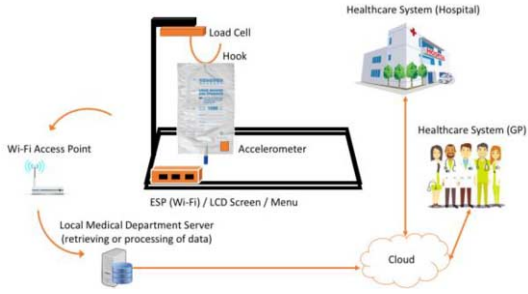

Figure 1. Proof of concept of UMOD integrated with a Healthcare System

Figure 1 illustrates a proof of concept of how UMOD will be integrated with a health care system providing useful information about the state of the patient in terms of urine output. Typically, this data will be made available to the medical department the patient is treated through a local server, as well as to the cloud for external access through the healthcare system of the country.

3. Discussion of Results

Initial tests devised to verify the operation of the device were accuracy and shock tests. For accuracy, a bottle of water at room temperature (25℃) was attached to the urine bag and water (with 997kg/m^3 density at 25℃) was manually allowed to flow in the urine bag. **Figure 2**(a) illustrates the actual prototype and **Figure 2**(b) the data recorded by UMOD when urine (water) was released in the catheter on the 13th minute and the

weight measured was 0.105 kg (0.105L). Another release took place on the 14th minute where the weight moved up to 0.200 kg (0.20L). The next release took place on the 22nd minute and the weight increased to 0.420 kg (0.420L). All instances were cross-checked for validity using a precision weighing machine as well as based on the quantity of the water poured into the urine bag.Another test that took place after the 30th minute was the shock-test where the catheter's bag was intentionally moved to check if the value of the weight recorded has changed but as it can be seen, the readingsremained the same.In this particular example it can be deduced that the patient produced a total of 0.420L of "urine" in an hour. This will become more meaningful when data is collected for longer periods, and particular urine release patterns are recorded to estimate the rate of flow.

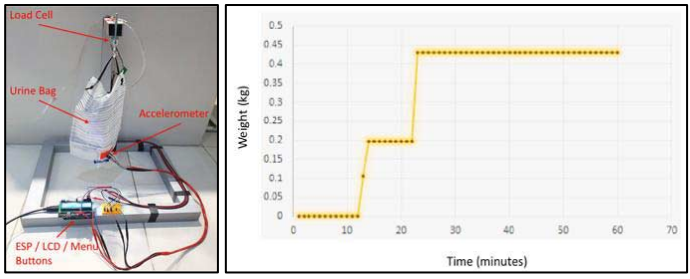

Figure 2. (a) UMOD Prototype (b) Results Water filling and shock test of UMOD

4. Conclusions and Future Work

UMOD constantly monitors the levels and rate of flow of urine in a urine bag and reports this in a local server / cloud for further processing. UMOD assumes that urine density is constant in order to estimate the rate of flow in milliliters. UMOD development was a proof of concept ofa low-cost device for monitoring postoperative urination. Next step is to associate the results of the instrument with confidence values, calculated based on the standard deviation of urine density of potential patients. Furthermore, test its accuracy by measuring urine sample weight / volume and comparing it with existing practices. Finally, a mobile app will be developed for better user experience along with an API for our device so that this data can be integrated with existing healthcare systems.

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Design and Development of a Mobile Application Supporting Planning for Future Parents

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Abstract. Life is changing after recognizing a pregnancy. Then the future parents, who are often healthy individuals, need to change their lifestyles, meet different healthcare institutions, follow new rules, and reschedule their everyday activities. This paper illustrates the design and development of a novel mobile application supporting future parents in planning their activities after recognizing the pregnancy. The focus is on identifying and sharing relevant data between future-parents, healthcare institutions, and the supporting social groups. First, the design and development of the application are sketched, and then we present early evaluation results with major stakeholders: future parents and responsible actors from healthcare institutions, based on data from interviews. The results contribute to increased understanding of developing mobile applications for future parents, considering temporal, situation dependent needs during the pregnancy process, but also after having given birth. To handle temporal and longer-term needs, and provide contextualized information, considering patient-pathways are beneficial.

Keywords. Patient pathway, pregnancy, future parents, communication, mobile applications, mParent

1. Introduction

Recognizing the pregnancy means reorganizing everyday activities in many future parents' life. Activity changes can relate to acquiring adequate information about the new status, considering new goals for the situation, changing habits and routines, but also can mean planning health-related visits at different healthcare units (HCU). While there are many mobile applications(mApp) or mobile health application (mHealth) supporting future parents (here we call these health-related parental applications mParent apps) [1], there are no applications on the market today, according to our knowledge, supporting all possible changing activities due to pregnancy and later on delivery and through childcare. Additionally, communication between patients and HCUs and between different HCUs regarding pregnancy and childcare is experienced as fragmented [2,3]. The motivation behind this study is to investigate how the communication between parents and relevant HCUs during the parents´ pathway through the pregnancy can be simplified by organising the information flow around the parents, and developing a mobile application to facilitate this. We call this application

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Elisa. One of the main hypotheses is that by supporting the planning around the meetings with the responsible HCUs, the future parents will experience a quality improvement in their process from the time the pregnancy is recognized, through the childbirth and the postpartum period. Obstetrics is the field examining this period. This study considers Norwegian laws and regulations; however, the technology support is examined from international studies. The goal of this paper is to present the design and development of a mobile application supporting planning activities for future parents. Data comes from three major stakeholder groups: the future users, practitioners involved in obstetrics (midwives, nurses, and clinicians) and technicians involved in designing software for healthcare. This report incorporates evaluations and activities for designing and developing a functional prototype. The focus is on identifying and sharing relevant patient data between HCUs and future parents. We examined possible needs for such an mParent app, with respect to actual requirements for interoperability, safety, and efficiency. The market form Parent apps is exponentially growing [4]. These apps started to be more popular than a simple search on the internet [5], andare predicted to overcome trust in physicians [6]. Many of the current apps are focusing on specific functionalities, e.g. following the growth of babies or the mothers, eating advices, training advices, or helping mothers with some health problems. More than 75% of pregnant women are using mParent apps, according to several studies in different countries [1,5,7]. The most commonly used are pregnancy wheels (84%), cervical cancer screening algorithms (68%), and contraceptive eligibility guidelines (47%) [7]. Current research agrees that the information about the pregnancy process is fragmented and the communication with the involved HCUs is limited. There is a need for cooperation with qualified healthcare professionals and having a more general overview on and during the parental process. Now, the question is how to choose the most relevant functionalities and add missing functionalities in relations to communication with HCUs. Even if the future-parents need to have a good overview of the process, they may have different needs in the different moments of the pregnancy, delivery, or childcare and at different moments when different HCUs are involved. To understand the whole process, we examined how literature treats ‘pathways’ through HCUs. Care pathway (CP) is defined as a methodology for HCUs to make mutual decisions and organize care for a well-defined group of patients for a well-defined period with the aim to optimize clinical routines [8]. From the future parents perspective, CP can be stable, since most of the *patients here are healthy individuals.* Harmonizing CPs with patients’ pathway (PP) may help to organize activities with temporal characteristics supporting future parents and their common need. Here, the patient pathway is the abstract description of resources and activities needed to handle communication through the network of affected HCUs [9].

2. Methodology

Data for this paper comes from three major stakeholder groups: the future users (parents), practitioners involved in obstetrics from healthcare (midwives, nurses, and clinicians) and technicians involved in designing software for healthcare. This report incorporates evaluations and activities for designing and developing a functional prototype. Design requirements were identified from literature study and possible and needed activities from secondary documents [10]. Based on this, the involved HCUs (and CP) were identified and a PP was sketched. Then, with help from a designer and

with tools such as ADOBE XD, PHOTOSHOP, and Marve app an interface with major functionalities were designed. The activities during this PP were discussed during semi-structured interviews with possible users, a group of four pregnant women, a midwife and two clinicians. What to share, when to share, and basic needs for communication depending on time, were the main questions for both professionals and future parents.

3. Creating a prototype

The basic parts of Elisa are the timeline, the PP following time dependent activities from the pregnancy, through birth and delivery with focus on communication during CP and possible visits at the involved HCUs. The associated CP was a synthesis of recommendations from the Norwegian gynaecological organization [10] and determined the suggested pathway for the future parents (the PP). According to international practice for a healthy pregnancy, the recommendation for visiting midwife is on average 10 visits for first pregnancy and 7-8 visits after. None of the interviewed parents were aware of the amount of recommended visits. Only the firstly interviewed midwife recalled this amount of visits. However, even she recognized that the number of visits is not always communicated with future parents, and the overall plan is not taken into consideration. At each patient control, mainly only the next upcoming check is discussed. There were cases where either the patient or her medical doctor knew that some of the partners are planning longer trips during the gravidity, but these trips were not discussed. Many of the functionalities acknowledged by the presented literature were recognized as important. They were included as a basic functionality, one of the nine buttons from the main page (A) or inside in some of these, as Fig. 1 shows. The main page includes information about the process for a pregnant woman (here: 22 weeks and 5 days), including a visit notification. The second (B) and third page (C) are from the journal, while the fourth (D) one called “about me” describes changes in the pregnant body. These functions and activities were discussed during the semi-structured interviews.

Figure 1. Screenshot from the main page of the prototype (A) and three other pages.

The interviews identified three main categories of problems: “Critical”, “Important” and “Desired”. *Critical* functions were related to information regarded to decisions which have to be taken by the mother during the CP. *Important* functions were related to routine timeline activities, e.g. drug administrations and recognizing patterns to be aware of during the pregnancy. Information regarding patients’ rights and communication facilities towards HCUs also belong here. Communication facilities

with other parents, social support groups in the same situations were identified as a *desired* function. Most importantly, having a functional prototype to communicate with users was important. The early sketches and description were not considered equally important due to, according to a clinician, the large number of functions one needs to remember. Looking to all possible alternatives on the digital journal was also important. All people interviewed and tested were curious and intuitively interested in the app. With the help of the proposed app and situations, the future parents can be stimulate to take a more active role in their pathway, and becoming more aware of several sources of information.

4. Conclusions and future work

This paper sketched the design and development of Elisa, a novel mobile application designed to support planning activities for future parents. By acknowledging earlier studies, arguing for the involvement of midwives and healthcare professionals for such applications, this study took a further step and examined possibilities for involving health professionals and investigating their role in developing and using such applications. During the design and development, the importance of having a functional prototype was beneficial for communicating with the different stakeholders. To design and prioritize functions following the patient pathway helped to keep the focus on future-parents actual and overall needs, and helped to harmonize with HCU activities around the clinical pathway. Important next steps are how this harmonization can be made more complete and consider e.g. other juridical and official documents, special cases for handling mother or child problems, and considering the opinions from the fathers. The results also contribute to increased understanding the importance of designing interfaces and handling representations of temporal and longer-term needs for planning mApps.

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Computer Virus Models – The Susceptible Infected Removed (SIR) Model

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Abstract. The healthcare domain requires security against possible threats, such as viruses to defend the integrity of the health and patient records. During the system analysis, different parts of the sub systems are connected under a main system. Under these connections into the Internet, malicious programs are spread into the system network and damages to vital information have been appearing. For that reason, it is crucial to model the spreading of the computer virus using dynamic equation systems and the solution of these systems will be presented. In this work an epidemiological model SIR is presented, and the analysis of its performance is illustrated.

Keywords. computer virus, SIR model, computer security, malicious software

1. Introduction

During connection procedures as a network or as individual standard process unit, various times threats can approach the system and viruses can be spread. [1,2]. Computer virus is a malicious software that infects other programs by modifying them. This technique includes a copy of the virus program that can then use another uninfected program for his spreading. A computer virus carries in its initial main code to other programs by making copies of itself or by copying parts of the infected program to the network. Each time an infected host is in contact with an uninfected piece of software, a new copy of the virus infects the new program. [3-6]

2. Methods

Computer virus is malicious software that infects other programs by modifying them. A computer virus carries in its initial main code to other programs by making copies of itself or by copying parts of the infected program to the network. Each time an infected host is in contact with an uninfected piece of software, a new copy of the virus infects the new program [7,8]. The main categories of computer virus are: (1). Boot sector infectors; (2). Macro Viruses; (3). Polymorphic viruses; (4). parasitic viruses, and (5). Memory resident [9,10]. Epidemiological models have been used to analyse the outcome of virus spreads in human or animal populations. However, the same models were recently applied to the analysis of computer virus epidemics [7]. Epidemics

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models require the definition of a set of possible states and a set of transition rates. One complex model is the *Susceptible-Infected-Removed* (SIR) model. Spreading of the virus leads us to the analysis of the epidemiological structures of the process and modelling of the procedures, so the researchers could apply the techniques to predict the effects of the computer virus [7,9].

***Susceptible-Infected-Removed* (SIR) model**

The SIR model is an extension of the Susceptible-Infectious (SI) Model, in which is included one more factor (Removed) in relation to the SI model. This stage is stable removed and represents the hosts which have recovered from the infection and cannot be re-infected again, or which have been in quarantine and those who have died during the infection (Figure 1) [11-13].

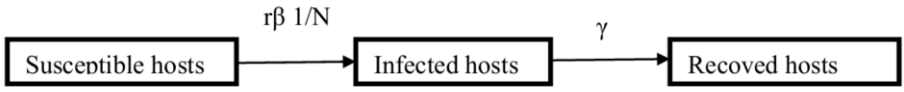

Figure 1. SIR Model [7]

In this model, S(t): the number of uninfected hosts at time t; I(t): the number of infected hosts at time t; N: the size of population (N=S+I) and β: the medium rate of population. The R(t) which represents the number of removed hosts at time t and the γ. The size of population is N=S+I+R. The system of the dynamic equations is given by [14]

$$\frac{dI(t)}{dt} = \beta I(t)S(t) - \gamma I(t)$$
$$\frac{dS(t)}{dt} = -\beta I(t)S(t)$$
$$\frac{dR(t)}{dt} = \gamma I(t)$$

Including the rate of removal β the first equation becomes: $\frac{dI(t)}{dt} = \beta\left[S(t) - \rho\right]I(t)$ with final result this $\frac{dI(t)}{dt} > 0$, iff $S(t) > \rho$, meaning that no infection to the system except the host is bigger than ρ. Simulation of the SIR model under β-rate is given in Figure 2 where it is clear that as the rate increases the infection becomes quicker.

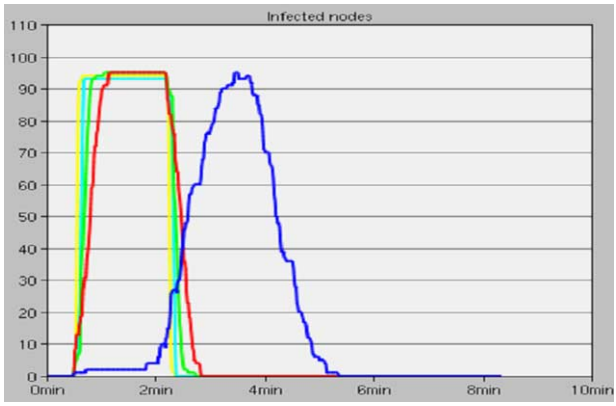

Figure 2. Simulation of SIR model with rate β

3. Conclusion

In this work, the introduction of computer virus modeling is introduced and the description of the characteristics for the SIR epidemiological model is illustrated. Based on this model, the dynamic equations system is explained considering the rate of inflection for the computer network system and the final mathematical solution is presented.

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Exergames for Parkinson's Disease Patients: How Participatory Design Led to Technology Adaptation

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Abstract. Parkinson's disease (PD) is a neurodegenerative disorder that affects more than 10 million people worldwide. Assistive technology and exergames come to play a beneficial role in positive mood and socialization improvement, overall quality of life and improved confidence with everyday functional activities. More and more Exergames inserts in the market but how many of that are fitting the patient's needs? How many of that took into consideration theirs's opinion. This study describes the Minimum Viable Product (MVP) model "Develop-measure-learn" circle in a co-creation way with the PD patients to develop and improve Exergames for them, and the tools that are needed to accomplish. The most important outcome of this procedure was the proposed development of more realistic games, giving the researchers the step of starting the investigation of 3D solutions.

Keywords. Parkinson's disease, Design, Exergames, webFitForAll, Unity3D

1. Introduction

Development of games and application in the previous decade was taking place only in the developers' offices, in front of their computers. It was a common practice that the end users were contacted only after the game or app was considered as final. In many cases this was leading to low acceptance levels which in turn was leading to wasted resources. This has started changing over the last years where end users have started considered to be involved from the beginning of the design. Exergames for older adults could be highlighted as a representative example where, based on the literature [1-5], end users and developers work together, even from the inception of the exergames concept.

In this paper, the Minimum Viable Product (MVP) model "Develop-measure-learn" circle is presented along with its impact on the decision for the development tools and technologies. An example of designing exergames for Parkinson's Disease (PD) patient's, along with their feedback [6] and how this influenced low-level technical decisions (changing game engine from 2D Exergames to 3D) is discussed.

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2. Aims and Objectives

The aim of this study is to show how the selection of the appropriate tools and the methodology to design and develop new Exergames in a co-creation way with PD patients is strongly influenced by meeting and experimenting with the end users early enough. To do so, and given the requirement for designing and developing exergames for the i-PROGNOSIS H2020 European research project [7], the web FitForAll platform was used. The i-PROGNOSIS project aims at developing early Parkinson's disease detection methods. The web FitForAll platform is a web based application, is an integrated exergaming platform using depth sensor controllers (the Microsoft Kinect initially and the MentorAge sensor currently) for healthcare monitoring and game-blended exercises and interventions [2-3]. It includes specific exercises within an engaging game environment aiming at promoting physical exercise protocol adherence [4-5].

3. Design process

The procedure of co-creation that we follow is based on circles that include develop, measure and learn attempting to create Exergames suitable for the PD patients taking into account their feedback. PD patients from Parkinson's Disease Association located in Thessaloniki were fully informed about the purpose of the study and signed the informed consent.

3.1. Storyboards and 2D version

To understand the real PD patients' needs and what they would expect from a new exergame, we started the design thinking phase by engaging them in a discussion even before starting developing the games. In this discussion, a draft version of the games where presented through storyboards **(Figure 1)** [6]. An open discussion with the patients was followed by a questionnaire. The collected feedback led the designers and developers to design the first version of the games in a 2D framework.

Figure 1. Storyboard

Figure 2. First 2D prototype of fishing game

The first 2D prototype of the fishing game was developed with the JavaScript 2D game engine CraftyJS and implemented in the wFFA platform **(Figure 2)**. This prototype was presented to the PD patients. An open discussion and a questionnaire have been used for the feedback acquisition. The most remarkable point is that although in the design thinking phase the PD patients had reported that they would prefer 2D simple graphics, they were not so enthusiastic with the first prototype and they asked for more realistic 3D games.

3.2. 3D game engines

After getting the feedback, and well before advancing the development of all the games, the designers and developers had to review and select the most appropriate 3D game engine. There are many 3D game engines available in the market, bothopen source and paid. Although the team had some experience with some open source WebGL based game engines, such as ThreeJS and BabylonJS, a more proper solution for fast prototyping was sought such as Unity.

Considering all the above including new depth sensor that uses android and PD patient's desire for 3D games, the **Table 1** shows in summary the comparison of the game engines that leads the researchers to use Unity3D for the next prototypes.

Table 1. Game engines comparison table

	iOS		Android		PC	
	Native(.ipa)	**WebGL**	**Native(.apk)**	**WebGL**	**Native(.exe)**	**WebGL**
Unity 3D/2D	*YES*	*YES / low FPS on high resolution 3D*	*YES*	*YES / low FPS on high resolution 3D*	*YES*	*YES*
BabylonJS 3D, ThreeJS 3D	*NO*	*YES / low FPS on high resolution 3D*	*NO(.apk through IONIC)*	*YES / low FPS on high resolution 3D*	*NO*	*YES*
CraftyJS 2D, 2.5D	*NO*	*YES*	*NO (.apk through IONIC)*	*YES*	*NO*	*YES*

4. First 3D prototypes

Using the Unity3D to adapt the games to thePD patients' feedback, the fishing game was re-developed in 3D design with realistic graphics and physics in high resolution **(Figure 3)**. However, after several performance tests in different devices in the lab (PC and Android) the performance on Android devices was not the one expected (~10 Frames per Second). The processing requirements of the realistic physics in conjunction with the high resolution graphics could be supported by the Android device, leading even to the application's crashing.

Figure 3. First 3D prototype of fishing game

Figure 4. Second 3D prototype of fishing game

The compromise between the PD patients' feedback and the selected technology's limitations was the workaround to use low resolution 3D models. The "Low Poly" design is a new trend in 3D modeling which offers very fast rendering because of the small amount of polygons of the model. The second 3D prototype **(Figure 4)**, following this new and modern style, improve the frames per second a lot, and consequently the gameplay experience (60 FPS).

5. Results

The results from the first procedure show that 7 out of 10 patients asked about the graphics presented in storyboards/2D would like the abstract/animated design. The next stage includes the involvement of health professionals leading to the creation of the 3D prototype. The results from the currently procedure show that 3 out of 4 patients asked about the graphics presented in 3D prototype, they liked more the design from the 2D. The evaluation process of the first 3D prototype will continue according to PD patients' needs. These more accurate findings along with the feedback provided will be analysed and presented in a future study.

6. Conclusions

The current study presented a game design case study towards highlighting the importance of involving the end users early enough, even from the design phase. The case study presented in this paper showed that the involvement of the PD patients in the design phase of the games influenced not only the design or game play of the game but also the development tools.

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Augmented Reality Glasses and Head-Mounted Display Devices in Healthcare

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Abstract. Augmented Realty (AR) technology has a significant contribution in healthcare sector by offering valuable solutions the last two decades**.** The aim of this paper is to investigate the implementations of Augmented Reality technologies in healthcare, which include wearable devices such as AR Glasses and Optical Head-Mounted Display Devices (OHMD), by searching the international scientific literature. Relevant studies were retrieved online from scientific databases using keywords related to Augmented Reality in healthcare. The results indicate the numerous applications of these technologies in healthcare procedures, like diagnosis, treatment, and rehabilitation, as well as in the education of healthcare professionals. The international scientific community encourages the usage of the AR wearable technologies like AR glasses in Healthcare.

Keywords. Augmented Reality, Smartglasses, OHMDs, Healthcare

1. Introduction

The Augmented Reality (AR) technology is focusing on mixing virtual with real world data in order to enhance the real world environment with additional information using the assistance of Information Technology Systems [1]. AR devices include, among others, Smartphones, Tablets, Smartglasses. Wearable devices with AR technology features, can offer limitless AR applications [2-4]. New wearable optical head-mounted display devices, like Google Glass and Microsoft HoloLens, seem to be very promising for the future development of the AR applications and the implementation of this technology in people's everyday life. Meanwhile, AR Technology could also contribute in Healthcare [2]. Valuable solutions have been developed over the last two decades in this sector. A lot of AR initiatives contributed on several medical specialties, for example on complicated surgery operations such as neurosurgery [5,6], or on medical imaging and other diagnostic tests [7,8]. Additionally, AR proves to be an effective tool on chronic diseases management and rehabilitation [9-11], on medical education and on new skills development [12,13], and on dentistry [14]. Therefore, Smartglasses, new Optical head-mounted display devices and other wearable devices can be included in AR Systems in Healthcare. The aim of this paper is to investigate the implementations of Augmented Reality technologies in Healthcare, which involve

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wearable devices such as AR Glasses and optical head-mounted display devices, in order to record the current technological status in this field of study.

2. Methods

A non-systematic literature review was conducted on May 2018. Specific keywords and their combinations were used in Pubmed, IEEExplore, Sciencedirect, and Google Scholar to identify studies related to Augmented Reality in Healthcare. The search terms included: "augmented reality", "healthcare", "wearable devices", "glasses", "optical head mounted display (OHMD)", "Google Glass" and "Microsoft HoloLens". Studies published during the last five years were considered, as wearable devices and augmented reality applications in healthcare sector have been developed recently [15].

3. Results and Discussion

Over 40 publications related to applications of wearable devices that utilize AR technologies in healthcare were collected. The overwhelming majority of these studies deal with Optical head-mounted displays. Thus, it can be assumed that in recent years the international scientific community encourages the usage of the AR glasses in Healthcare [16]. One of the most famous Optical head-mounted display device is Google Glass, and according to the related literature, it has been used widely on surgical operations as supporting equipment [17-19]. Microsoft's HoloLens is an Augmented and Mixed Reality Device, which has already been applied in Healthcare and produced positive outcomes in surgical practice and education [20-23]. In general, Smartglasses have been applied in several health domains especially in surgery [24]. Neurosurgery, plastic surgery, orthopaedical surgery and urological surgery are typical examples of AR glasses application in surgical treatment [25-29]. AR systems with head-mounted displays were found to be used in Ophthalmology [30], for Concussion Assessment [31], by patients with Parkinson's Disease [32], and by people with Autism [33], in order to support their everyday life. AR glasses may assist patient diagnosis, mainly in orthopaedics [34], patient triage in cases of emergencies, disasters and mass casualties [35,36], treatment of phantom limb pain [37] and minor surgical operations on spine [38]. OHMD may also facilitate medical education and training of health professionals for obtaining new skills [18,39-41]. The main applications of AR glasses technologies investigated in Healthcare are presented in Figure 1.

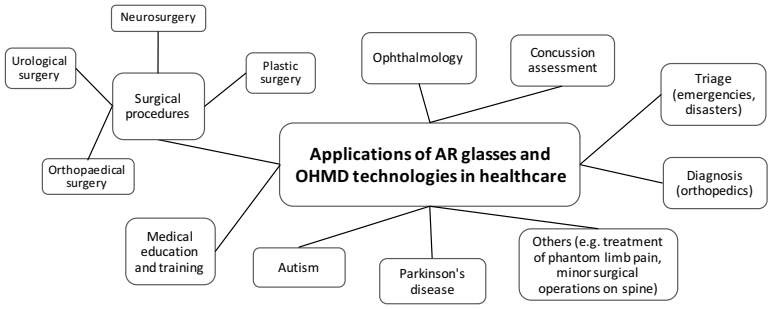

Figure 1. Applications of AR glasses and OHMD technologies in healthcare.

A few studies evaluated specific prototype AR systems in Healthcare and produced quite positive results, which can encourage further implementation and usage of this technology [42-44]. However, such technologies may have negative impact to the health of their users. A recent study reveals the potential health hazards on retinal health caused by head-mounted displays [45]. Nevertheless, it was found that new experimental devices are being developed to promote improved AR OHMD technologies in Healthcare [46,47].

4. Conclusions

Optical head-mounted displays and other AR technologies are in a preliminary implementation stage in Healthcare sector. However, they are proving to have a positive contribution in Healthcare services and a huge potential for further innovative solutions. In the current review, publications related to wearable AR devices other than glasses and optical head-mounted displays were excluded due to their limited number. Future work may include a survey to examine the attitude of health professionals towards the AR technology based on OHMD.

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Section II

Data Analysis and Decision Support Systems

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Structuring Clinical Decision Support Rules for Drug Safety Using Natural Language Processing

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Abstract. Drug safety is an important aspect in healthcare, resulting in a number of inadvertent events, which may harm the patients. IT based Clinical Decision Support (CDS), integrated in electronic-prescription or Electronic Health Records (EHR) systems, can provide a means for checking prescriptions for errors. This requires expressing prescription guidelines in a way that can be interpreted by IT systems. The paper uses Natural Language Processing (NLP), to interpret drug guidelines by the UK NICE BNF offered in free text. The employed NLP component, MetaMap, identifies the concepts in the instructions and interprets their semantic meaning. The UMLS semantic types that correspond to these concepts are then processed, in order to understand the concepts that are needed to be implemented in software engineering for a CDS engine.

Keywords. Pharmacovigilance, drug safety, CDS, NLP

1. Introduction

Advances in interoperability and architecture of Health IT systems have enabled provision of new functions that allow integrating aspects of healthcare that were previously isolated. Examples include, integrating data sources under a single record, and provision of personalized care plans that can be accessed and evaluated by multiple stakeholders such as experts, family and the patients themselves [1]. Such health IT infrastructures, are based on collaboration amongst components, using messaging standards such as FHIR provide an overarching new capability.
Clinical Decision Support (CDS) modules often provide a means of checking the information exchanged between components for medical significance. For example, improving drug safety, checking prescriptions for validity, as well as identifying adverse interaction between prescribed drugs, particularly to polypharmacy patients. Such check is the validation of a prescription against typical instructions, such as maximum dose during a time period. However, in order for this to be achieved by a health IT based system, these instructions need to be captured in a format that is executable by IT systems. The instructions need to be modelled in a way that an IT

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system can understand their semantics, in order to be applied as rules when checking a prescription. The National Institute for Care Excellence (NICE) provides dose instructions for the drugs listed in their British National Formulary (BNF). The NICE BNF provides structured definitions of drug aspects such as drug to drug interactions, but uses free text for drug instructions. For example, "*500mg 3 times a day"*, and "*300–900mg every 4–6 hours as required; maximum 4g per day.*". Dose instructions are expressed using a number of (semantically) common concepts. For example, quantity of a substance, frequency, quantity checks (e.g., maximum 2g), as well as more complex logic including past or future events and checks.

The work presented in this paper looks into the UK NICE BNF dose instructions, and using Natural Language Processing (NLP), identifies the types of semantic expression and investigates how we can generalize these types, and how they can be used to specify rules that can be applied to health IT systems that contribute to medication prescription. NLP has been used to extract semantic relations from clinical texts categorizing and mapping clinical knowledge [2- 5].

2. Overview of the Approach

Information about drugs are taken from the UK NICE section of the British National Formulary (BNF), a reference on pharmacology and prescribing. The drugs are stored in a structured way, as objects, in an Eclipse Modelling Framework model; this allows processing the elements of the model. The UK NICE BNF provides instructions for each combination of *patient category*, *drug administration route*, and *indication*. All instructions are exported in a format suitable for NLP analysis.

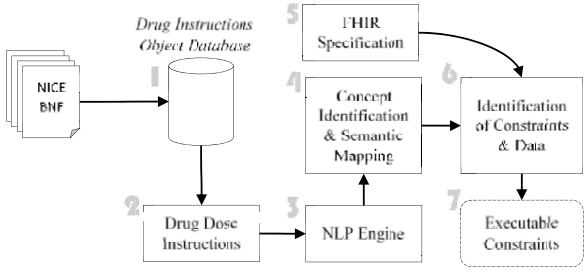

Figure 1. Overview of the Approach.

The instructions are then processed by MetaMap [6], an NLP tool that recognizes UMLS Metathesaurus concepts referred to in biomedical text entered in the NLP Engine. The UMLS, or Unified Medical Language System, is an interoperable collection of health and biomedical vocabularies. Concepts, i.e. vocabulary terms, are categorized in semantic types, i.e. broad subject categories, such as *Activity*, *Genetic Function* and *Fungus*.

The NLP engine annotates blocks of the text according to its semantics; for example, *less than 200mg*consists of a quantitative concept (200mg) and a functional concept (*less than*) that is the operation on the quantity. A total of 15000 instructions for 1660 drugs have been processed using NLP, for identification of their semantic building blocks. This produces a set of concepts that will either represent a resource (i.e. an information about prescribing that will be available in the system), or a rule (an

operation that will need to be performed on a resource which will be enforcing the instructions). In order to identify whether the identified resources will be available, we are looking at how they can be matched with the data elements of the *MedicationPrescription* data structure of the Fast Healthcare Interoperability Resource (FHIR) standard. FHIR is a messaging exchange standard that has improved interoperability of health IT systems, by offering a standardized means of exchanging information. Although not a storage standard, any component complying to FHIR would be expected to provide a specific set of information, structured in a specific way. Figure 2 shows the class diagram equivalent of the *MedicationPrescription* FHIR resource which is of interest. The last stage of the process (7) is outside the scope of this paper.

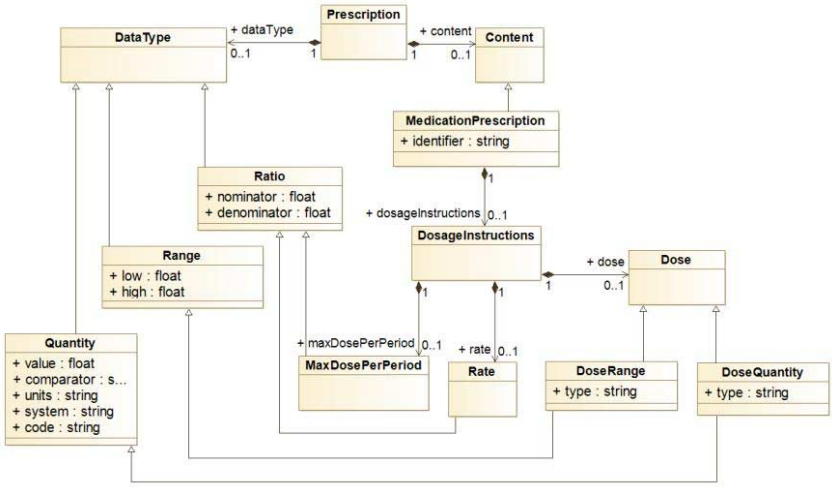

Figure 2. UML class diagram showing some of the typical information concepts expected in a prescription, according to the FHIR *MedicationPrescription* resource.

3. NLP Concepts

Table 1 presents the seven most frequent UMLS concepts that appear in the instructions, along with their associated semantic types.

Table 1. Frequency of the UMLS concepts in the NICE BNF drug instructions.

Position	Frequency	CUI	Semantic Type	Concept
1	4200	C0439210	Quantitative Concept	MILLIGRAM (milligram)
2	2888	C0178602	Quantitative Concept	DOSE (Dosage)
3	2757	C0332173	Temporal Concept	/day (Daily)
4	1289	C0205265	Temporal Concept	Initially
5	1015	C1883708	Temporal Concept	Then
6	974	C0442805	Functional Concept	Increased (Increase)
7	923	C0585361	Temporal Concept	Twice Daily (Twice a day)

A total of 1984 concepts were identified; however, the 80 most frequent concepts had 37,000 appearances in the instructions, and the rest 1904, 52,173. These 1984 concepts were identified to belong to 128 semantic types, with the 10 most frequent semantic types appearing 45,000 times.

4. Designing rules based on FHIR resources

Concepts and semantic types can be mapped to specific rules that will be implemented in an executable format in a CDS engine. This section shows an example of how such rules can be specified using the Object Constraint Language (OCL). OCL can then be applied to any object-oriented environment and transformed into relational database query and rule. For example, three of the most common concepts appearing were *mg*, *dose* and *twice a day*. This respectively correspond to *Quantity*, *Dose*, and *Rate* in the *MedicationPrescription.* Figure 3 shows how such a rule would be specified in OCL.

```
context Prescription inv correctDosage:
  self.content.oclAsType(MedicationPrescription).dosageInstructions-
  >forAll( i | i.dose -> forAll(d | oclAsType(DoseQuantity).type = 'mg' and
  d.oclAsType(DoseQuantity).oclAsType(Quantity).value <200))
```

Figure 3. OCL rule using the *Quantity*, *Dose*, and *Rate*, FHIR resources.

5. Conclusions

The experiment offered two main conclusions. Firstly, there is a strong indication that drug instructions only need a limited number of concepts to be expressed. This can allow the specification of a controlled vocabulary language that can be used to define all potential instructions. Secondly, the concepts, and the even fewer semantic types they correspond to, allow their mapping to FHIR *MedicationPrescription* resources, which is the gold standard in health IT interoperability. This will allow the definition of CDS rules that can be imported and executed in any compliant module. Further work being planned entails a controlled vocabulary, as well as training of the NLP engine to recognize concepts specific to drug administration instructions. The latter will address a common limitation in NLP, which is the confidence with which the interpretation of the text is done.

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Data Collectors' Design Preferences for Mobile Electronic Data Capturing Forms

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Abstract. Data collectors collect health data using Mobile Electronic Data Collection Forms (MEDCFs) particularly in hard to reach areas. However, the usability and user acceptance of these forms by the data collectors are seldom considered, and yet these have an implication on the quality of the data collected and on the health decisions thereof. In this study we aimed at collecting the design preferences the data collectors felt would improve their data collection experience. For that purpose, a mid-fidelity prototype was used to accomplish six tasks and a semi-structured usability questionnaire was given. Forty eight data collectors from Uganda participated in the study between December 2017 and January 2018, indicating their preferences after interacting with the prototype. The results included a detailed feedback regarding the presentation of the forms content, form navigation, error handling, data input, and visualization of progress status. Involvement of users and other stakeholders in the design of MEDCFs using the User Centred Design (UCD) will presumably enhance usability of the data collection forms.

Keywords. User Centred Design (UCD), mid-fidelity prototype, Mobile Electronic Data Capturing Forms (MEDCFs), user experience, data collectors

1. Introduction

Data collectors like Community Health Workers (CHWs) are increasingly collecting field based health data using mobile technology particularly in low resource settings for client care, program monitoring or for health research [1]. This health data is collected using Mobile Electronic Data Capturing Forms (MEDCFs) that may be downloaded onto the user's phone and can be used in an offline or online state. Previous studies have underestimated the importance of user acceptance and usability as a means of increasing the efficacy and sustainability of mobile health applications [2,3], and yet it is important that the data collectors are comfortable using the technology, which is sometimes not the case [4]. Often times the data collectors are not experienced with technology, and may be put off trying to learn [5]. To our knowledge, end user involvement in form development is rare especially in rural settings due to resource constraints coupled with the perception that the end users are merely receivers and thus

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their experience with the design is hardly considered. This results in errors and having to deal with less than optimal design features hence users disliking the forms.

One way of addressing the usability and user acceptance problem is through training of the data collectors for a duration of 1 week or less [6], which is usually not exhaustive enough to cover every possible scenario or technical issue that may occur during the data collection process [7].

User Centered Design (UCD), with a major focus on a robust needs assessment is recognized as the best practice during technology development [8], and could address such short comings in electronic data collection. In this research we wanted to test the feasibility of the UCD to capture user preferences and to understand user expectations at a minimal cost.

2. Methods

The number of participants in this study were forty eight (n=48) and were data collectors on maternal and child health projects and clinical trials implemented in Kampala, Mukono and Lira districts in Uganda, and these had trained in various fields. Twenty five of the data collectors had collected data for a period of less than 1 year, 15 data collectors for 2 years or less while 8 had collected data for a period between 4 to 6 years. All the data collectors had previously used Open Data Kit, however 3 reported in addition to have used tangerine, Survey Monkey and OpenMRS.

We used a mid-fidelity prototype to display variations in the design features namely; progress presentation, navigation buttons, list pickers, question layout, color layout, data validation, data format and different table presentations. (Figure 1 and Figure 2). The prototype was used to collect information on the data collectors' design preferences with an aim to better understand the requirements and needs of users which is seldom done. We then developed a semi-structured questionnaire consisting of 30 questions based on Nielsen's usability heuristics to capture the data collectors' most preferred design features and how they would want these features to be implemented. The data for this study was collected between December 2017 and January 2018.

To analyze the responses on the design options, the questions were entered in an excel spread sheet and responses with the highest number of participants agreeing to them considered as the most preferred design features particularly for the single choice questions. For multiple choice questions, the responses that had more than half of the participants were considered.

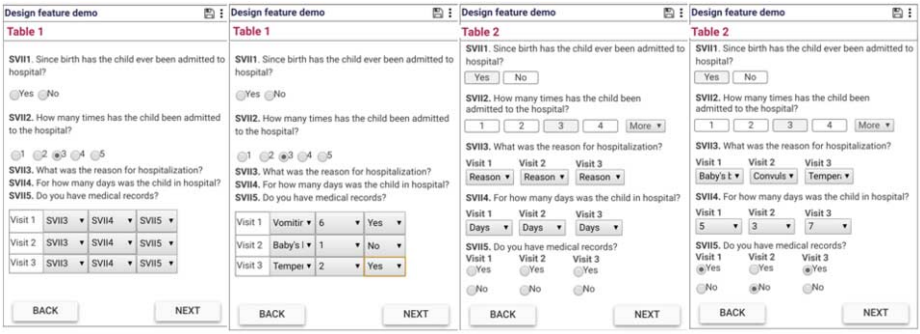

Figure 1. Two types of table designs in a data collection form, first blank and then populated

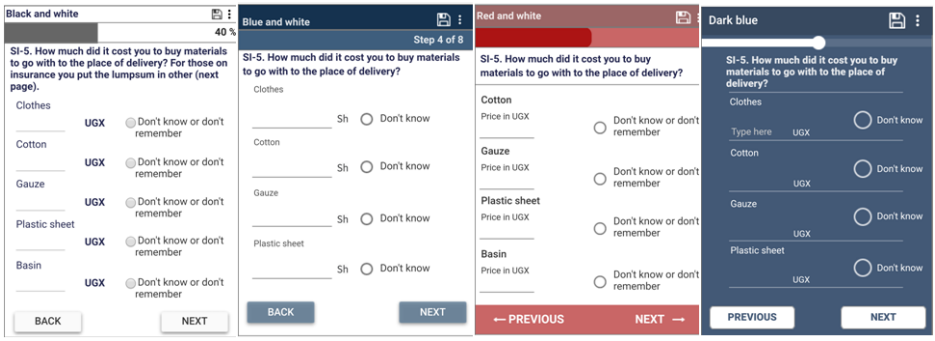

Figure 2. Different color layouts that could be adopted for MEDCFs

3. Results

Thirty three of the data collectors wanted to view their status of progress during data collection, with 21 opting to use page numbering. Thirty five participants would like to receive feedback immediately when they move to the next screen, specifically as a text message for 23 data collectors. Data validation in real time with the data validation results being presented in form of text below the text box was preferred by 19 data collectors.

The data collectors also felt that typing short responses and with clear and accessible help instructions would ease their work. Data input instructions were equally important for 39 data collectors, specifically presented as symbols in the text box, or as help instructions above the text box. Ability to edit their responses at any time was also very important to more than half of the data collectors.

According to 32 of the participants, use of simple words and proper translation of the original language was very important. Swiping was the most preferred way of navigating the form compared to the use of navigation buttons.

The rows and columns in a table should be clearly visible, with clearly labelled fields. Having unique identification for the different entities in the form was extremely important for 36 of the participants with 25 agreeing to an automatically generated identifier as compared to a manually generated one.

Error handling was equally important with 46 of the data collectors preferring to be notified immediately after an error has occurred, and not being allowed to proceed with the rest of the form until the error has been rectified. The error message needed to be outstanding and placed in a strategic position with a clear indication of what the mistake is and how the issue can be solved according more than 20 data collectors.

4. Discussion and Conclusion

The mid-fidelity prototype illustrated the design features very well, making it possible for the data collectors to clearly state their design preferences. However, there is more need for a better understanding of how mobile health tools may be better designed in order to enable the performance of data collectors globally [1]. Thus the very first step is to know the kind of users (novice, intermittent or experts) collecting the data, their

skill levels and the tasks they will be expected to perform [9]. The context in which the data is to be collected is also important [9,10]. User Centered Design (UCD) is one iterative design approach that can be adopted in order to understand the user needs using investigative and generative methods or tools such as surveys and brainstorming [10].

One limitation however is that the mid-fidelity prototype could not illustrate fully all the design features as is expected of a high- fidelity prototype, which left some of the users wanting to see a fully functioning prototype. Secondly, a big number of data collectors did not have any prior health training and also had used MEDCFs for varying periods of time, which may have had an influence on the results.

Our study has indicated that the design of better health tools can be achieved if the users of the tools are involved in the tools' development which improves the user experience due to ease of interaction with the forms. Our research has also shown that adopting the UCD leads to designing more usable forms, and is an added value to the quality and accuracy of the collected data, hence improved decision making which is very critical for health care. However, organizing these kinds of user experience trials requires some additional resources, which is a challenge in resource constrained areas. The next steps are to create a high-fidelity prototype based on the results of this study, conduct one more user evaluation and the next design iteration.

Acknowledgements

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On the Representation of Machine Learning Results for Delirium Prediction in a Hospital Information System in Routine Care

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Abstract. Digitalisation of health care for the purpose of medical documentation lead to huge amounts of data, hence having an opportunity to derive knowledge and associations of different attributes recorded. Many health care events can be prevented when identified. Machine learning algorithms could identify such events but there is ambiguity in understanding the suggestions especially in clinical setup. In this paper we are presenting how we explain the decision based on random forest to health care professionals in the course of the project predicting delirium during hospitalisation on the day of admission.

Keywords. Electronic health records, machine learning, delirium, important features

1. Introduction

1.1. Background

Delirium is an acute neuropsychiatric syndrome which is common in elderly patients. It is generally under diagnosed and 40% of the cases can be prevented when identified earlier [1]. Therefore, early prediction of Delirium is a promising candidate for machine learning (ML) approaches. There are high expectations on the application of ML methods in various areas [2]. However, interpretation of results obtained from the ML algorithms is often difficult for health care professionals. Hence there is a necessity for a tool that shows why a certain prediction has been obtained.

1.2. State-of-the-art and motivation

Several attempts have been made to predict delirium using clinical assessment methods and risk factors during hospitalisation [3]. They have mainly used regression models

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with rather small patient groups and obtained an Area Under Receiver Operating Curve (AUROC) ranging between 70 % and 85 % [3]. In a previous publication, we have received an AUROC of approximately 90 % in a retrospective analysis of data from more than 8,500 patients [4] of "Steiermärkische Krankenanstaltengesellschaft m.b.H"(KAGes). KAGes as Styrian healthcare provider with about 90% market share in terms of acute care hospital beds can use more than 1 million longitudinal health records as basis for its analyses in its premises. One strategic initiative of KAGes Management was to prevent delir as good as possible and to provide its healthcare teams with tools for diagnosis and prevention. Lead by KAGes several research partners contribute to this project with the goal to provide clinical decision support for everyday work.

A systematic statistical analysis has been applied on data to exclude irrelevant attributes. In remaining features, some attributes were represented as binary values and others were derived from attributes such as number of diseases, Charlson comorbidity index [5], number of procedures etc., are represented as numerical values.

By applying RandomForest (RF) with one thousand trees and a10-fold cross validation, we achieved an AUROC of 89.8%. Among all ML approaches at hand, RF has performed the best. The results were presented in one of our papers [4]. In [6] and [7] authors proposed how to explain individual decisions obtained from different classifiers. There have been methods for visualising feature importance of a RF using tree structures, bar charts, graph networks, etc., to explain the predictions [8]. We have published our approach to derive feature importance for individual decisions from RF [9]. However, none of these approaches were able to reach sufficient acceptance when presented to the health care professionals.

1.3. Objective

The objective of the paper was to develop a tool to visualize results from a ML system that predicts delirium in hospitalised patients for health care professionals to check the plausibility and also to understand ML results and thus support their clinical reasoning.

2. Material, Technologies and Methods

2.1. Data

KAGes routinely records data about their patients related to diseases, procedures and laboratory measurements based on international standards, such as ICD-10, ICPM/ICHI and LOINC, respectively. Inclusion and exclusion criteria for extracting the cohort and control group are described in [4]. We derived a cohort of 4,596 delirium patients and randomly selected 25,000 patients for a control group.

2.2. Methods

2.2.1. Technologies

Data were retrieved from the hospital information system (HIS) through a data warehouse platform (HANA, SAP, Walldorf, Germany). R software (R Foundation for Statistical Computing, Vienna, Austria) was used for data pre-processing. the caret

package has been used for modelling and online deployment and the shiny package [10] for presenting decisions to health care professionals. Additionally, further investigations and simulations were done using AIT's Predictive Analytics Toolset for Health and Care (PATH) based on Matlab (The MathWorks, Nattick, USA) [11].

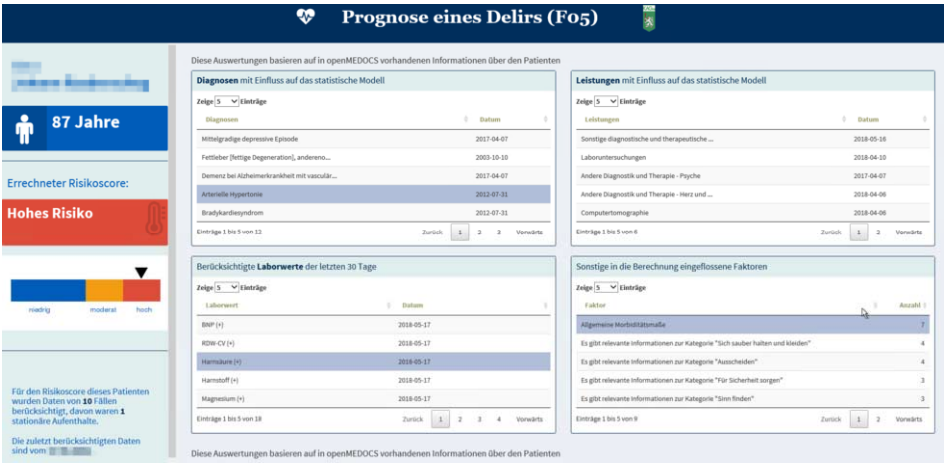

Figure 1. Presentation of delirium probability to health care professionals, along with features that influenced the particular decision

2.2.2. Feature selection requirements

The health care professionals need to understand the results derived from ML algorithms to conceive a decision. We have had discussions with health care professionals in focus groups as well as individual debates. The focus groups included doctors, management, nursing, IT staff along with academicians and statisticians.

3. Results

Probability of occurrence of delirium is derived for each patient from the model. For each feature, the importance was calculated from RF based on Out-of-Bag permuted predictor importance. We have selected features that were relevant for individual patient and sorted them based on their importance and classified into four different categories: diseases, procedures, laboratory results and others. Others included nursing assessment, transfers and demographical data. Diseases which were stated as high risk factors in the literature were given higher importance (E.g. Dementia). Each feature is represented with the description and date recorded. A screenshot of the visualization tool is provided in Figure 1. Thus, we are able to provide a context sensitive view on the longitudinal electronic health record. At any time, it is possible for the user to navigate to the full EHR of the patient in order to evaluate the situation in more detail.

4. Discussion

Our tool provides the features along with the associated information and date of that feature recorded for individual patient. This representation gives the personnel a quick glance of a patient's health history and complications.

Initial feedback for this representation was encouraging as the concept was accepted by the health care professionals. We are continuously updating the tool according to new health care professional's requirements (e.g., related diagnoses). Although the tool has been accepted for its usability, for some patients with few number of previous hospital admissions or none, the features that are presented may not be important for delirium. Presently, we work on a solution by analysing the results obtained for such cases.

5. Conclusion and Outlook

Our solution based on listing the most important features which are relevant for an individual patient and grouping the features in four categories is a promising approach, with the potential to increase acceptance of ML solutions significantly at hospital care, not just in the delirium case but in additional real-world applications as well.

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An Exemplar Dashboard for the Assessment of Home Health Comorbidities

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Abstract. Comorbidities are multiple co-occurring disorders associated with a primary diagnosis and affect health outcomes and cost of care. Using home health medical claims data, a comorbidity database with frequent item-sets, and an exemplar dashboard were created. The dashboard extends the decision making capacity of clinicians by providing data-driven information about (i) the frequency of comorbidities for any primary diagnosis, and (ii) primary diagnoses sufficiently exclusive to a given comorbidity. Regression models estimate total charges, for any underlying patient comorbidity profile. Using the exemplar dashboard, a panel of healthcare researchers recommended appropriate system parameters to adjust system sensitivity and improve construct validity. The comorbidity database will be useful in future research efforts to study comorbidity, while the exemplar dashboard can provide the foundation for integrated home healthcare decision support systems.

Keywords. Comorbidity, data mining, diagnosis, decision support, home health

1. Introduction

A comorbidity is the presence of additional disorders co-occurring with a primary disease [1]. More than 80% of the Medicare spending in the US addresses patients with at least four conditions. The cost to treat comorbidities is higher than a summation of the cost for each disease separately, since comorbidities increase the complexity of treatment [2]. In this paper we describe an exemplar dashboard for the dynamic assessment of comorbidities using home health data. Home health care includes a wide range of services, provided at the patient's home place. We used large home health data [3] to give insights to providers about patient diagnosis (Dx) and comorbidities, and total charges estimation. The dashboard provides information about (i) possible comorbidities that they need to investigate, given a known primary Dx (ii) the probability for primary Dx when an existing comorbidity is already known.

2. Methods

To develop the system, a 2015 Medicare home health claims dataset [4] was purchased, which includes, among other variables, the primary and every secondary ICD-9-CM Dx, and the total charges, for 270,000 home health patients. The dataset was firstly

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used to find frequent comorbidities (item-sets) for each primary Dx using the apriori algorithm, and results were stored on a relational database schema. This database then served as the backend of an exemplar interactive comorbidity dashboard. The dashboard allows the user to find (i) for any primary Dx, the frequency of its comorbidities, and (ii) those primary Dx's that are sufficiently exclusive to a given comorbidity item-set. A collection of multiple regression models was finally created to dynamically estimate total charges for home health patients, according to the underlying patient comorbidity profile.

2.1. Data Preparation and Frequent Item Sets

Since there are more than 14,000 different ICD-9-CM codes, the Clinical Classification Software (CCS) to ICD-9 mapping was used, to group the ICD codes into one of 285 mutually exclusive CCS disease categories. The CCS to ICD-9 mapping is available from the Healthcare Cost and Utilization Project (HCUP) [5]. To estimate item-sets correctly and create regression models for the cost prediction, a total of 266 dummy variables were generated (one for each secondary CCS code). Groups of co-existing items frequently appearing together in transactions (occurrences in dataset) are called item sets. Since there are many different co-occurring conditions, the number of possible combinations is huge, making the study of all combinations computationally inefficient. The most common measure of an item set importance is the percent of all transactions that contain the item set. Item-sets that meet a minimum support threshold are called frequent item-sets. We used the Apriori algorithm with an 1% support threshold to find frequent secondary Dx item-sets [6], separately for each primary Dx.

2.2. The HHCD Database

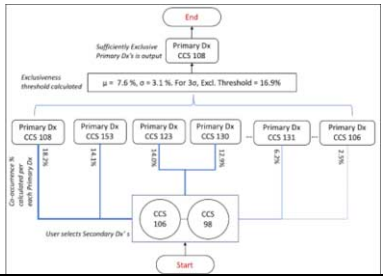
The completed item-set output was stored on an SQL database schema (Fig. 1), which we refer to as Home Healthcare Comorbidity Database (HHCD). The database includes, for each primary Dx, the aforementioned comorbidity item-sets, alongside with the item-set level (solo, pairs, triplet). HHCD also includes the frequency ($N_{item\text{-}set}$) of each item-set, it's % of occurrence, and was later on updated with total charges information.

Figure 1. The Home Healthcare Comorbidity Database (HHCD) schema

2.3. Sufficient exclusivity

The percent of co-occurrence is equal to the quotient of the item-set frequency by the frequency of its primary Dx observations. It is the conditional probability $P(k_i \mid j_i) = P(\{k_{i1\ldots}k_{in}\}, j_i)/ P(j_i)$where, for a given primary Dx, j_i, the portion $P(\{k_{1\ldots}k_n\})$ is a secondary Dx item-set probability. Since many secondary Dx's (solo) or constructs of secondary Dx's (pairs, triplets etc.) are more common for specific primary Dx's, we were interested in quantifying this exclusivity. Any given item-set is associated with a different percent of co-occurrence across different primary Dx's, and this difference

often varies significantly. While *hypertension* (CCS=98) is a common secondary Dx, its percent of occurrence is similar across different primary Dx's. This is not the case for other less frequent secondary Dx's. By simply looking at the ratio of secondary Dx co-occurrence, it is not possible to differentiate between candidate primary Dx's. To quantify the above variation in a clinically relevant way, for each frequent secondary Dx item-set, the percent of co-occurrence is calculated for all primary Dx's, in a comparative manner: A secondary Dx (solo) or a construct of multiple secondary Dx's (pairs, triplets etc.) qualify as 'sufficiently exclusive' to a primary Dx, if the percent of co-occurrence is above the mean % by a given amount of standard deviations. When one or more secondary Dx's are selected, the HHCD database is queried, to show, for each primary Dx, the percent of occurrence of this item-set. This query result is forwarded to a function that estimates the mean occurrence % and the standard deviation (σ) and calculates an exclusivity threshold. The exclusivity threshold is equal to the $\mu + k\sigma$, where μ is the mean of occurrence, σ is the standard deviation and k is the user desirable number of σ. This approach assumes normal distribution.



The line thickness visualizes the strength of the *item set- primary Dx* relationship. For a patient with *cardiac dysrhythmias* (CCS=106) and *hypertension* (CCS=98), *congestive heart failure* (CCS=108) is the top primary Dx. Additionally, for k= 3σ, the exclusiveness threshold is 16.9% and the comorbidity item-set {*dysrhythmias*, *hypertension}* qualifies as sufficiently exclusive to the primary Dx, *congestive heart failure.*

Figure 2. Estimation of sufficiently exclusive Primary Dx(s) for a given item-set

2.4. Estimation of Total Charges

To estimate the effect of comorbidities on the total charges, a collection of linear regression models was created, one for each primary Dx. The regression coefficients were stored into the HHCD database. The secondary Dx's (dummy variables) were included as predictors of the numerical 'total charges'. Using a linear equation, regression coefficients are fetched to predict the total charges for the sufficiently exclusive comorbidity of a primary Dx. In Fig. 2, after the comorbidity {98, 106} qualified as sufficiently exclusive to the Primary Dx=108, the corresponding regression model was retrieved from the database. The linear formula $Y_{total\_charges} = c + b_{ccs=98} * 1 + b_{ccs=106} * 1$, estimated the total charges to be \$2,555 ($b_{ccs=98}$ = \$3, $b_{ccs=106}$ = \$164, constant = \$2,388.). Predictions are automatically calculated, for any Dx combination.

3. Results and Evaluation

The HHCD database served as the backend of exemplar dashboard (Fig.3) which allows the user to select an item-set of co-occurring secondary Dx's (solo, pairs, triplets etc) and find primary Dx's that are sufficiently exclusive to that item-set. It also provides information about the most common co-occurring secondary Dx's for the user-selected primary Dx and estimates total charges accordingly. Three healthcare researchers used the dashboard and provided written reports regarding the degree to

which the system measures what it was designed for (construct validity). According to the reports, the desired number of SDs for clinically meaningful exclusiveness may differ across primary Dx, with a consensus that at least k=3σ would be needed. In addition, there was indicated that when a comorbidity appears in low frequency, it should be filtered from the output.

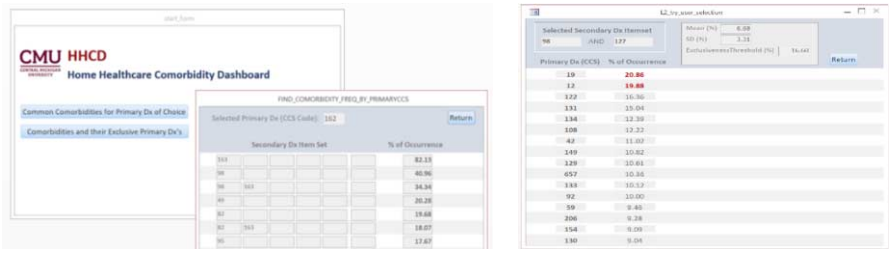


Figure 3. The Home Health Comorbidity Dashboard

The dashboard can be used as a recommender and validation tool, extending clinicians' decision making capacity.

4. Discussion

This research can serve as a foundation for data driven assessment of comorbidities in home health patients. Since doctors, especially when dealing with elderly patients, do not treat diseases but complex disease co-occurrences, this research will assist them in patient assessment decisions. The system does not stay at returning rates of occurrence. It also compares frequency distributions across all candidate primary Dx's to find those primary Dx's that a comorbidity item-set is exclusive to and provides an estimate of total charges specific to the comorbidity under investigation. The HHCD database will be useful in future research efforts to study comorbidity, while the exemplar dashboard can provide the foundation for integrated home healthcare decision support systems

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Dataware for Improvement of Clinical Practice Quality in Phthisiology

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Abstract. A hot point of phthisiology in Russia during the last decade is the rising morbidity of tuberculosis associated with the drug resistant Micobacteria tuberculosis. The causes of MBT resistance are often related with human factor. Reducing the errors rate in complex Clinical Decision-making in phthisiology requires adequate software support and treatment monitoring. The methodology for structuring of the diagnosis characteristics at the moments of Clinical Decisions in phthisiology is represented. The Quality models and real Clinical Situations have the digital codes. The ontological modeling of the real Clinical Situations is used for analysis, construction the inference rules and improvement of Clinical Decisions and treatment results.

Keywords. Ontological modeling, OWL, inference rules, digital coding of Clinical Situations, phthisiology.

1. Introduction

Phthisiology is the care, treatment and study of tuberculosis (TB). TB gains a special attention of the World Health Organization the last decades because of the rising morbidity of forms of TB associated with multidrug resistant (MDR) and extra-wide drug resistant (XDR) Micobacteria tuberculosis (MBT). Prevention of the MDR- XDR-MBT infection attracts researcher's interest since these forms of TB dramatically decrease the chances for effective therapy. In Russia the therapy of 36% of all patients with MDR – MBT shows poor effectiveness. The causes of MBT resistance are often related with human factors, such as: inappropriate drug prescriptions, low adherence of the patients for treatment etc [1,2]. Reducing the errors rate in complex Clinical Decision-making in phthisiology requires adequate software support. Clinical Decisions are the most important moments of Clinical Events. Information support and further monitoring of care are key steps to the Quality Clinical Practice and better treatment results. The methodological basis for the conceptual framework and the

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systematization of the elements of Information Clinical Practice Space are very important for the creation of the software. The growing demand for ontological approach is essential for the development of functional elements of automated systems. Particularly, ontologies and inference rules are widely used in the Clinical Decision support systems [3,4] and in the related commercial applications [5].

2. Methodology and Methods

The methodology is generated on the basis of the actual and relevant problems to solve. The inappropriate drug prescriptions and individual differences of the Additional Factors and conditions with their influence on Clinical Decision at definite Clinical Situations (CS) are the main information vectors for improving Clinical Practice. The structure of the Clinical Information Space is developed according to the methodology of system approach [6]. Elements of the CS model structure are reflecting the features of the Clinical Diagnosis (sets): the name of disease (ICD-X is used for general statistics), stage, phase with activity assessment, severity of CS. Sets are constructed as 5-dimensional information vectors. Each set includes 5 facets with criteria for identification and formalization of particular CS diagnosis features. The information for particular CS is processed using mathematical (coefficient-based) or logical (rules-based) algorithms. There is also the set of Additional Factors and Conditions with the influence on the Clinical Decisions (AFC). The factors and conditions are signed by the consecutive numeration at the knowledge base. When the facets of CS are determined and marked by the physician on the screen, the system forms the CS digital code as the cortege of signs. For example: (A15.0); (Stage 3); (Phase activity 3); (Severity of CS 4); (AFC - 3,16). This code corresponds to the formalized Quality model created on the base of regulatory documents, evidence-based medicine data and National recommendations for phthisiologists. The current CS digital code of the patient may be compared with the previous one, thus reflecting dynamic and results of the treatment. The ontologies are very useful natural technical way of the perceived knowledge representation [7-9]. Our system uses a simple OWL ontology built from a scratch, which contains classes for representing above listed sets and facets as well as their relations with the Quality models of Clinical Practice. One of the main ontology opportunities is the availability of inference rules for information processing. It is necessary in our case because of the nature of logical relations between the premises and conclusions in Clinical Decision-making. The modeled Decision-making process is rather complex, and inference rules are probably the most convenient way to construct and manage them. The inference rules are the key component which powers the information processing in the system. Ontology elements – classes, attributes, individuals – are used for the inference rules formulation. To obtain the individual recommendations not covered in the Standard Quality models of Clinical Practice, a number of specific inference rules may be created in the system after the analysis Clinical Events, CS and treatment results. Onto.pro ontology editor is used to construct ontology. The whole system is built on the ArchiGraph.KMS platform (provided by TriniData, LLC), which contains the visual inference rules constructor and a SPIN-like inference engine. The main user interface consists of the list of patients, list of CS for each patient, and a space for working with the selected CS.

3. Results

Our work has included formalization of the normative knowledge on the TB treatment made by the domain-specific experts. A compact and convenient conceptual model was created to represent the main characteristics of CS diagnosis as discrete clinical information vectors (sets) in the terms of Stage, Phase activity, Severity of CS and AFC. The opportunity of matching the real CS and concordant Quality models of Clinical Practice by digital codes was field-tested by this work. The ontologies are providing a reliable basis for the clinical information representation according to the general conceptual model and reference data sets and facets. Inference rules construction for personal recommendations production is also proven to be a good way of the actionable knowledge formalization. The CS data is saved in the database for collecting CS and following statistical analysis in order to fill up the clinical evidence base in phthisiology.

4. Discussion

The medical literature analysis shows clearly, that there are no formal consensual definitions for the features of Clinical Diagnosis (stage of the disease, phase of activity, severity of CS) in phthisiology. The theoretical foundations for conceptualization of the Clinical Diagnosis features are the very important points for the informative and re-usable representation of the Clinical Events and CS in databases. Exactly defined and indisputable terms are required. We have defined the terms for the features of CS Diagnosis based on the fundamental scientific conceptions which were described by the theoreticians in physics, chemistry, mathematics and philosophy [10-12]. These cornerstone conceptions were used to formulate the terms and to represent the Diagnosis of the CS in digital codes. The Clinical Information Space consists of discrete vectors (sets) with the constant dimensionality – 5 facets. According to the nature law of symmetry 5 sensory organs for reception of external signals by human being formed 5 ways for operative distinction of the subjects [6]. A good example of applicability of such approach is the model of “Big 5” in the dynamic psychology. The last model now is one of the most popular tests for business staff characters and psychological type recognition [13]. At the end of the steps sequence, the system performs CS classification and matches the digital code of real CS against all existing codes of the Standard Quality models of Clinical Practice at the knowledge base. In the industrial use case, the CS features data shall be acquired automatically from the integrated clinical and laboratory information systems. The inference rules are used to perform CS classification leading to the choice of Quality model of Clinical Practice and generating of the particular recommendations.

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Learning Healthcare Systems in Pediatrics: Cross-Institutional and Data-Driven Decision-Support for Intensive Care Environments (CADDIE)

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Abstract. Background: The vast amount of data generated in healthcare can be reused to support decision-making by developing clinical decision-support systems. Since evidence is lacking in Pediatrics, it seems to be beneficial to design future systems towards the vision of generating evidence through cross-institutional data analysis and continuous learning cycles. Objectives: Presentation of an approach for cross-institutional and data-driven decision support in pediatric intensive care units (PICU), and the long-term vision of Learning Healthcare Systems in Pediatrics. Methods: Using a four-step approach, including the design of interoperable decision-support systems and data-driven algorithms, for establishing a Learning Health Cycle. Results: We developed and started to follow that approach on exemplary of systemic inflammatory response syndrome (SIRS) detection in PICU. Conclusions: Our approach has great potential to establish our vision of learning systems, which support decision-making in PICU by analyzing cross-institutional data and giving insights back to both, their own knowledge base and clinical care, to continuously learn about practices and evidence in Pediatrics.

Keywords. Clinical Decision Support Systems, Pediatrics, Critical Care, Health Information Interoperability, Learning Healthcare System

1. Introduction

Assembling, analyzing, interpreting and reusing once collected data sets bear enormous potentials for clinical decision-making. Currently, clinicians use personal expertise and the best available evidence to make high-quality decisions (*evidence-based medicine*) [1]. Because clinicians are faced by time pressure, work interruptions, stress and risky situations, the quality of decisions can be lower than aspired [2]. Especially within critical and intensive care settings, clinicians have to reach decisions under challenging conditions. Factors like the high degree of dynamics, uncertainty and risk, the need for immediate decisions and the vast amount of data might result in medical errors and patient safety concerns [3-5]. Furthermore, in pediatric critical and intensive care, the evidence level is low because randomized controlled trials (RCTs) are scarce and

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difficult to conduct. It was reported that only about 14% of RCTs concentrate on children [6]. For example, for evidence-based guidelines on the systemic inflammatory response syndrome (SIRS), 76 adult-specific but only 22 pediatric-specific recommendations exist [6]. Ethical considerations limit meaningful studies, and cohorts, health conditions and diseases might be too complex to generalize findings [7]. Additionally, there seems to be a discordance between diseases studied and their - often much smaller - prevalence, and therefore relevance, in practice [6]. The lack of guides fosters many variations of treatment approaches. Moreover, those may be built upon insufficient knowledge about age- and weight-appropriate therapies (e.g., for medication) [8]. RCTs are successful in studying biological and acute disease processes in restricted and consistent patient settings [9] but they appear to be not applicable in complex contexts as in Pediatrics. To strengthen evidence-based practice, it might be useful to follow the idea of practice-based evidence [10]. In our work, we want to introduce our CADDIE approach (**c**ross-institutional **a**nd **d**ata-driven **d**ecision-support for **i**ntensive care **e**nvironments). We aim at supporting decision-making in pediatric intensive care units (PICU) by integrating data from different systems and reusing that for developing data-driven clinical decision-support systems (CDSS). We have a long-term vision of using CDSS not only as a tool for enabling evidence-based medicine, but for generating practice-based evidence by considering the idea of *Learning Healthcare Systems (LHS)* [7].

2. Methods

A **first step** towards achieving our objective is *the design of an interoperable, evidence-based CDSS*. Lately, it became apparent that CDSS might have an impact on the quality of health-related decisions, improved patient safety and quality of care [11-13]. Although successful systems exist, the use is still lacking. The poor adoption in clinical routine might be due to an inefficient integration in the clinician's workflow, a design as standalone solutions or insufficient data and knowledge quality [14-16]. Current CDSS indeed provide interfaces to infrastructures, as electronic health records, but they are often designed specifically for individual institutions. Because no interoperability features are provided, their reuse requires large financial and human resources. Within the first step of designing an interoperable CDSS, those challenges should be addressed. In our approach, such system will serve as a basis for further implementations. Hence, the capabilities of the system should be appropriate, not only from a technical, but also from a clinician's point of view. Hence, our **second step** comprised the conduction of an enhanced *clinical-driven evaluation* for assessing the correctness of the CDSS knowledge model (e.g., by measuring the diagnostic accuracy). We constructed the knowledge model with medical experts and in accordance to international agree-upon guidelines. However, especially within Pediatrics, there are different ways for guideline interpretation. Additionally, other cohorts at other institutions might include unusual cases, which may not be covered so far. Therefore, as a **third step**, we started to incorporate *data-driven approaches*. In the long-term, we will assemble once collected data sets from different sites for gaining new insights. This requires an *implementation of the CDSS at another institution* as the **fourth step** of our approach. The results will be interpreted and given back as feedback to both, system and clinicians, and may result in system- or care-related changes (see Figure 1, The CADDIE approach and *The Learning Health System Cycle* by Friedman et al.).

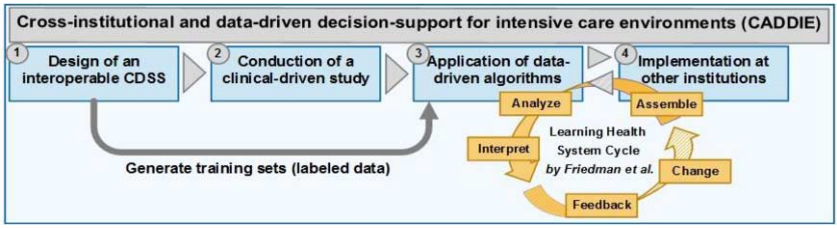

Figure 1. The CADDIE approach and the Learning Health System Cycle

3. Results

We implemented a rule-based CDSS for SIRS detection in PICU [17], which is based on expert-knowledge and the best available evidence. We used technologies that enable an easier reuse, comprising (1) clinical information modelling standards as openEHR [18], (2) semantically enriched and standardized data retrieval by the Archetype Query Language (AQL)[2], (3) standardized knowledge representation with terminologies as LOINC and formats as Drools (http://www.drools.org/) rules, and (4) knowledge bases and inference procedures acquired by extensive knowledge engineering processes in cooperation with the department of Pediatric Cardiology and Intensive Care Medicine of the Hannover Medical School[3]. We evaluated the CDSS on real vital signs and laboratory data originating from the patient data management system, and compared the results with the experts' assessment, by which we proved the technical feasibility. Further details are described in [17]. Another extensive study will be conducted during this year. In accordance to our methodology, we are currently investigating, how to enhance the CDSS by using data-driven approaches (e.g., prediction algorithms). By reviewing other research work, we identified many approaches for SIRS detection in Adults but not in Pediatrics. For Neonatology and Adult Care even training data is available (e.g., in MIMIC - https://mimic.physionet.org/), whereas there are no such data sets available in Pediatrics. Hence, we are currently using the data sets of our open EHR based data repository [19] and the SIRS labels, which were assigned by our CDSS, as training data (see Figure 1).

4. Discussion

Our work aims at reusing data from various systems and sites to support PICU care. We strive to make data meaningful by implementing data-driven CDSS, which are based on cross-institutional data. Such systems must be semantically interoperable and easy to implement, as well as a shared meaning of data is needed. Our approach bears that in mind by following interoperability standards as open EHR. This approach fits to the current efforts of the Medical Informatics Initiative of the German Federal Ministry of Education and Research, which was initiated for strengthening cross-institutional data sharing, data analytics and data infrastructures. The HiGHmed (http://highmed.org) consortia also adopts open EHR and FHIR (Fast Healthcare Interoperability Resources) and, therefore, open ups major possibilities for our CDSS.

[2] http://www.openehr.org/releases/QUERY/latest/docs/AQL/AQL.html
[3] https://www.mh-hannover.de/33483.html

Our approach strives at assembling data from different sites, so that CDSS are not restricted to local environments. Before, studies on the cross-institutional use are vital for evaluating the interoperability features and the knowledge bases to find bottlenecks. Furthermore, our system works in retrospective and not at the clinician's workplace, but for our long-term vision, we are in the need of a 'live-system'. A future CDSS-based learning healthcare system in Pediatrics should be able to uncover aspects, which can be used in combination with RCTs to overcome the lack of evidence in Pediatrics. Then, decision-making won't be based on individual procedures but on cross-institutionally gathered and data-based evidence.

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Striving for Use Case Specific Optimization of Data Quality Assessment for Health Data

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Abstract. Data quality (DQ) assessment is advisable before (re)using datasets. Besides supporting DQ-assessment, DQ-tools can indicate data integration issues. The objective of this contribution is to put up for discussion the identified current state of scientific knowledge in DQ-assessment for health data and the planned work resulting from that state of knowledge. The state of scientific knowledge bases on a continuous literature survey and tracking of related working groups' activities. 95 full text publications constitute the considered state of scientific knowledge of which a representative selection of six DQ-tools and -frameworks is presented. The delineated future work explores multi-institutional machine learning on the DQ-measurement results of an interoperable DQ-tool, with the goal to optimize DQ-measurement method combinations and reference values for DQ-issue recognition.

Keywords. Data quality, quality assessment, information science

1. Introduction

The suitability of a dataset for a specific purpose is referred to as its data quality (DQ). DQ-assessment is advisable before taking decisions based on, deriving knowledge from or reusing data. Besides supporting DQ-assessment, tools for DQ-assessment can be useful to indicate data integration issues [1,2].

This contribution relates to a thesis, in an early work in progress state. Overall objective is multi-institutional machine learning of optimized combinations of DQ measurement methods (MM) and a first evaluation of this approach. The motivation is twofold: First, to make experience based knowledge on informative DQ-MMs and DQ-assessment more objective and shareable. Second, optimizing DQ-MM combinations for specific purposes and health data contents has the potential to improve its informative value for DQ-assessment and indication of data integration errors. The objective of this contribution is to present the initial state of scientific knowledge on which the thesis builds up on (methods and results) and to delineate the planned work (discussion).

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2. Methods

First building block for the analysis of the current state of scientific knowledge on DQ-assessment for health data is a continuous non-systematic literature survey. An originally planned systematic review was abandoned because first steps yielded a sound publication covering the planned reviews matters [3]. The literature survey consists of checks for new publications from related working groups with own publication lists ([4,5]) as well as a continuous search in PubMed employing an iteratively refined search term:

("data quality" [Title] AND ("evaluation" [Title] OR "evaluating" [Title] OR "assessment" [Title] OR "assessing" [Title] OR "quantifying" [Title] OR "quantification" [Title] OR "measurement" [Title] OR "measuring" [Title]))
OR ("data quality" [Title/Abstract] AND ("secondary use" [Title/Abstract] OR "reusing" [Title/Abstract] OR "reuse" [Title/Abstract]))
OR ("metadata" [Title/Abstract] AND ("secondary use" [Title/Abstract] OR "reusing" [Title/Abstract] OR "reuse" [Title/Abstract]))

No additional search filters were used. Publications were filtered by reading title and abstract. Reference sections of included publications are analyzed regarding other relevant publications. Using other literature databases than PubMed was considered and tested with IEEE Xplore, but abandoned as inefficient. Second building block is tracking of and participation in activities of working groups and medical informatics societies addressing the topic (e.g. TMF AG IT-Infrastruktur und Qualitätsmanagement[2], GMDS - https://gmds.de, EFMI - https://www.efmi.org/). The first of December 2017 defines the initial state of scientific knowledge for the thesis. Publications that published after that date will of course be considered in the thesis, but not in this description of the initial state.

3. Results

Targeted literature survey started in 2016. PubMed search results listed 317 publications in December 2017. Including publications found in reference sections, from related working groups etc., 95 full texts constitute the considered state of scientific knowledge. In 1996, Wang and Strong published a classification for data quality features (DQF) which is still state of the art [6]. Since there are many publications on DQ, proposing many different DQFs and MMs, using many varying definitions, Kahn et al. published a unified terminology and a conceptual framework for DQ-assessment of health data [3]. The following list of DQ-tools and -frameworks for health data is not intended to be complete, but rather to give a representative view on the current state of the art in DQ-measurement for health data and frameworks influencing the planned work.

- The Achilles Heel [7] DQ-tool developed by the Observational Health Data Sciences and Informatics Collaborative (OHDSI) applies a set of plausibility checks (e.g. number of occurrences, null values, order of events etc.). The tool is available as open-source software. Plausibility checks were determined for each attribute by human experts. More than one publication evaluates its application. This kind of DQ-tool is widespread (cf. [1,2]).

[2] http://tmf-ev.de/Arbeitsgruppen_Foren/AGITQM.aspx

- The 3x3 Data Quality Assessment [8] emphasizes the dimensionality of DQFs. The assessment proposes a set of DQ-MMs for completeness, correctness and currentness of health data in the three dimensions patients, variables and time. The MM selection is based on a literature review, earlier research on DQ-measurement and interviewed experts. There were no publications on the application of the 3x3 DQA (probably due to its recentness).
- The ontology for data quality characterization [9] emphasizes the task dependence of DQ. It "references separate Domain and Task ontologies to compute Measures which quantify how well the data conforms to the Domain and how well it fits the Task." The 19 MMs enable an automatic calculation. The concept's application study chose arbitrary assessment thresholds and did not apply all proposed MMs.
- The German TMF guideline [10] defines 24 DQ-MMs and aggregates them in a single DQ-score. The MMs and their weights in the aggregation process result from a literature review and an expert survey. There is more than one application.
- The Data Quality Vector from Saez et al. [11] is designed to assess DQ in seven DQFs (completeness, correctness, consistency, uniqueness, multi-source and temporal stability, predictive value). The MMs result from literature as well as from previous research in the area of shifting health data (i.e. multi-source and temporal stability). At least one publication evaluates its application.
- The Metric Based Approach [12] describes DQ-measurement with a focus on requirements that MM-results should fulfill (normalization, interval scale, interpretability, aggregation, adaptivity, feasibility). Considering a literature review on MMs, it proposes new MMs addressing correctness and timeliness. Only the MM for timeliness is evaluated in the case study.

4. Discussion

The results present the author's view on the current state of scientific knowledge in DQ-assessment for health data. Acknowledging that there are existing DQ-tools and measurement methods (e.g. [1,2], [6-12]) as well as general research on assessment of health data quality, there is still a lack of empirically founded DQ-MMs and reference values for assessment of DQ [1,7]. The selection, weighting and assessment of MMs in DQ-tools for health data is mostly unspecific regarding the intended data usage and relying on experts' experience based knowledge (cf. [1,2], [6,13]). This view and the selection of relevant publications are obviously subjective. Furthermore, the required brevity of this contribution prevents a comprehensive description of the state of scientific knowledge. However, the motivation of this contribution is to make the proceeding for analyzing the current state of knowledge tangible, to present the state of scientific knowledge on which future work will be building up on and to put both as well as the planned future work up for discussion. A rule- and model-based DQ-tool is planned as interoperable solution for DQ-assessment. Model based means that, e.g. a DQ-check, will notbe defined on database fields but on a common content model ([1] and [7] use the OMOP CDM[3], in the planned work it will be openEHR archetypes and templates [14]). Rule-based describes a software architecture in which rules (i.e. MMs) are not hard-coded into the application source code, but defined in separate files with a

[3] https://www.ohdsi.org/data-standardization/the-common-data-model

rule language for easier maintenance of rules. Measurement results of this tool will be the input data for multi-institutional machine learning with the goal to optimize DQ-MM combinations and reference values for DQ-issue recognition in different use cases and clinical contents. Measurement results will comply with the normalization and aggregation requirements described in [12], which enables a multi-institutional learning without the need to exchange patient datasets. Exchange of aggregates for particular nodes in a tree structure defined by MMs and content models is sufficient. Machine learning will be tested using established tools and methods like decision trees or support vector machines, since sophisticated methods do not seem necessary for a simple evaluation of the general idea. The evaluation will be a comparison of optimized MM combinations and reference values for a limited amount of use cases. It is foreseeable that the amount of instances for machine learning will be limited in the medium term (one instance = one assessed dataset for a specific task), even though the planned solution enables multi-institutional learning. Three approaches could moderate this issue: Additional user input denoting relations between MM-results and DQ-issues in datasets could reduce the amount of training instances necessary. Learning DQ-assessment models independently of the Task Ontology or Domain Ontology [9] can increase the number of applicable instances. Implementing semantically equivalent MMs and content models in other standards than openEHR (e.g. HL7 CDA, OMOP) can increase the amount of available training data instances.

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Using Innovation-Decision Model to Describe the Adoption to Utilization of HIV-Data for Decision-Making in LMICs

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Abstract. Data informed decision-making (DIDM) plays a fundamental role in the fight against HIV and AIDS in Low-and-Middle-Income Countries (LMICs). Despite the scale-up of HIV care services, supported by health information systems (HIS), cases of under-utilization of data in decision-making are still being reported at different levels of the health system. Literature revealing the process involved in data users' decision to adopt DIDM in LMICs is meager. To fill this gap, we employ the innovation-decision model to describe the stages of adoption of DIDM by data users. Thus, we extract reports on efforts to promote DIDM in HIV from existing literature, and map this to the model. We then identify important stages, which require emphasis in the adoption process. Hence, implementers could benefit from use of the innovation-decision model in understanding adoption process of DIDM.

Keywords. HIV-data, innovation-decision stages, data utilization, informed decision-making

1. Introduction

The human immunodeficiency virus (HIV) epidemic remains a challenge globally with the highest number of infected individuals found in low-and middle-income countries (LMICs) [1]. To counter the epidemic, LMICs have witnessed scale-up of HIV care services, supported by health information systems (HIS) [2] and HIV data warehouses [3]. These information systems produce large amounts of data, which are essential in data informed decision-making (DIDM). In addition, HIV-data is complex in nature comprising of different aspects. Therefore, it is salient in strategic, tactical and operational decision-making at the different levels of the health system (facility, district, provincial, and national). Despite the importance of DIDM, inadequate utilization of data in LMICs is still being reported, years after implementation of HIS [4-5]. Nevertheless, various efforts have been initiated to promote DIDM in LMICs[1, 6-8].

However, literature revealing the process involved in data users' decision to adopt or reject DIDM is meager. To fill this gap, we employ the innovation-decision model, a component in diffusion of innovation theory (DOI), to describe the stages of adoption of DIDM by data users.

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2. Method

A literature review was performed between January 2018 and April 2018. Publications were identified by searching several databases. These included PubMed, Google Scholar, ProQuest, and Oria database. The following are examples of words and MeSH terms used individually or in combination: "HIV", "AIDS", "monitoring and evaluation", "data*use", "decision-making", "health information system", "developing countries*". The inclusion criteria were confined to studies that aimed at promoting DIDM in LMICs at the different levels of the health system (facility, district, national). Emphasis was placed on recent publications on use of HIV-data in strategic decisions. Publications included peer-reviewed empirical studies and institutional reports on HIV-data use. Studies not compliant with the inclusion criteria were excluded. Following this, we employed DOI. The motivation to use DOI is influenced by its significant contribution in understanding dissemination and utilization of research for policy and evidence-based practice in healthcare [9]. DOI has also been used to understand dissemination and implementation of HIV interventions [10]. Rogers defines an innovation as "an idea, practice, or object that is perceived as new by an individual or other unit of adoption" [11]. Thus, the "innovation" in this paper is the practice of 'DIDM' as applied on HIV data.

3. Results

Existing literature was mapped to the five stages in the innovation-decision process model.

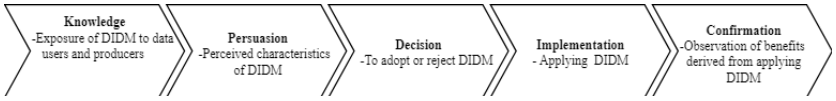

Figure 1. Stages in the adoption of DIDM using Rodgers innovation-decision model [11].

3.1. Knowledge, persuasion and decision stages

The literature reveals use of dissemination strategies such as initiatives for monitoring and evaluation [12], and data use workshops [8,13] in creating awareness of DIDM. The knowledge stage therefore exposes data users[2] and data producers[3] to the existence of DIDM for them to gain some understanding on how it functions [11]. Upon knowledge formation, data users go through a persuasion[4] stage which determines whether a favorable or unfavorable attitude is formed towards DIDM [11]. Nevertheless, the literature reveals certain characteristics of DIDM, which have limited the achievement of success in persuasion. These include complexity of data collection requirements (negatively affects quality of data) and lack of culture of DIDM, which then shape the data users and data producers perception of DIDM [1,4,14]. These

[2] Data users are referred to as individuals such as program managers, policy makers, who use the data for strategic decision-making.

[3] Data producers are referred to as individuals such as monitoring and evaluation officers, responsible for generating and disseminating data.

[4]Persuasion here refers to attitude formation and change on an individual, and not the intention to induce attitude change in a desired direction [11].

perceptions determine the results of the decision stage[5]: whether data users and data producers adopt or reject DIDM. The literature reveals challenges in adoption of DIDM [12,14] with limited reports on full adoption[6] of DIDM in HIV at the various levels of the health system.

3.2. Implementation and confirmation stages

The literature reveals limited studies that take a rigorous approach in reporting the outcomes of use of different types of HIV-data in decision-making. Furthermore, challenges in adoption of DIDM are evidenced by the cases of inadequate use of data [4,8,13,14]. Nevertheless, substantial efforts to ensure active acceptance in implementation of DIDM in HIV are still ongoing [1,12]. Thus, evidence on types of decisions-made using HIV-data and their outcomes such as patient health, allocation of resources, and contributions in HIV program improvements would potentially provide confirmation[7] of DIDM adoption.

4. Discussion

The literature reveals implicitly a form of innovation-decision process in adoption of DIDM, though the stages are not followed sequentially in the literature as described in this paper. Thus, we employ the innovation-decision model to describe an overall view of the adoption of use of HIV-data for DIDM by data users and data producers. From the results, the decision to adopt DIDM is determined by the knowledge obtained about it, and perceptions formed towards it. The literature reveals efforts in dissemination of knowledge such as training and data use workshops. Nevertheless, such initiatives also require resources, which are not always readily available due to dependence on funding agencies and global initiatives. As such, knowledge dissemination may be limited. This is a barrier since awareness-knowledge determines the rate of adoption of DIDM. Further, Hassinger [15] posits that 'need' for an innovation should precede awareness-knowledge of the innovation, which then creates motivation for its adoption. The literature reveals scenarios were data producers are overwhelmed with complexity of data requirements for HIV [1,14] Hence, data producers perceive generation of data as a clearing and forwarding exercise, often at the cost of other aspects such as high quality data. Thus, the element of 'need' seems to be less obvious among data producers as they focus on certain scopes of patient data management. On the other hand, decision-makers have the element of 'need', which creates a favorable condition to adopt DIDM. Nevertheless, perceived attributes of the DIDM such as lack of culture of DIDM have hindered the practice of DIDM. This is referred to as the knowledge-attitude-practice (KAP) gap [11]. Thus, continuous emphasis on knowledge and persuasion stages can contribute to full adoption DIDM. Further, organizational, technical and behavioral factors also contribute to choice of adoption of DIDM [16].

[5] At decision stage, an individual or organization engages in activities that leads to a choice of adoption or rejection of an innovation

[6] Adoption refers to the full acceptance to use an innovation as the best course of action available.

[7] At the confirmation stage, the individual seeks reinforcement of the innovation-decision already made or reverses a previous decision to adopt or reject the innovation if exposed to conflicting messages about the innovation

5. Conclusion

Awareness of the various stages in which an individual or organization goes through in order to decide whether to adopt or reject an innovation is important. This is because it facilitates the identification of areas that need improvement for adoption to take place. Nevertheless, this requires organization readiness in terms of availability of technical, human and financial resources as well as organizational awareness of the new technological advancements, all of which impacts the utilization of HIV data.

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Knowledge Management for Brazilian Cancer Care Services

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Abstract. Nowadays Brazil has a complex cancer care scenario. There are nearly 600.000 new cancer cases each year in Brazil, and the huge majority of patients have some contact with hospital services. However, long waiting queues for diagnostics and treatments have become common. One of the critical success factors in a cancer treatment is early diagnosis. The reduction of waiting time to start therapeutic procedures is one of the main issues for improvement of patient's quality of life and possibilities of cure. The objective of this work is to describe the development of a decision support system that improves the identification of access alternatives, appointment scheduling and employment of available resources. The Theory of Constraints was used to identify bottlenecks in patient treatment flow and a Discrete Events Simulation model was used to reduce patients' waiting time to start cancer treatment.

Keywords. Decision Support System, Theory of Constraints, Discrete Event Simulation.

1. Introduction

The majority of countries have been facing serious difficulties in healthcare, intensified by the growth in the demand for health services due to the increase in the number of elderly citizens with chronic diseases; greater request for accessibility to extra hospital care, personalization of patients' care, scarcity of financial resources and difficulty recruiting and retaining staffs[1].

Healthcare is knowledge intensive, and Information and Communication Technology (ICT) is widely used to support knowledge management at healthcare organizations. Knowledge content quality is highly important in healthcare because low-quality knowledge can lead to deficient clinical decisions and even endanger lives [2].

In this scenario, Knowledge Management is crucial for medical decision-making and for delivering better results for patients. The relevance of medical knowledge has

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been highlighted in the studies to promote evidence-based medicine and clinical quality improvement. Progressively, healthcare professionals depend on information technology tools to deal with the ever-increasing necessity to manage knowledge[3, 4].

Considering the main function of Knowledge Management (KM) in medical decision-making, it is important to use KM tools to ensure efficient sharing of information among the users. Access to suitable and accurate information is critical. The use of information technology improves the storage of a large amount of information, which can be used by advanced decision support systems in healthcare organizations[5].

Brazil presently has a complex cancer scenario. Mortality rates are increasing, with the mostly high incidence of prostate cancer in men and breast cancer in women. There are around 600,000 new diagnoses of cancer each year in Brazil. This study presents the knowledge management framework and the decision-making support architecture developed at Brazilian National Cancer Institute (INCA).

2. Method

The framework developed at INCA incorporates four phases: creating, structuring, sharing and applying. The four steps represent the pillars of the framework deployed which promotes a secure environment for the knowledge management about cancer care. Figure 1 presents a short list of procedures and tools included in each step.

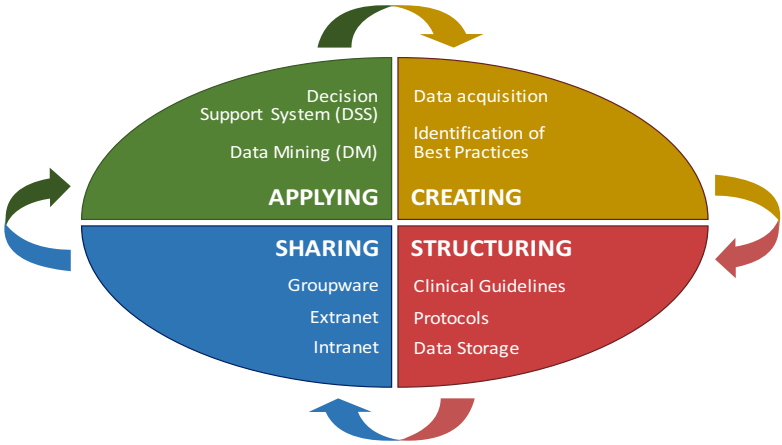

Figure 1. Knowledge Management Process

The creating step includes identification of best practices, data and knowledge acquisition. The process for obtaining knowledge, from internal and external sources, is strongly dependent on the clinical staff involved in cancer control and treatment.

The structuring step involves defining, storing, indexing and linking clinical guidelines and protocols. The sharing step involves the dissemination of best practices using the intranet, groupware, extranets, communities of practice, benchmarking and cross-functional teams.

The last step, applying, involves activities related to decision making and problem-solving using Decision Support Systems and Data Mining applications.

To support the physicians' activities, INCA's ICT technicians have developed data mining applications to find out the most effective treatments. These applications compare treatments patterns, symptoms and undesirable effects and then keep investigating which medical procedures will be most effective for a group of patients. This is also a way to identify the clinical best practices and protocols for cancer care.

Knowledge mining has a wide range of applications at INCA: The frequently mined knowledge by these applications is related to associations (groups of patients with particular profiles), clusters (groups of drugs with the same characteristics), sequences (Treatments linked over a period of time), predicting cancer survival and exceptions (unusual results).

Data mining holds great potential for the cancer care services by enabling decision makers to systematically use data science and analytics tools to identify inefficiencies and best practices that improve care and reduce costs. The INCA goal was to develop data mining applications to support patient-related decisions. Most of these tools are patient-centric as shown in the INCA Knowledge-based decision framework.

This solution has included enhanced collaboration between physicians and managers, simplifying the physician work, and empowering managers with sophisticated and cost-effective applications on the Web architecture. The legacy systems have fed the INCA data warehouse, which was the base to build the clinical data marts.

INCA data warehouse has integrated data from 536.000 patients collected since 2002. This data repository was the backbone of all analysis. Some queries were developed to validate data consistency. The creation of a multidimensional data set was carefully planned to develop analytics applications and visualize the key performance indicators.

3. Results

Recently, the Brazilian Constitution has included a new right for patients to start cancer treatment within a maximum interval of 60 days. To analyze this issue, INCA technicians have developed dashboards to analyze patients' treatment waiting times. The patient treatment flow follows a well-known protocol. The location of the tumor, stage, and diagnosis is usually identified after preliminary exams. The dashboard identifies patients who already have been registered at INCA and are in diagnostic analysis. In this phase the patient is submitted to a series of exams of pathological anatomy, clinical pathology, radiology, among others, to detect the location and evolution of cancer.

All patients' data were aggregated in a clinical Data Mart to create the automated patient's treatment flow. The patient treatment flow has integrated the electronic medical record and the sequence of events of a patient in only one screen. This approach is innovative allowing physicians to examine the clinical evolution of a patient quickly by using past events, current situation, and future clinical procedures.

The dashboard has increased the traceability and was totally patient-oriented. It was possible to see, in an animated fashion, the details of the flow of a particular patient over the treatment process. The doctor in charge of the case has been able to follow a patient or a group of patients step by step in their cancer treatment. Based on the easily available information, one was able to detect and/or predict the bottlenecks in the treatment flow.

These analytics applications were developed to support physicians' access robust data visualizations on their own, enabling them to drill down into and filter data based on their specific information needs.

4. Discussion

Healthcare organizations have structures with little formalization where employees are very specialized and autonomous. Highly trained specialists are grouped into functional units for particular goals. The coordination among departments is made by fragile regulation and frequently informal communications. Furthermore, the staff relations are predominantly weak, and the adoption of technologies is extremely dispersed as the work differs within each medical specialty. Integrating these knowledge islands is a great challenge.

Current healthcare systems generate huge quantities of data, but regrettably, this asset is not yet entirely used for improving the management and delivery of healthcare services. The benefits gained with the implementation of this Knowledge Management Framework are real-time knowledge access; knowledge share; costs reduction; cancer diagnosis agility and treatment quality.

The adoption of Knowledge Management framework can improve the efficiency of healthcare delivery in terms of capturing and sharing patient data among the different health professionals. The use of learning practices can bring a positive impact on the adoption of the evidence-based decision-making process by physicians.

A clear understanding of the knowledge management process by professionals and administrative staff is fundamental. Resistance against the new data mining tools on the part of some physicians has been overcome by the development of user-friendly web interfaces. An additional facilitator has been the enthusiastic adhesion of young physicians. Patient care is improved because data mining furnishes knowledge that supports physicians to recognize diagnostic and treatment patterns, current and future needs, and patient preferences.

Through this case study, this research has provided a better understanding how healthcare organizations can leverage knowledge management as a means of to improve care and reduce costs. it's important in the future research to study the validation of this knowledge framework and make a comparison with other relevant approaches.

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Physical Fitness Forecasting and Risk Estimation in Slovenian Schoolchildren

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Abstract. Physical fitness is important in view of reducing risks for a number of non-communicable diseases, both for individuals and policy-makers. In this paper, we present a prototype tool that combines forecasting of individual fitness parameters of schoolchildren to early adulthood with estimation of relative risk for all-cause early mortality in adulthood based on the forecasted fitness. This tool is a first step in the development of a platform that will show age, gender, and geographical distributions of risk and suggest potential interventions.

Keywords. SLOfit, exercise, machine learning, CrowdHEALTH

1. Introduction

The prevalence of overweight and obesity is rising globally [1], with the current obesity epidemic especially alarming among children and adolescents [2]. Lack of physical activity (PA), alongside poor nutrition, is proposed as one of the major contributors to childhood obesity [3] and one of the major public health problems in the world [4]. A wealth of evidence demonstrates that regular PA reduces all-cause mortality and the incidence of cardiovascular diseases, type-2 diabetes, and cancer, and enhances bone strength and psychological health [5]. Therefore, both halting adiposity and rising physical activity have been included as global non-communicable disease targets in the forthcoming period by the WHO [4].

Physical fitness is closely linked to PA level of an individual and is often used as a proxy measure for it. Abundant evidence links both overweight and low fitness with higher incidence of several non-communicable diseases and mortality in adult population [4], with the strongest protective effect being found for cardiorespiratory fitness (CRF) and muscular fitness (MF) [6-8]. However, these outcomes are very rare in children. Hence, it is difficult to relate either weight status or low fitness to hard health outcomes in this age group. Instead, the associations of fitness and obesity with proxy measures of health are usually described. Examples include clustered metabolic or cardiovascular risk [9] (i.e. a set of biochemical measures of carbohydrate and lipid metabolism). Yet, a stronger message to policy-makers, as well as the public, would be

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conveyed if the risk of future death based on childhood health-related fitness could be presented.

In Slovenia, every April, almost the entire Slovenian population aged 6 to 18 (220,000 students) is measured using 8 motor tests and 3 anthropometric measurements (SLOfit, www.slofit.org) [10]. The study contains data on physical fitness of Slovenian primary and high school students and enables annual monitoring of physical and motor status of children in all Slovenian schools from 1987 onwards. On the national level, the SLOfit data serves as the scientific backbone for most of the policies related to enhancement of physical activity of children and youth, and the policies related to school physical education. To date, the SLOfit database includes over 7 million sets of measurements for over 1 million children and is one of the largest cross-sectional and cohort databases of physical and motor development in the world. Slovenian educational policy, informed by the SLOfit data, managed to develop one of the most efficient system of physical education and extracurricular sports programs in the world, which results in a very favourable level of physical fitness and physical activity of children in Slovenia in comparison to the rest of the world [11].

Here, we present the prototype of a tool that allows us to estimate the total relative risk for premature death related to weight status, CRF, and MF in adolescence. The tool is based on the SLOfit dataset and shows the relative risks for all-cause mortality based on the BMI, MF, and CRF at the age of 18. The forecasting of parameters from a given age to the age of 18 is done using methods of artificial intelligence. This tool, developed within the framework of the EU H2020 project CrowdHEALTH (http://crowdhealth.eu/), will serve to suggest health-related interventions for policy-makers.

2. Forecasting algorithms

The task of the forecasting algorithm is to predict a particular SLOfit parameter (height, weight, 60 s sit-ups, 600 m run) at the age of 18, based on the data form previous years and knowing the general population trends.

The simplest baseline model uses the percentile method: for example, if an individual is in the N^{th} percentile at the age of 13, we assume he would be in the same percentile at the age of 18 (of course, this model clearly has limitations, such as not taking into account the fact that the puberty can start at different ages). More advanced approaches use machine learning. To improve the prediction accuracy, we generated additional features, including average, maximum, minimum year growth, standard deviations, peak height velocity (the year with the largest increase in growth), as well as the percentile data. Next, we built a model for each year up to which we have available data. For example, the model for the age of 13 takes the measurements from 6 to 13 and forecasts the value at the age of 18. Each model is built on a single type of data (e.g. height).

Several machine learning algorithms were tested on a dataset of about 2000 children. To evaluate them, the average absolute error was calculated. The best results were obtained using a linear regression model [12]. An example forecast is shown in Fig. 1. In future work, the entire SLOfit dataset will be used to build models, as well as combinations of SLOfit parameters instead of single-type data.

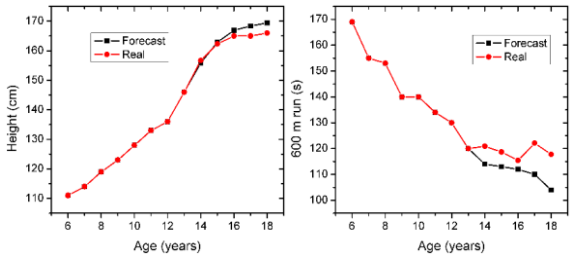

Figure 1. Real height and 600 m data together with the forecast data, based on the data from ages 6 to 13.

3. Risk assessment

Among 11 measures included in the SLOfit system, BMI, 600 m run, and 60 s sit-ups were chosen as indicators of weight status, CRF and MF, respectively. To estimate the risk of all-cause mortality in adulthood, we first predicted the values of these traits at age 18, and then related this to the relative risk of premature death these values convey at young adulthood. To ascribe risks to the specific trait, we searched the PubMed database for studies on young to middle-aged subjects (20-50 yrs.) relating obesity and/or fitness to all-cause mortality. Search terms were entered separately for each of the 3 traits included in the study (e.g. CRF OR aerobic endurance AND all-cause mortality OR premature death). The available studies were first ranked according to the type: 1. meta-analysis; 2. prospective cohort study; 3. retrospective cohort study; 4. cross-sectional study. Next, we ordered the studies based on: 1) method of obesity/fitness assessment, 2) methodological quality, 3) N of participants. Out of several meta-analyses extracted for weight status, we chose the highest-ranking one according to the criteria mentioned above [13]. Conversely, the absence of appropriate meta-analysis for CRF and MF forced us to rely on the highest ranked among the prospective cohort studies available [8,14]. The relative risk reported in these studies relates to prospective risk of early death in individuals that were healthy at baseline. Deaths in the first few years are excluded to minimise the risk of reverse causality.

Table 1. Relative increase in risk (in %) for all-cause mortality in men, related to suboptimal values of BMI, CRF, and MF (based on [12], [13], and [8], respectively)

BMI (kg/m^2)	15-18.5	18.5-20	20-22.5	22.5-25	25-27.5	27.5-30	30-35	35-40	40-60
Risk increase (%)	82	44	2	ref.	7	27	66	166	335
CRF (600m run)	Q1 (best)	Q2	Q3	Q4	Q5 (worst)				
Risk increase (%)	ref.	28	59	78	85				
MF (60s sit-ups)	Q1 (best)	Q2	Q3	Q4 (worst)					
Risk increase (%)	ref.	47	47	172					

Based on how each of the traits was presented in these studies, we divided participants into BMI categories, quantiles of 600 m run and quartiles of 60 s sit-ups. The associated relative risks of all-cause mortality for specific traits are shown in Table 1. Relative risk shows the percentage increase in risk for a specific outcome compared to a reference category. In our case, the reference individual is a lean, very fit person (specifically, an individual that belongs to top 20 % of CRF and top 25 % of MF). For women, the approach is the same, only with different risk increase percentages.

4. Discussion

We present the prototype of the tool that allows both forecasting of fitness from childhood to young adulthood, and estimation of relative risk for all-cause mortality at middle age. This approach allowed us to link fitness in adolescence with health risks in adulthood. In this initial version, the forecasting component only uses single type of data to build the models. Next steps will include a combination of parameters, as well as risk estimates for individual chronic diseases, such as cardiovascular disease or diabetes. As for the risks, at the moment we treat them (mostly) independent of one another. Although estimates for both CRF and MF were adjusted for each other and BMI, we are not aware of a meta-analysis that adjusts BMI for fitness.

The tool will be coupled with an intervention planner. A policy-maker, such as a school principal or an employee at the ministry of education, will be able to see the main risks a particular region faces, and what interventions have proven successful to alleviate these risks in the past. Examples of such interventions include additional physical education classes or improved infrastructure for sports and recreation.

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An Individual Patient Outcome Tool for Joint Replacement Patients

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Abstract. Patient specific forecasting tools are an area of active research and very much seen as a necessary tool for future improvements in healthcare. In order to succeed with decision making tools, fine-grained data are required to build models relevant and valid at an individual level. Location and assemble of data to build such tools is not trivial. Even then the ability to perform accurate predictions is not guaranteed. This study outlines a method to integrate existing data sources to base predictions on. A key benefit of the method is the minimal extra burden on the patient and the healthcare system. A pilot study is performed to implement the system architecture on data from total knee arthroplasty. Output from the system is presented using web technologies. In doing so, the viability of the method to implement a tool for the prediction of pre-operative and post-operative follow-up is demonstrated. Future steps will include testing and deployment of the system.

Keywords. Adverse events, arthroplasty, decision making, patient outcomes, integrated databases, web technology

1. Introduction

The most cost-effective treatment for osteoarthritis of the knee or hip is to replace the damaged cartilage with a total joint replacement (TJR). In 2014, 1.4 million patients in the EU were implanted with a knee or hip replacement [1]. Indications from arthroplasty registries show this number is increasing annually, and is predicted to double by 2030 [2]. Whilst this treatment is generally successful the implant has a finite life – currently a revision operation is required in 5% of cases by 10 years. Revision surgery is technically more difficult and is associated with considerably higher costs. Moreover, survival is lower, and the health-related quality of life is poorer than after the primary operation.

Patient specific forecasting tools are an area of active research and very much seen as a necessary tool for future improvements in healthcare. Numerous clinical tools have been developed to predict patient outcome post total joint arthroplasty [3]. Whilst showing promising results they are not widely used outside of their development institutes. One issue that if predictions are valid outside of these specialist centers. Recently there has been a move to better utilize information contained within national

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arthroplasty registries to forecast outcome of individual patients. However the patient data within registries has been shown to be insufficient [4] leading to an effort to combine data with other quality registries [5] or genomic data [6]. To date the use of fine grained data currently available preoperatively or at routine follow-up has not been fully exploited. This includes clinical assessments, x-rays and blood ion levels. A major reason for this is that data is not accessible for the development of predictive models. The aim of this study was to design a system that could make use of existing data sources. The system is then implemented to demonstrate potential functionality.

2. Material and Methods

2.1. Construction and content

The Bergen Implant Retrieval centre collects fine grained data on hip and knee arthroplasty (termed "retrievals") in Norway [7]. Along with the explanted prostheses, peri-prosthetic tissue biopsies, blood, and x-rays are collected. As collection is an additional task for medical staff this is typically limited to failed implants, creating a lack of data on well-functioning implants to act as controls in development of prediction models. Randomized clinical trials are one source of information on well-functioning implants. In Norway an RCT is required prior to use of any new hip or knee implant thus providing a source of high quality control data. Further this data is available before widespread usage.

Evidence of mechanical and chemical damage can be assessed from the retrieved prosthesis. Tissue can be examined to identify particles or elements released from the prostheses, and the patient's immune bio-response. Blood samples may be analyzed to determine the systemic release of degradation products from the biomaterials into the patient. Each failure is then linked to the national registry by a personal identity number maintained by the Norwegian Tax Agency. This facilitates collection of data regarding patient outcome and diagnosis.

Combining these data sources provides the fine grain information that can be used to construct a predictive model for total joint arthroplasty (Figure 1).

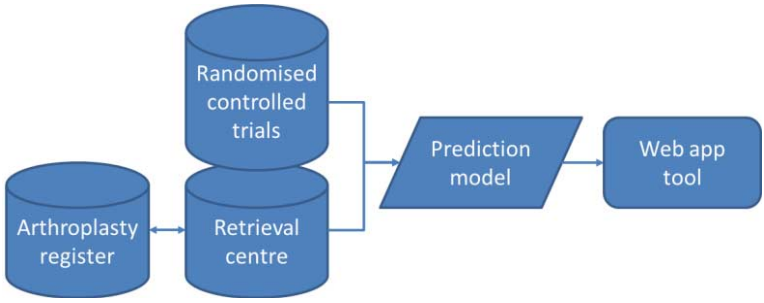

Figure 1. System architecture indicating how existing sources of clinical data can provide fine grain data for the prediction of survival in total joint replacement patients.

3. Implementation

In order to test the validity of the proposed architecture a simplifed pilot system was implemented to demonstrate the concept. This was based on a logistic regression model previously reported [8].This combined data from 32 failed cases and 43 control cases. Regression coefficients for gender, BMI, implant position, and bone cement thickness were computed. The covariate-specific risks were then estimated by adjustment of the term of the model intercept using the survival estimate for overall population [9], which has been previously published by the Norwegian arthroplasty registry. All calculation using patient data was performed within the local intranet in accordance with ethical approval. Internal validation was performed using the concordance index, being 0.67 (CI 0.57-0.78).

A web application was created using the R package Shiny (figure 2). This used the prior calculated coefficients. The outcome was an overall survival estimate to allow the users to make patient specific predictions, i.e. postoperative failure free period estimated in years.

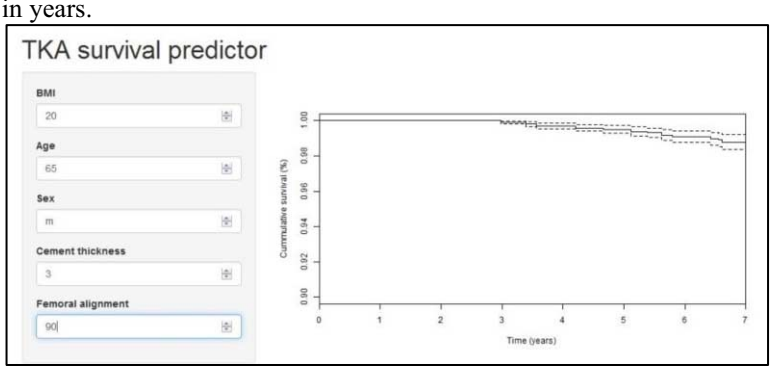

Figure 2. Web application implementing prediction model for total knee arthroplasty (TKA).

4. Discussion

This article proposes a system through which existing data can be used to build predictive models to estimate survival pre-operatively or at routine follow-up. To achieve this we have developed a system to integrate data from a retrieval centre with existing RCTs. This minimizes the additional costs required to achieve the goal. By developing the model in a local network and only deploying the model to a central web-application patient data is untraceable. A web-based solution makes possible future extensions to mobile technology solutions.

The suggested model is simple and based on the essential variables that are commonly used by the treating medical staff. This could act as a framework for inclusion of more complex outcome modelling based on additional clinical information and tissue biopsies were the extra cost is justified by improved prediction accuracy.

The ability to accurately predict clinical outcome has direct benefits to the patient and healthcare system at large. This project is loosely based on a population based case-control study design. Future work will concentrate on selecting the optimal datamining techniques to provide the most accurate survival estimate possible, whilst balancing the temptation for ever increasing data sources.

Developing patient outcomes tools based on fine grained has the added benefit of identifying details about failure mechanisms. Thus, they are considered idea generating. The use of national registries for post-market surveillance of medical devices has been successful at identification and removal of inferior designs from the market. However, in total joint replacement this has created a barrier to innovation and the introduction of new designs of prostheses.

5. Conclusion

There is a wealth of information on the outcome of total knee arthroplasty (TKA) however it is not fully utilized in patient level decision making or technology development. Collection of the patient level diagnostic data for relevant groups to allow predictive models to be constructed is difficult to implement in an economic and ethically viable way. This study has explored the possibility of using web technologies to define a concept and platform that would integrate existing data sources with minimal extra burden on the patient and the healthcare system. This provides a viable method to implement a tool for the prediction of pre-operative and post-operative follow-up. Future steps will include full implementation and testing of the system to predict individualized patient outcomes using patient specific features and integrated databases.

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Alternative Medicine Patient Records Moving to a Digital Environment

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Abstract. As technology immerses in daily life, all types of clinical practices migrate more on storing medical records on electronically media. The issue is up for debate on several fronts, as both paper and electronic records offer strengths and weaknesses. This paper presents the process of changing from paper medical records to a digital environment in the case of an alternative medicine clinic, having years of stored paper records, with its benefits and challenges. Focusing on quality criteria, the current study shows how beneficial an electronic medical record could be, while arguing how the diagnosis coding from the paper-based patient record resulted in major qualitative disadvantages.

Keywords. Electronic medical record, alternative medicine, Spring framework

1. Introduction

Medical records contain treatments and individual experiences specific to a patient. As the records are continually updated, they provide the physician with the written proof of the medical experience of a patient, over time, and helps determining the further course of the treatment or even for medical research. The paper written medical records have a lot of shortcomings: not properly organized, incomplete or even unintelligible [1-3].

The advance of computer technology has proven that the use of electronic medical records greatly increases the data quality as well as the data processing. Electronic medical records are defined as medical records located on a shared computer network that are both read and written electronically on a relational database through a graphic user interface [4,5].

The current study aims to determine how the data transfer from a physical format to an electronic one helps a private alternative medicine clinic better understand its patients.

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2. Method

2.1. Data collection

The data is collected from an alternative medicine medical center, specialized in acupuncture, api-phyto therapy, homeopathy, massage and ayurvedic medicine. It provided us for the study with data around 40 patients from Timisoara, Romania, with ages between 31 and 86 years old.

The data collection process proved to be time consuming, and we agreed to consider in a first phase 20 records from patients having their last name starting with letter A and another 20 records from patients having their last name starting with letter B, since we needed assistance from one of the physicians to read the paper records, and there was an imperious need not to create discontinuity in the daily clinical activity.

The patient records we had to move to the database were written by three different physicians, each having a hard to read handwriting, each putting in data in its own style and each recording different aspects about their patient's treatment, even though they had to fill in the same fields. To overcome this problem, one of the physicians had to assist us filling the database.

2.2. Data management

2.2.1. Development

To process the data provided by the clinic, a web application was built using the Spring Framework [6], where one creates an electronic medical record for a patient. This is a work still in progress since there are still discussions on how to better adapt to their needs. This framework is an excellent support for developing RESTful web services – as resources are acted upon by using a set of simple, well-defined operations [6]- requiring a minimal effort for adjustments. The most important advantage is the independency of platform-specific and non-standardized components, the app resulting highly portable and independent of application servers.

In designing the application, we choose a classic three-layered design, with a Web Layer responsible with processing the user's input and returning the correct response, including error handling. The second layer is the Service Layer which is responsible for transactions, having both application and infrastructure services. This layer also manages the authorization and the connections to external services like databases or system files.

The third component is the repository Layer which handles the communication with the used data storage.

For support reasons the application is deployed on one of the most popular servers for a java ecosystem, Apache Tomcat, very well documented and tested, with many enterprises and government organizations using it.

The electronic record contains all the data of a paper record, to which we decided to add some new fields to describe the patient's state at each medical examination, and more important some intelligence with predictions for short, medium and long-term status of the patient. The new fields are useful once the physicians will start using exclusively the electronic record. The allopathic diagnostics are being coded using the ICD-10 standard.

The platform also performs graphs supporting physicians in identifying key groups of patients, and age to disease relations or if a disease is specific to a certain geographical area or a job.

2.2.2. Administration

To access the complete system functionalities, a user must sign in for an account on the platform. This is possible for an employee of the clinic. A patient will access the website to view statistics, articles and contact the clinic.

To ensure the data security the application uses Spring Security, a framework that focuses on providing both authentication and authorization to Java applications, being the de-facto standard for securing Spring-based applications.

Spring Security provides comprehensive and extensible support for both authentication and authorization, protecting against attacks like session fixation, clickjacking, cross site request forgery [7].

3. Results

3.1. General usage

Using this specially developed platform, the clinic will be able to manage the new patients as well as gradually add the old ones.

From the human resources point of view, we found that physicians want shift to digital technologies due to potential features helping them improve work, but when it comes to replacing their old system with a digital one and interfering with their current day to day work creates discomfort and the process is rather slow. We are working to develop new interaction modalities keeping the data security at high level standards.

3.2. Data records

To gather some relevant data, a template was created containing the data for the new electronical medical record. It was based on the old paper record, so the process of transferring old data is as smooth as possible.

3.3. Using technology in alternative medicine

After discussing with the physicians, a couple of new metrics were added, such as predictions about the evolution of a patient's condition. Such a metric could still be correlated to the old records by analyzing the type of treatment administered for a certain condition. To do so, the specialist which applied the treatment would need to analyze that specific record and come up with a reason for it. In the experimental discussion of such an event, the specialist was able to accurately predict how the patient treatment would evolve based on the first treatment proposed and the initial condition of the patient. The system will contain a training algorithm to provide such a functionality to the users.

The team found that the main interest for the clinicians is to have a more efficient system of data management and advertise their results to possible future clients.

4. Discussion

Analyzing the 40 records it resulted that exists an increase in popularity among younger persons for an alternative treatment (Figure 1). After discussing with the physicians, the team members found out that the reason why mostly only elders came to the clinic in the beginning was since the Romanian medical system would cover the expenses for such a treatment if the family doctor would recommend it.

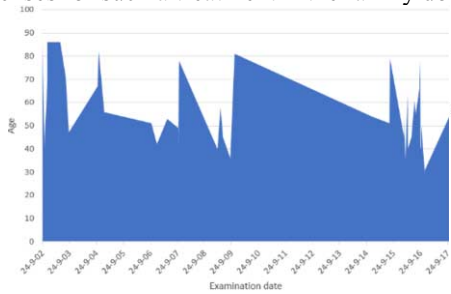

Figure 1. Age to examination relation.

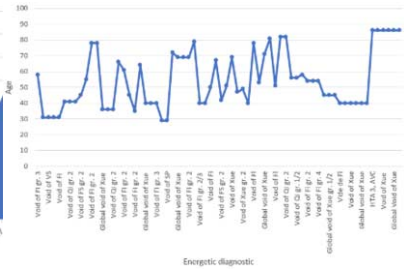

Figure 2. Energetic diagnostic by age

In the recent years, the graph shows a rise in the number of persons between 40 and 60 years that decided to follow an alternative medicine treatment, while the elderly would keep coming at a constant rate. For the 40 records we also checked the clinical status, to confirm the results (Figure 2).

Interesting results were obtained when it came to establish a correlation between age and a certain diagnostic. As Figure 2 presents horizontally on a specific age it can be clearly seen which energetic diagnostics are characteristic to it. The facts observed here were mostly confirmed by the specialists, agreeing that a diagnostic such as the Global Void of Xue is mostly seen in elders while the Void of SP is specific to younger people. Still, for a diagnostic like Void of Fl, for which our data would point it to a younger group of people, the medics were not certain.

Analyzing further the data and working to confirm the results, the conclusion is that to have a better understanding of their patients, such an analysis system would be useful for the physicians, but it is agreed that more data needs to be added as soon as possible.

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Health Analytics Types, Functions and Levels: A Review of Literature

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Abstract. Health analytics is a business-driven term that encompasses a wide spectrum of aspects and dimensions of business intelligence applications and big data analysis. Healthcare organizations recently are eager to know whether they are getting the full value from the massive amounts of data and information they already have, to achieve their strategic effectiveness goals and operational efficiency objectives. It is very crucial to learn more about the diverse functions, types and levels through which health analytics can support such tasks. A careful review of literature was conducted, and a qualitative analysis was used to classify health analytics. Five main types of analytics could be identified; these are descriptive, diagnostic, predictive, prescriptive and discovery analytics, each has its own distinct role in improving healthcare. In addition to the five types, health analytics could also be classified into three levels of performance and engagement, these are the operational, tactical and strategic health analytics.

Keywords. Health Analytics, Big Data, Business Intelligence, Hospitals.

1. Introduction

Health analytics is a business-driven term that encompasses a wide spectrum of business intelligence applications and big data analysis. This new concept is based on the availability and accessibility of data and information pooled through good integration and interoperability of a wide range of health information systems, such as electronic medical records, picture archiving and communication system, laboratory information systems and backend healthcare data warehouse systems [1]. Healthcare organizations are recently eager to know whether they are getting the full value from the massive amounts of data and information they already have, to achieve strategic effectiveness and operational efficiency [2]. The Healthcare Information and Management Systems Society defines health analytics as "the systemic use of medical data and related management information via the application of analytics methods and tools such as quantitative and qualitative statistics, context analysis and predictions to develop actionable insights and lead information based strategic and operational management for better healthcare" [3]. Over the last two decades, health analytics has emerged as a major area of study for both researchers and professionals, reflecting the magnitude of influence of information based management on solving problems and making decisions [4]. Health information systems are rapidly adopted worldwide, which will greatly increase the quantity and improve the quality of available health data.

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In the same time, revolutionary progress has been made in health analytics methods for analyzing enormous quantities of data and gaining new insights. Consequently, there are many new unmatched opportunities to use such methods to improve the quality and reduce the costs of healthcare [5]. It is very crucial to learn about the diverse functions, types and levels of health analytics through which it can support such tasks.

2. Methods

A careful review of literature was conducted through searching multiple databases, including MEDLINE, EMBASE and Google Scholar. The main search terms used included Health, Healthcare, Analytics, Big Data and Business Intelligence. Out of 833 retrieved studies, only 56 studies were eligible for review. References of studies as well as recent studies that cite publications were examined. Qualitative analysis was used to classify the main themes of health analytics into distinct types, based on the functions discussed, and levels, based on the impact described in studies.

3. Results

Five main types of health analytics could be identified; these include descriptive, diagnostic, predictive, prescriptive and discovery analytics. In addition, Health analytics could also be classified into three levels of performance and engagement; these are the operational, tactical and strategic levels analytics.

4. Discussion and Conclusion

Health analytics is now moving from the operational level into the higher level of strategic analytics and from the simple descriptive toward the more sophisticated diagnostic, predictive and prescriptive analytics. In the very near future, hospitals and organizations that used descriptive and diagnostic analytics, to collect data on the performance of different services, will utilize the more advanced types of predictive and prescriptive analytics to choose among different feasible alternatives. The most advanced discovery analytics supports users to discover new scientific facts. The analysis needs huge volumes of data with plenty of detail to discover new knowledge [6]. Figure 1 shows the five main types of health analytics discussed.

Descriptive analytics is the easiest level to understand and use. It simply describes the data with no more inferential analyses, explorations or correlations between variables or information elements. It is completely data controlled. Descriptive analytics work by categorizing, characterizing, aggregating and classifying data to be converted to valuable information to help healthcare professionals understand and analyze decisions, performance and results. The presentation of data is usually in simple graphs and tables that show hospital occupancy rates, discharges, average length of stay and other related indicators. Data visualization is used to help answering specific questions or identify patterns of care, thus providing a broader view for evidence-based clinical practice. They allow managing real-time, or near real time data, or operational content, and capture all patients' visual data or electronic medical

records. This can identify previously unnoticed patterns in patients, related to hospital readmissions and support a better balance between capacity and cost [2,7].

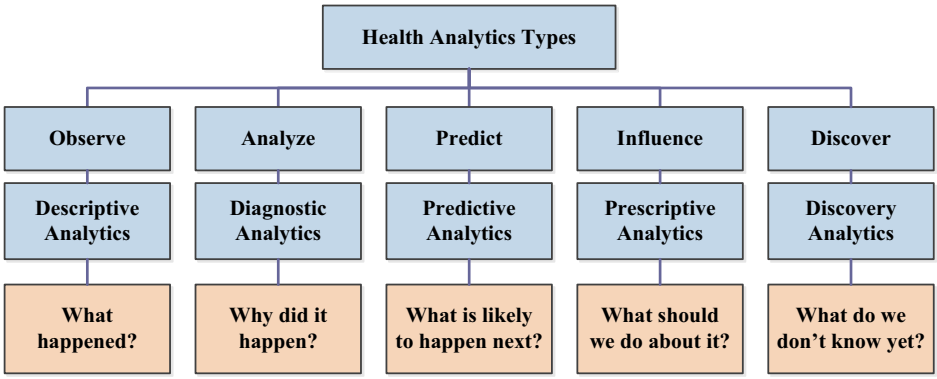

Figure 1. Types and Functions of Health Analytics

Diagnostic health analytics works on answering why something happened. It needs extensive exploration and directed analysis of the existing data using tools such as visualization techniques to discover the root causes of a problem and help users realize nature and impact of problems. This may include understanding the impact of input factors and processes on performance. For example, the increased waiting time in providing certain healthcare services could be tracked down to multiple influential factors including patient related, provider related or organization related factors [8].

Predictive health analytics works in a more complex way than simple descriptive analytics. It focuses on the use of information rather than simple data. It examines existing past readings and indicators to predict future performance. A pharmacist may need to expect the amounts of a drug to stock in anticipation of an outbreak of an epidemic disease. Certain medical changes or clinical patient outcomes could be predicted and evaluated based on the enormous amounts of previously collected data, such as patient's length of stay; patients who might choose surgery; patients who likely will not benefit from surgery or would have complications or even mortality [9].

Prescriptive analytics role comes into action when decisions have to be made regarding a wide range of feasible alternatives, it enables executives not only to look into consequences and expected results of their decisions and see the opportunities or problems, but it also provides them with the best course of action to take advantage of that foresight in a timely manner. The success of prescriptive analytics depends mainly on the adoption of five basic elements; utilizing hybrid data, including both structured and unstructured data types, integrating predictions and prescriptions, considering all possible side effects, using adaptive algorithms that can be tailored easily to each situation in addition to the importance of robust and reliable feedback mechanisms [10].

Discovery analytics utilizes knowledge more than information or what can be considered as wisdom in discovering new medications or alternative treatments or detect new symptoms, signs or diseases or unknown side effects. The Data–Information–Knowledge–Wisdom hierarchy is based on filtration, reduction and transformation. Besides being causal and hierarchical, the scheme is pyramidal, in that data are plentiful while wisdom is almost nonexistent [11]. Health information systems provide horizontal clinical information at the individual level. Analyzing patient level

data can yield population level inferences and results, such as the strength of association between medical product exposure and subsequent outcomes. It is important to understand the value of knowledge discovery methods and the challenges in extracting clinically relevant knowledge from big medical data [12].

Health analytics can also be categorized into operational, tactical and strategic levels. Each has its own role in helping to improve organizational decision making. Operational analytics helps usually in routine situations where basic performance indicators are reported and visualized, in relation to daily operations. It could include a group of sub-types or categories, such as monitoring analytics and event driven analytics [13]. Tactical analytics usually works for longer term objectives and focuses more on results to assist management in handling visible problems, and usually incudes simple predictive models which builds on past performance information, an abnormality in the waiting time of some ER patients maybe due to specific patient criteria. The hospital now should investigate this data to avoid future similar situations. So, we can identify the cause and find the solution [14]. Strategic analytics level can play a vital role in making long term decisions affecting the strategic direction of the organization. More complex systems and disciplines are needed for strategic analytics to become a key part of the organization's decision making. Strategic analytics also has a few sub-types or sub-categories such as predictive analytics, drill-down analytics, subject-matter analytics and comparative analytics [15].

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Using Predictive Model for Screening Bacterial Meningitis in National Surveillance System in Iran

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Abstract. Bacterial meningitis is a dangerous infectious disease that the entire community can be influenced by its epidemics. The objective of this study is to develop a predictive model as a screening tool to accelerate distinguishing between patients with acute bacterial meningitis and non-bacterial ones to prevent bacterial meningitis epidemics in Iran. This study was conducted on Iranian meningitis registry, which consists of 7,945 suspected cases of the disease between 2009 and 2011. Each sample has 8 predictive and a target variables. The predictive model was developed by decision tree algorithm and, the overall accuracy was 78%, with a sensitivity of 87%, and a specificity of 70%, respectively. This model can help health policymakers and epidemiologists to identify bacterial meningitis outbreaks and support them to make a decision in infection dynamics. In conclusion, we developed and validated a predictive model that can be used in meningitis surveillance system in Iran. However, further research is needed to use the model in practice with different pathogen types of bacterial meningitis in order to proper antimicrobial therapy planning.

Keywords. Medical screening tool, predictive model, data mining, decision tree, bacterial meningitis

1. Introduction

Bacterial meningitis is a dangerous kind of meningitis worldwide; as a result, its early detection is highly important [1]. Diagnosis of bacterial meningitis is based on microbiological tests of cerebrospinal fluid (CSF) and blood culture, Gram stain result, and latex agglutination, as well as imaging techniques [2], which are time-consuming, and some of them are a bit expensive. On the other hand, any delay in identification and beginning of treatment can lead to increase morbidity and mortality rates; therefore, it is necessary to establish a surveillance system to detect disease outbreaks, control epidemics rapidly, and prevent death rate [3]. In Iran, each suspected case of bacterial

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meningitis has urgently reported to the national meningitis registry at Iranian center for disease control and prevention (ICDCP) database [4]. In this paper, we focused on developing a predictive model by decision tree algorithm in order to distinguish bacterial meningitis from non-bacterial ones to prevent the disease outbreak in early phases in Iran.

2. Method

In this study, we used Cross Industry Standard Process for Data Mining (CRISP-DM), which includes six phases [5]. At the phase of business understanding, the diagnosis and treatment methods of bacterial meningitis were studied [1]. At the data understanding phase, the dataset including 7,945 records (26 variables) of an individual suspected of meningitis between 2009 and 2011 in Iran was assessed. At the data preparation phase, in considering the goal of our study, our target variable was constructed as a new nominal variable named final diagnosis, which is further categorized into bacterial (Haemophilus Influenzae, Nyseeria Meningitides, and Streptococcus pneumoniae) and non-bacterial (viral, unknown, and others). Moreover, the missing values were imputed and also, outliers and extremes were replaced using Coerce method by SPSS Clementine software (version12) [6]. Since age variable was in both year and day formats, they were all transformed to day format and stored as a new "age in days" variable to make analysis possible [4,7]. According to this standard, all activities to construct the final dataset, including featureselection should be performed in data preparation phase [5,8,9]. As a result, 8 predictive variables which had the highest amount of correlation with the target variable [10] were selected in this phase (Tables 1 and 2).

Table 1. Continuous variables for modeling

Variable	Mean
Age in the day (day)	4026.24
White blood cells (WBC) in CSF (cell/mm^3)	889.24
Lymphocyte percentage of WBCs	31.05
Polymorphonuclear (PMN) percentage of WBCs	33.41
CSF protein level (mg/dl)	75.81
CSF glucose level (ml/dl)	59.03

Table 2. Discrete variables for modeling

Variable	Frequency (percent)
Gender	Male = 4,369 (41.5%)
	Female = 3,103 (58.5%)
CSF appearance	Bloody= 70 (2%)
	Clear = 2,578 (70.6%)
	Opaque = 713(19.5%)
	Unknown = 286 (7.9%)

At modeling phase, the final dataset was partitioned into two independent datasets, a training, dataset and a testing dataset, by holdout method. Themodel was developed by decision tree algorithm on the training dataset, containing about 70%, and 30% of the rest was used as the testing dataset. The model was developed by KNIME data mining software version 1.2.10. We, also, used Decision tree parameters in determining cut-off points, including a minimum number of record per node to set a limit value and prevent further splitting of a node which has reached the specific minimal size in building the decision tree [11], Gini index to measure quality attributes [12], and minimum description length (MDL) pruning method to improve predictive accuracy, decrease tree size and achieve fast execution time [13,14].

3. Result

In this study, the first variable or root is WBC count in CSF which is the most important factor in our decision, and the next important variables are in far away from the root are CSF protein level and CSF glucose level, which are in stratifying the data. The most important rules were extracted from this model are:
Rule 1: If WBC count in CSF > 32 and CSF protein level >51 and CSF glucose level<=50, then class: A person with bacterial meningitis (BM) - (2664/3162 or 84%).
Rule 2: If WBC in CSF > 32 and CSF protein level >51 and CSF glucose level>50, and if CSF protein level >73, then class: A patient with bacterial meningitis (BM) - (825/1123 or 73.5%). As the dataset was large enough,the holdoutmethod was selected; as a result, the model was driven on the training set, and whose accuracy was estimatedwith the testing set to assess the validation. Theoverall accuracy was 78%, with a sensitivity of 87%, and a specificity of 70%,(Table 3). Measuring the quality of the model was performed by the area under the receiver operating characteristic (ROC). The area under the curve (AUC) is 84%, which displays good discrimination.

Table 3. Confusion Matrix of Outcome/Prediction (Result)

		Actual Class	
		Patient with BM	Patient with Non-BM
Predicted Class	Patient with BM	1929	684
	Patient with Non-BM	290	1607

4. Discussion

The purpose of this study was to develop a predictive model by decision tree algorithm to support public health decision making to improve Iranian bacterial surveillance. Decision trees have benefits in public health settings, including an ability to captures multilevel interactions among predictors automatically, a capability of generating rules, interpreting and visualizing by decision makers easily, and ability to handle both continuous and discrete variables [12]. In this study, decision tree algorithm was used because it had more acceptable accuracy, sensitivity, and specificity than over supervised learning algorithms. This model can be acted as a screening tool by three predictors, which are CSF parameters [1]. Based on the rules, each probable case with WBC in CSF more than 32cells/mm3, CSF protein level more than 51 mg/dl and CSF glucose level less than 50 mg/dl was identified as a patient with acute bacterial meningitis. These new cut-off points can promote national guidelines, help in early detection of epidemics [7,15], and aid policymakers in making optimized public health policies [16]. In this condition, it may be the cornerstone of early warning systems and improve surveillance system at the national level [17]. One limitation of this study was that the dataset included the data which have not been gathered based on research goal; as a result, so much time was spent on data preparation. A large percentage of missing data in the dataset was another limitation that was conducted with imputing methods; however, it may have affected the precision of the model (78%). The model could not be deployed in ICDCP because of some technical and infrastructural limitations.

5. Conclusion

Predictive models in infectious disease informatics are tools that can identify possible disease outbreaks [18]. Further research needs to develop the models sensitive to the pathogen types in order to proper antimicrobial therapy planning.

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Intensive Care Decision Making: Using Prognostic Models for Resource Allocation

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Abstract. Accurate outcome prediction by the means of available clinical contributing factors will support researchers and administrators in realistic planning, workload determination, resource optimization, and evidence-based quality control process. This study is aimed to evaluate APACHE II and SAPS II prediction models in an Iranian population. A a prospective cross-sectional study was conducted in four tertiary care referral centers located in the top two most populated cities in Iran, from August 2013 to August 2015. The Brier score, Area under the Receiver Operating Characteristics Curve (AUC), and Hosmer-Lemeshow (H-L) goodness-of-fit test were employed to quantify models' performance. A total of 1799 patients (58.5% males and 41.5% females) were included for further score calculation. The overall observed mortality (24.4%) was more than international rates due to APACHE II categories. The Brier score for APACHE II and SAPS II were 0.17 and 0.196, respectively. Both scoring systems were associated with acceptable AUCs (APACHE II = 0.745 and SAPS II = 0.751). However, none of prediction models were fitted to dataset (H-L ρ value < 0.01). With regards to poor performance measures of APACHE II and SAPS II in this study, finding recalibrated version of current prediction models is considered as an obligatory research question before applying it as a clinical prioritization or quality control instrument.

Keywords. Intensive Care Unit, Prediction Models, Performance Measures, Iran.

1. Introduction

Although, as a part of modern medicine, Intensive Care Units (ICUs) have been customized as particular units aiming to provide specific health care services to a particular group of patients who share a common acute disorder, but the continuous time-limited decision making process remains as a significant challenging issue in this area. Regarding vulnerability and rapid fluctuations of vital organs clinical decision making should be accompanied by accurate prioritization [1]. It should be also noted that ICUs contribute to a growing proportion of health care expenditures which in turn include internal and external mechanical equipment [2]. Utilizing scoring systems like the Acute Physiology and Chronic Health Evaluation (APACHE) may help to provide

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a clinical standard for severity prioritization by the means of routine blood investigations. Various contributing factors such as age, duration of acute disorder, special medical consideration e.g. malignancy, immunosuppression or the need for kidney transplant and emergency ICU admission increase the mortality rate in ICU [3]. APACHE II incorporates 14 variables (The most deviating symptoms and laboratory results from normal definitions during the first 24-hour period post-admission), each of which is scored from 0 to 4 and results in an ordinal total score ranging from 0 to 71 in which higher score reflects more severity of acute disorder [4]. It was first developed to predict an individual's mortality risk in ICU, however numerous studies evaluated this score as a patient triaging tool [5]. This may highlight the fact that APACHE II score may be utilized as a quality control instrument [6]. Similar existing scoring systems such as Simplified Acute Physiology Score II (SAPS II) have been rarely evaluated within various countries around the world, but a few studies have confirmed the acceptable predictive power of SAPS II in Europe and North America [7]. Regarding the limited number of patients in previous studies around the country, a multi-center prospective study was conducted in the top two most populated cities in Iran to evaluate the predictive power and to provide performance-related statistics for APACHE II and SAPS II scoring systems.

2. Methods

A prospective cross-sectional study was conducted to collect a pre-specified set of variables in four centers located in Tehran, capital Iran(67% of patients)and Mashhad, northeast Iran(33% of patients) as the top two most populated cities in country, from August 2013 to August 2015. Patients who were admitted due to traumatic surgeries, burn patients, patients underwent cardiac surgery or psychological disorders were excluded with regards to the nature of diagnoses. In addition, any use of psychotropic agents in medication profile or symptoms of dysarthria or paramnesia due to a type of brain disorder were considered as exclusion criteria. A total of fourteen variables in APACHE II in addition with remaining variables requested by SAPS II were designed as a structured paper form to be filled out for consecutive 1799 adult (>16 yrs.) patients. The highest APACHE II score for each particular patient during the first 24-hour period post-admission was considered as the final score. Regarding predetermined personnel cooperation framework, minimal missing values were included in this study (less than 0.2%) which were excluded. Using online calculators (available at: http://clincalc.com/Error.aspx) APACHE II and SAPS II scores were calculated for each particular patient by two of authors. The Brier score (overall performance), Area under the Receiver Operating Characteristic Curve (AUC) and Hosmer-Lemeshow (H-L) goodness-of-fit test were considered as performance indicators for both models. Analyses were performed using medcalc-13.3.3.0 and R-3.3.1 (Resource Selection package).

3. Results

A total of 1053 (58.5%) males and 746 (41.5%) females were included in this study, 834 patients (46.3%) were post-surgical, N=230 (12.8%) of patients were diabetic, N=766 (42.6%) were supported by mechanical ventilation and N=859 (47.7%) were

post-surgical admitted patients. The overall mortality rate was 24.4% (N=439) and the mean APACHE II score for all patients was 10.8 (±6.129). About 67.4% (N=1213) of patients were associated with APACHE II lower than 15. Mean APACHE II score for living and dead outcomes were 11.4 and 16.7, respectively (ρ value < 0.01). As expected, mortality rate and APACHE II score were increased similarly. Also, total population was associated with 20 (± 11.43) SAPS II score (Table 1).

Table 1. Comparison of Observed Mortality Rates in ICUs with International Standards regarding APACHE II Score

APACHE II score	Total N (%)	Observed Mortality N (%)	International Standard (%)	ρ value a
APACHE II ≤ 15	1213 (67.4%)	187 (15.4%)	10%	ρ < 0.01 [b]
16 < APACHE II < 19	335 (18.6%)	118 (35.2%)	15%	ρ < 0.01 [b]
20 < APACHE II <30	251 (13.9%)	134 (53.3%)	35%	ρ < 0.01 [b]

[a] Comparison was performed using chi square test.
[b] Observed mortality rate more than international standards.

While APACHE II was associated with better overall performance (Brier score=0.17), SAPS II performed a more acceptable discrimination of alive and dead cases (AUC=0.751). This is while, both scoring systems revealed unsuccessful calibration (H-L ρ value < 0.01) (Table 2 and Figure 1).

Table 2. Performance measures calculated for APACHE II and SAPS II scoring systems.

Scoring System	Overall Performance	Discrimination					Calibration
	Brier Score(min-max) [STD]	Mean	SE	95% CI	Difference	ρ value	H-L Test
APACHE II	0.17(0-0.94) [0.25]	10.745	0.0133	(0.725-0.765)	0.00608	0.4694	Chi2(8) = 98.588, ρ<0.01
SAPS II	0.196(0-0.999) [0.35]	0.751	0.0132	(0.731-0.771)			Chi2(8) = 1608.9, ρ<0.01

AUC: Area Under the ROC Curve, SE: Standard Error, CI: Confidence Interval, H-L: Hosmer-Lemeshow.

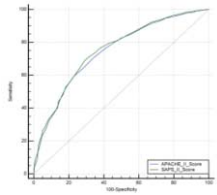

Figure 1. Area under the ROC curve for APACHE II and SAPS II.

4. Discussion

Recruiting patients from four tertiary care referral centers may increase the generalizability of results to a large subset of our target population in Iran. While both of APACHE II and SAPS II scoring systems performed relatively admissible classifications of alive and dead predicted probabilities estimated by APACHE II were closer to observed events (Brier score = 0.17). The H-L goodness-of-fit test revealed poor calibrations for both models (ρ value < 0.01). It is worth noting that observed ICU mortality rates were significantly higher than internationally published standards. Correct outcome prediction in 75% of cases is similar to accuracy measures reported by Gupta et al. for Indian population [8]. Also, an observational study in Rasoul Akram hospital, Tehran, Iran revealed that observed mortality rate for low-risk patients

(APACHE II ≤ 15) was comparable to international standards. However, mortality rate for the rest of patients was significantly higher than reported standards which may be due to variability of provided treatments in the center. This may highlight the fact that APACHE II score may be utilized as a quality control instrument [6]. Safavi et al. proved that APACHE II was the most accurate prediction tool (sensitivity=90%, specificity=32%, and accuracy=81%) in compare with Infection Probability Control (IPC) and APACHE III to estimate the overall ICU mortality rate [5]. A brief comparison of AUCs may indicate the fact that discriminative ability of APACHE II in Iran is relatively lower than those published in similar studies around the world. The aforementioned issue may be addressed by model recalibration approach which may provide us more accurate outcome predictions in research, practice and policy making (esp. benchmarking) areas. Integration of different clinical prediction models for benchmarking purposes will support researchers and administrators to step forward in severity prioritization, ICU bed allocation scheme, and evidence-based distribution of intensive care capacities. Prospective data collection approach, minimal missing values, recruiting acceptable number of patients for evaluation purposes, and representativeness of our sample due to geographic situation and annual number of ICU admissions in four included hospitals may be noted as strengths for this study. Regardless of the diagnosis at the time of admission, all patients were included aiming to assess the performance of APACHE II within patients involving with various organ malfunctions. Although, a 2-year sampling duration will adjust the effect of time-related confounders and may guarantee the inclusion of probable seasonal disorders, but time and sample-related limitations remains as an inevitable issue. With regards to poor performance measures of APACHE II and SAPS II in our included sample, recalibration of current prediction models is considered as an obligatory research question before applying it as a clinical prioritization or quality control instrument.

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Oncology Information System Data - Implications for 'Big Data'

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Abstract. Our Oncology Information Systems (OIS) with local User Documentation manages the medical data explored in this 26 item report of a minimal medical dataset. Over 10 years to 2016, 12906 diagnoses were registered (ICD10: C00-C80), with 18.84% of cases, and 63.9% of data points complete. Two sites were quality assured with high completion rates (H&N – 97.4% [4.26% of total cases], RECTUM – 88.74% [4.06%]). Sites lacking clinician attention varied from poor (eg, LUNG – 23.23% [13.24%]) to largely incomplete (eg, BRAIN – 2.01% [0.38%]).This disappointing medical data completion rate makes its use in a 'Big Data' effort suspect. Data extrapolation is compromised by variable natural history. Extrapolation techniques are unlikely to cope with only 18.84% complete data. Data mining requires input from domain experts. The 4 requirements of Big Data are not evident in oncological data.

Keywords. Oncology information system, Big Data, MOSAIQ, Quality Assurance, Incomplete data

1. Introduction

The department uses an OIS[2] for radiotherapy and chemotherapy delivery and data storage. Data extracts assess clinical, workflow and funding performance, and could be used for data mining if assessed for quality. User Documentation details clinical workflow and data collection.

2. Methods

All patients consented to the use of de-identified data. A reporting tool[3] extracted data for all diagnoses (ICD10: C00 - C80; years: 2007 – 2016) on 13/02/2018, to assess completeness. Data were summarized (MS Excel®) and analysed for survival (Prism[4]).The 26 fields extracted came from the hospital PAS (Sex, Country of Birth, Birth Date), from the oncologist via the Diagnosis & Staging screen (Diagnosis, Histopathology, T/N/M & Overall stage), the CarePlan screen (Intent, Surgery, Radiotherapy, Chemotherapy, Brachy therapy, Immunotherapy, Hormone therapy), and

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[2] Elekta MOSAIQ ® (version 2.64)
[3] SAP Business Objects, CR Developer V14.0.2.364 RTM®
[4] GraphPad Prism 7 for Windows (version 7.03)

the Follow Up screen (Date of Death, Cause of Death, Local/Regional/Distant recurrence, and 5 calculated fields (Age at Diagnosis, Duration of Overall Survival, and Duration of Local/Regional/Distant control).

3. Results

There were 12906 diagnoses in 11233 patients. The commonest ICD10 groups (Table 1) included BREAST, SKIN, PROSTATE and LUNG (64.20% of cases), while H&N and RECTUM (8.32% of cases) contributed 43% of completions. The extracted fields [% complete] were Sex [100%], Country of Birth [90.13%], Birth Date [100%], Diagnosis [100%], Histopathology [75.39%], T stage [78.16%], N stage [78.13%], M stage [78.59%], auto-generated Overall stage [77.88%], Intent [65.97%], Surgery [65.34%], Radiotherapy [64.81%], Chemotherapy [63.74%], Brachy therapy [64.99%], Immunotherapy [65.09%], Hormone therapy [64.10%], Date of Death [100%, 'alive' if no Date of Death], Cause of Death [100%, 'no cancer death' if no Date of Death], Local recurrence [19.82%], Regional recurrence [19.82%], Distant recurrence [19.82%], Age at Diagnosis [100%, Date Diagnosis – Date Birth], Duration of Overall Survival [100%, Date Death/Date Report – Date Diagnosis], Duration of Local/Regional/Distant control [19.82%, Date Recurrence – Date Diagnosis].

Table 1. Results of Diagnostic Groups Extracted

No.	% Cases	No. complete	% Complete	Diagnosis Group	ICD10 code
2806	21.74%	169	6.02%	BREAST	C50
2027	15.71%	151	7.45%	SKIN	C44
1744	13.51%	222	12.73%	PROSTATE	C61
1709	13.24%	397	23.23%	LUNG	C34
599	4.64%	583	97.40%	H&N	C00–C14, C30–C32
524	4.06%	465	88.74%	RECTUM	C20
3497	27.10%	452	12.93%	OTHER	
12906	99.98%	2439	18.90%		

Some data item completion rates appear correlated because of similar source (hospital PAS) or entry screen(Diagnosis & Staging; CarePlan; Follow Up). The completion rates(H&N, RECTUM)resulted from QA by 2 oncologists undertaking data analysis. Overall survival based on incomplete data is inaccurate for all cases and lung cancer (Figure 1). Assuming that calculated Date of Death is a surrogate for a confirmed Date of Death is incorrect.

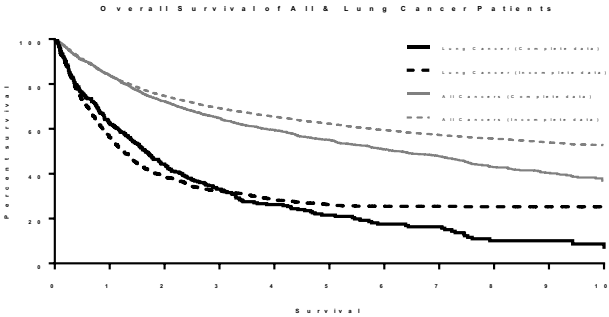

Figure 1. Overall Survival of cancer patients with complete or incomplete data.

4. Discussion

We report medical data from an OIS without a QA system which raises issues for oncologists and data miners who might manipulate similar clinical data. These data items that assess medical performance are 'routine', and not 'research' data. Research data is collected by researchers. Clinical audit data is collected and owned by clinicians, which merits responsibility. Data in its journey accumulates owners [1,2], it accumulates 'owners'. Oncologists own medical data along with patients, hospitals and managers, and so have responsibility for collection and quality. Many 'mandatory' QA and reporting datasets recognize important non-research medical data. Also, accurate medical data is required in retrospective literature, so oncologists have responsibility for data quality, either achieved in normal workflow or later as a 'research effort'. The audit data set is small and occurs occasionally. More importantly, constant, accurate collection reduces the impact of outcome analyses. This thinking underpins our base OIS functionality use to achieve contemporaneous data collection and QA. Counter-arguments based on extra workload are inaccurate. Mandatory data entry or QA by others (data managers, NLP) is error-prone[3]or does not occur, leading to the time-expensive and inefficient, repetitive, duplicative process of creating and filling in spreadsheets for retrospective analysis, which are rarely shared or reused. All medical data collected benefits oncologists, as well as managers. Oncologists should collect data routinely as they are responsible for it, and their work maximises data acquisition and QA. This report examines 16 entries available before consultation (4 items), at first consultation (12 items), follow up (3 items), and death (5 items), all of which appear regularly in the clinical literature [4]. The manual transfer of data from an electronic repository to a blank spreadsheet for analysis is much more work than extracting data from an OIS used to slowly accumulate and QA clinical data. Incomplete data extraction into spreadsheet format allows for 'second look' OIS QA[5], and complete data extraction. Furthermore, OIS data will represent the gold standard data source. This data extraction indicates that data can be complete (H&N, RECTUM) with effort, and that incomplete data is greatly incomplete (10.8% complete).Missing data restricts data mining. While there are algorithms that can be shown to provide robust data prediction, it is unlikely that these can re-constitute 81.16% of missing data, irrespective of sample size. The natural history of cancer (Table 2) reveals aggression (LUNG) and indolence (PROSTATE). This data set's complete data (H&N, RECTUM) will produce inaccurate missing data interpolation for other sites. Identification of clinical data for reporting requires a domain expert (i.e., oncologist) to merge user interface, use patterns, and database fields to find relevant clinical data.

Table 2. Cancer Aggressiveness (Cancer Institute NSW 2017 data)

% Incidence (I)	% Mortality (M)	M:I ratio	Diagnosis Group
8361	3862	0.75	UNG
8948	3215	0.36	RECTUM
5608	1930	0.34	H&N
35618	5083	0.14	PROSTATE
more aggressive cancers have larger M:I ratios			

Data veracity is reduced if using '*data I have'* not the '*data I want*'. Births, Deaths, and Marriages information are highly accurate for time and cause of death, but not cause of death [6]. Our Date of Death for the incomplete data is not QA'ed. Overall Survival differs significantly from complete data ($p<0.0001$) (Figure 1).

The presence of 'Big Data' can be detected from its publicised characteristics [7].

- **Volume:** This incomplete dataset(17MB)has many data fields empty (39.1%).
- **Variety:** Data variety varies with volume and velocity. Search page events are small (1-2/person/second), of extreme velocity (millions/second), complete (known search page, known mouse clicks), of limited variety (only displayed page, browser & device variables), and limited human involvement. Oncological data is highly, idiosyncratically variable with more than the 16 clinical variables, often free text.
- **Velocity:** Oncological data accrues slowly in the normal workflow over years, not seconds, so its capture is an 'infrastructure' problem needing organisation and routine QA.
- **Veracity:** OIS data can &could be "truth" (H&N, RECTUM), but requires QA by oncologists in normal workflow and reported death. Other systems (NLP) are inaccurate.

Analysis of a 12906 x 26 spreadsheet is not a 'Big Data' analysis. All data fields are recorded because they are clinically significant. Certainly, machine learning can be applied, but this is essentially an epidemiological exercise but capable of improved predictation [8]. A 'Big Data' analysis might be advantages with a*complete*12906 x 12906 data set with additional columns of data with unknown significance. This department provides 18.84% complete data, other departments may be worse. Domain expert involvement produces better quality data (more completeness, and true). Data mining efforts require the involvement of oncology domain experts.

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Supporting Prescriptions with Synonym Matching of Section Names in Prospectuses

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Abstract. The field of medicine still reports errors because of insufficient knowledge or resources, work load or data not available at the right time and place, and this may be fatal for a patient. To improve the healthcare quality, a doctor needs accurate and complex information processing when accessing drug information. Our work builds on improvement of accessing drug information for a better treatment through homogenization of sections in a prospectus. The sections names in a prospectus may be different for one source to another, and in this article, we propose a method to homogenize the content of all drug prospectuses. Once a correct homogenization of the sections has been established, the prospectuses can be used in clinical decision applications to provide the necessary data for physicians. Classification of the section names is using the Cousine similarity method and the Scikit-learn machine learning software. The best results were obtained with the Scikit-learn software.

Keywords. Prospectuses, synonym, drugs, healthcare quality, data extraction, homogenization, model

1. Introduction

The field of medical informatics is a rich research field. The large amount of data that result over time and the need for knowledge for high quality healthcare drives the evolution in this area. Doctors need as much information as possible to properly treat a patient and avoid medical errors. Since 18 years the Institute of Medicine of United States reported alarming data on the impact of medical errors. In addition to the injury to the patient, medical errors make a significant contribution to costs for any country. There are reports [1] that estimate 237 million medication errors per year in England. The adverse reaction of drugs causes between 1700 and 22303 deaths in a year. Literature presents solutions [2] to prevent errors in medicine through the following actions: creating written procedures, improving training courses for medical professionals, automation of support or search operations, monitoring quality in medicine, improving communication between doctors and encouraging cooperation between medical departments. The activity which numbers the most errors is the drug prescription [3]. Many errors associated with the drug prescription are made due to incomplete medical data or limited information for the prescribed drug in a specific

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clinical context. When a doctor prescribes a certain drug he/she must know all the indications and contraindications that the prescribed medication implies. A certain medication can interact with certain allergies, or illnesses or other medication, may be contraindicated for some patients or may contain contraindicated substances under certain circumstances.

Synonyms are the words with similar or the same mining. Some examples of synonyms are: "automobile, vehicle", "doctor, physician", "field, domain", "therapeutic action, therapeutic indication, pharmaco-therapeutic action".

In this article we describe a model to extract and homogenize the prospectuses (drug leaflet) sections. Future work will concentrate on creating a library with "synonym" sections for easy structuring prospectuses data. For the current work we use Romanian prospectuses of drugs extracted from online medical websites. The national databases are not very well structured and not available in a form capable of being processed electronically. Currently, many researchers try to link knowledge and metadata in all domains to make data more searchable and to have all the needed information when taking decisions.

In [4] the authors proposed a model for supporting heterogeneity and exchange of different perceptions. This model combines different existing terminologies about the same reality but used by different communities. The model is mapped into many linked ontologies. [5] presents the automatically extraction of synonyms of medical terms from a large clinical text corpus using distributional semantics. The authors combine Random Indexing and Random Permutation for capturing different lexical semantic aspects and also identify the synonymic relations between terms. This model can be used also to map abbreviations to the full length of the terms. [6] proposes a patient similarity evaluation framework based on patients longitudinal Electronic Health Records (EHR) matching. The authors present two efficient methods to find similarities: unsupervised and supervised, both preserving the temporal properties of EHR. The supervised method uses a convolutional neural network architecture and learns optimal representation of patient clinical records. Authors in [7] present a method to replace difficult understanding of specialized medical terms with synonyms easier to understand by unspecialized people. The replacement was on a corpus of a Swedish medical journal text. As can be seen, in literature there is a great interest in the use of synonyms and similarities for the processing of medical texts. We started the study from this trend and aim to use it for prospectuses and improvement of prescription activities.

2. Methods

To support the work of Romanian doctors in relation with prescriptions, we started a model for structuring the medical prospectuses in Romanian language. First, the prospectuses in Romanian language where extracted from medical web pages [8,9] and saved in an .xml format, as a structured format. Each prospectus so saved was parsed and divided into sections such as: indications, contraindications, composition, dosage, adverse reactions, etc. After this structuring, we made a large xml file with all the prospectuses with an xml tag for section name and text the corresponding text for these sections. The problem that we have encountered was the unevenness of the section names, so that different names for the same type of section may appear for each drug. As an example, for the warning section, the following names may appear: caution,

special warnings, warnings, warnings and precautions, special warnings, precautions for use, warnings and special precautions, precautions, warning.

To overcome this problem, we started to uniformize these sections by creating files with similar section names and reference names. The method we propose goes through the following steps: i) Collecting all section names from all sources -drug prospectuses; ii) Ordering alphabetically the sections names; iii) Removing multiple names, creating a list of unique items; iv) Stating the reference names for the sections as the most common and easier to understand; v) Using2 methods to classify the section names. The first is Cosine similarity, a measure of similarity between two vectors with the cosine of the angle between. It calculates the cosine angle between two sections names and the result is a number between 0 and 1 that indicates the similarity grade between the two sections. We tested this method with a set of sections names:
"actiuneterapeutica","actiuneterapeuticasiindicatii","actiuneterapeutica, indicatii", "actiuneterapeutica, indicatiisicontraindicatii", "actiuneterapeutica, indicatiisi mod de administrare", "actiuneterapeutica, indicatii, contraindicatii", "actiuniterapeutice", "actiuniterapeutice, indicatii", "contraindicatii", "contraindicatiisiprecautii", "contraindicatiisireactii adverse", "contraindicatii, avertizari", "contraindicatii, precautiisiatentionari.", "contraindicatii, reactii adverse, precautii", "contraindicatii/precautii, "reactii adverse", "reactii adverse sicontraindicatii", "reactii adverse siprecautii".
The result vector is: [1. 0.73 0.82 0.68 0.41 0.75 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.] that indicates the similarity between the first sections and the others, from the vectors.

We train our section names with Scikit-learn machine learning library for Python and test for other names to predict the classification of the give name. The sections on the left are the test names and to the right are the classifications (reference) names.

actiuneterapeutica, indicatii, contraindicatii =>actiuneterapeutica, contraindicatii

contraindicatii/reactii adverse =>contraindicatii, reactii adverse

reactii adverse/contraindicatii =>contraindicatii, reactii adverse

vi) Building a file with the similar names for each reference name; vii) Using the created files to uniformize all section names in the collected prospectuses. Figure 1 presents the resulting model.

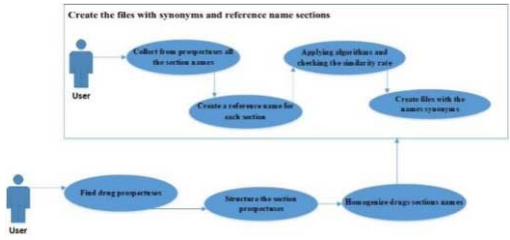

Figure 1. Model architecture for uniformization of section names

3. Results and Discussions

Domain literature presents solutions to streamline medical information or build similarities between patient's characteristics. It is of great interest to create homogeneous data for processing and reuse. There are databases with drug homogeneous information in English. Drug names and composition vary from one country to another. Our study involves a globally common element, namely the drug prospectus that has the potential to be structured and used as a source of complex information to design certain assisted decision-making applications. To search for

similar section names, we used two methods that automatically detect synonyms. The first method was Cosine similarity, which calculates the angle between two names of two sections, indicating the similarity between them and the second method was Scikit-learn machine learning library for Python. After training the neural network, the application will provide all similar sections for each name. Using the F-measure [10] metric we calculated the accuracy for each method, and for the test data provided from a website, the accuracy was 0.86 for the first method and 0.92 for the second method.

Unlike in existing literature that uses the medical documents extraction of synonyms in order to homogenize the medical terms, our solution implies homogenization in drug prospects to structure and use them in prescription decision support applications. In addition to existing solutions we use deep learning techniques (using Cousine and Scikit-learn) that lead to very good results in extracting relevant information. The study is in progress and the next step is to collect section names from 10 sources and to homogenize them, replacing the names with the reference section names. Supporting the prescription process improves quality of healthcare. We discussed with clinicians and the proposed structure was appreciated as of real help for physicians in making the right decisions for better prescriptions and treatments, especially for young doctors or the ones that enter a new specialization. There are countries were no structured databases of drug-related information exist, so physicians have to read each individual drug prospect. The proposed model creates uniform data with information about drugs that are ready and available to be used later in other applications. The model may be generalized for any language/domain only if the prospectuses have the form: section name -> text section.

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Structural Risk Evaluation of a Deep Neural Network and a Markov Model in Extracting Medical Information from Phonocardiography

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Abstract. This paper presents a method for exploring structural risk of any artificial intelligence-based method in bioinformatics, the A-Test method. This method provides a way to not only quantitate the structural risk associated with a classification method, but provides a graphical representation to compare the learning capacity of different classification methods. Two different methods, Deep Time Growing Neural Network (DTGNN) and Hidden Markov Model (HMM), are selected as two classification methods for comparison. Time series of heart sound signals are employed as the case study where the classifiers are trained to learn the disease-related changes. Results showed that the DTGNN offers a superior performance both in terms of the capacity and the structural risk. The A-Test method can be especially employed in comparing the learning methods with small data size.

Keywords. A-Test method, intelligent phonocardiography, heart sounds, deep time growing neural network.

1. Introduction

Recent advances in artificial intelligence and machine learning initiated a significant progress in medical informatics. Time series analysis is an important topic within the context of the artificial intelligence, especially in medical informatics where time series of vital signals play an important role in patient management. Several intelligent machine learning methods have been proposed for classification of biological time series and also for the regression analysis [1,2]. One of the important characteristics of most of the intelligent learning methods is the structural risk associated with a learning method. In artificial intelligence, the structural risk of a machine learning method is defined as the performance instability of the method when being tested by a dataset out of the training dataset [2]. A machine learning method with low structural risk is therefore, deemed to learn optimal contents of the input data in terms of the discrimination power, such that performance of the method is not affected by any

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group of the testing data [3]. This becomes more important when it comes with small or medium size of the training data, unlike big data in which a broad range of the data is mostly available.

Intelligent phonocardiography (IPCG) has recently become an important research topic, both for screening heart disease [4,5], and also for assessing severity of an underlying disease [1,6]. Recent studies revealed potential of IPCG in various aspects of pediatric heart disease assessments, including differentiation between pathological and physiological heart murmurs [7], diagnosing specific diseases [8-10], detecting pathological symptoms [11,12], which can make the approach frugal to be used both as a stand-alone and also as a web-based decision support system in the clinical settings [13,14]. However, one important issue in evaluating such an automated approach is reproducibility of the approach in real life usage. This is addressed by the structural risk that indicates stability of performance measures of the approach in practical situation. This paper introduces the A-Test method to quantify the structural risk in a systematic procedure, by which comparison of different artificial intelligence-based methods is feasible. Privileges of the A-Test method over other statistical methods is discussed for a specific case study on IPCG; comparison of a deep neural network and a hidden Markov model-based method.

2. Materials

Heart sound signals were recorded from the referrals to the Children Medical Centre of Tehran, using an electronic stethoscope of Welch Allyn Meditron Analyzer in conjunction with a portable computer. All the referrals underwent echocardiography and the study was approved by the appointed ethic committee and was conducted according to the Good Clinical Practice. All the referrals or their legal guardians gave their informed consent to participate in the study. The patient population is listed in Table 1.

Table 1. Patient population of the study.

Heart Condition	Number of Patients	Age Range (years)
Aortic Stenosis	15	1–8
Mitral Regurgitation	15	4–8
Normal without murmur	30	4–15
Pulmonary Stenosis	15	1–10
Ventricular Septal Defect	25	1–9

3. Methods

3.1. The A-Test Method

The A-Test method is based on k-fold validation method. In k-fold validation, the validation dataset is divided into k partitions with almost equal length. One partition is used for testing and the rest for training the classification method. This procedure is repeated k times with one partition is used only once for testing. The A-Test employs k-fold validation with different values of k ($k=2,\ldots,K_{max}$), and the classification error is calculated for each k-value.

$$\Gamma_{\mathrm{M}} = \frac{\sum_{k=2}^{K\,max} \Gamma_{M,k}}{K_{max} - 1} \quad (1)$$

Where $\Gamma_{M,k}$ is the classification error of the classification method M and k is the fold value for validation. K_{max} is less that the minimum group size of the validation data. For a classification method, the difference between minimum and maximum value of the classification error is an indication of the capacity for the classification method.

3.2. The classification methods

The A-Test method is employed to compare the structural risk of two different learning methods for classifying PCG signals, a deep time growing neural network (DTGNN) and a hidden Markov model (HMM), whose technical details are found in [2] and [15], respectively. The former is based on a three-layer neural network whose input layer by itself develops a separate learning, whereas the later in which the heart sound is empirically modeled by three states and the symbol probabilities constitute the discriminative features for the classification. Both the DTGNN and HMM are trained to learn the pathological characteristics of the signal, caused by aortic stenosis.

4. Results

Figure 1 shows variation of the classification error due to the k-value.

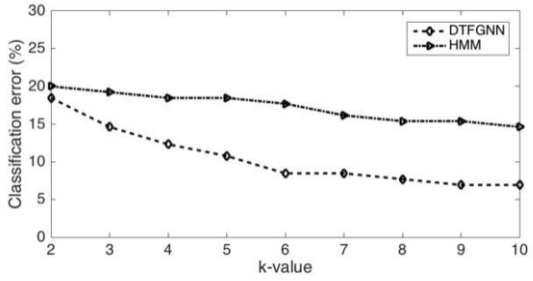

Figure 1. Variation of the classification error with respect to k-value for the two learning methods.

The descriptive statistics of the classification error are listed in Table 2.

Table 2. Descriptive statistics of the classification error for the two learning methods, the deep time growing neural network (DTGNN) and the hidden Markov mode (HMM).

Statistics	DTGNN	HMM
Average	10.51	17.27
Minimum	6.92	14.62
Maximum	18.46	20.00
Median	8.46	17.69

It is observed that the DTGNN provides a lower classification error for higher k-values showing a better learning capacity. The average classification error is lower in DTGNN, confirming superiority of the DTGNN. Interestingly, for lower k-values, the two methods offer almost similar performance. A reason could be the high learning capacity lays in deep layer of the DTGNN.

5. Discussion

There are mainly two alternatives to the A-Test for exploring the structural risk of a classifier; the k-fold and the repeated random sub sampling methods. However, the k-fold cannot provide an understanding about the learning capacity. Furthermore, it might lead incorrect comparison for certain value of k, as was the case for the DTGNN and HMM with *k=2*. Repeated random sub sampling has the deficit that a signal data receives a random share in ultimate validation, since the training data is randomly selected. As like as k-fold validation, the learning capacity is not inferable by using this method. The A-Test method has the limitation for small data with several classes that for some k-values variation of the classification error it trivial. However, it preserves effect of the training data size, which is ignored in other validation methods.

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Section III

Management

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Lack of Patient Data Privacy Challenges Patient Safety

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Abstract. Patient data privacy is emphasized due to increase in electronic health data processing. This paper highlights the importance of data privacy in healthcare and its connection to the European Union's (EU) General Data Protection Regulation, which aims to protect all EU citizens from privacy and data violations. The clinical environment is prone to hazards in information management, especially in care coordination, the management of patient data, and verbal communication. The Swiss cheese model was used to discuss the importance of patient data privacy based on statistics from a national patient safety incident registry. Patient identification proved an important factor leading to hazards that can cause severe harm to patients.

Keywords. Patient data privacy, patient safety, incident, registry.

1. Introduction

Patient privacy and data security are the cornerstones of the usage of electronic health records (EHRs) in healthcare. A variety of regulations and standards has been composed to guarantee the safe use of personal health information. Patients' privacy and health data should be better protected in healthcare. Healthcare providers' responsibility to protect patient privacy is emphasized due to increase in electronic health data processing [1]. Patient privacy concerns are highlighted in the use of EHRs, where system breaches occur accidentally, through cyber-attacks, or, e.g., due to lapses in professional conduct [2]. The European Union (EU) has recently launched the General Data Protection Regulation (GDPR), which seeks to create a harmonized data protection law framework across the EU and to give citizens back control over their personal data, whilst imposing strict rules on those hosting and 'processing' this data, anywhere in the world [3]. Principles relating to the processing of personal data (Art 5) are guiding documentation in healthcare. The key to personal data (identity) varies between countries. Personal identity codes were introduced in Finland in the 1960s [4], and these serve as the unifier for all personal data in Finland. Thus, in healthcare, the use of registries and databases is strictly followed to avoid misuse. However, the Finnish legislation on data protection is relatively permissive internationally, and it allows for the use of anonymized administrative data for scientific purposes. One of the

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main prerequisites for the utilization of register data is their good data quality, which has been proven true for several Finnish administrative registers [5].

2. Preventing Patients from Harm

This study adapts the inclusive definition of patient safety, articulated as the prevention of errors and harm to patients associated with the process of care. According to the health care degree from 2010, patient safety programs must include active monitoring of patient safety incidents [6]. This statement entitles healthcare service providers to have a system to record incidents and to have a process to remove risks [6]. The 'Swiss cheese model', introduced by Reason, describes the grouping of hazards that can lead to a safety incident [7]. It differentiates between latent failures and active failures. The method aims to investigate the cascade of events that leads to an adverse end result to assess the actions of those involved and then to look further back at the circumstances in which staff were working and at the context in which the adverse event took place [8] (Figure 1). The Finnish patient safety incident reporting system, HaiPro, was developed in 2006 and is used nationally. The development of the HaiPro online reporting system and process was initiated through a collaboration among the Technical Research Centre of Finland, healthcare units, and the Finnish Medicine Agency [9].

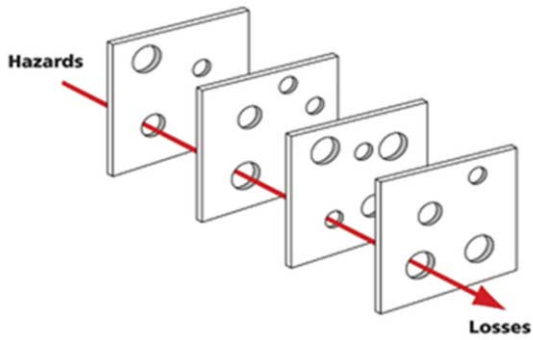

Figure 1. The Swiss cheese model [7].

The HaiPro system provides an amount of information on the reported data, as well as on how organizations have learnt from their incidents and improved their care processes. HaiPro classifies incidents into 13 structuredcategories, and the reporter can also add narrative text to clarify the type, context, and circumstances of the incident. The consequenses for patients or service providers are also assessed. Based on the process for safety promotion, the safety coordinators give guidance for actions to remove the hazards. The reporting process is confidential, voluntary, and anonymous, and it stresses learning from mistakes and blame-free actions. HaiPro has the potential to provide information on patient safety incidents at the level of all reporting organizations [9].

3. Aims of the Study

The purpose of this study is to analyze patient safety incident reports, focusing on risks in information management. The objective is to discover which types of hazards are damaging patient data privacy. A special interest was taken in information exchange in the coordination of care, documentation, and verbal communication.

The following research questions were set:

- What types of incidents lead to risks in patient data privacy?
- What are the consequences to patients?

4. Materials and Methods

The data (n=82,353) consisted of incident reports from seven healthcare organizations between the years 2007 and 2016. A data sample was extracted from the national database HaiPro with permission from the participating organizations. The sample consisted of incidents focusing on the category information management and information flow (n=12,294). The subcategories coordination of care, documentation, and verbal communication were analyzed using descriptive statistics. The results are presented with tables, and the SPSS software was used to analyze the structured data.

5. Results

Table 1 shows the frequencies in the subcategories, and it gives examples of the items, focusing on patient data privacy. The subcategories in the incident reports describe the reality in which the majority of hazards are related to patient. In the reported cases, missing, inadequate, or incorrect information caused no or mild harm to patients in over 70% of the incidents.

Table 1. Patient safety incidents with consequences to patients in the category of information management and information flow

Patientsafetyincidents (subcategory)	**Consequence for the patient,** No (%)				
Coordination of care before treatment (n = 2854)	*No harm*	*Mildharm*	*Moderateharm*	*Seriousharm*	*Unknown*
Missing or incorrect appointment (n = 1502)	568 (37.8)	636 (42.3)	109 (7.3)	5 (0.3)	184 (12.3)
Missing or incorrect referral to treatment (n = 676)	261 (38.6)	246 (36.4)	66 (9.8)	9 (1.3)	94 (13.9)
Communication between people (verbal communication) (n = 1937)	*No harm*	*Mildharm*	*Moderateharm*	*Seriousharm*	*Unknown*
Patient identification omission or ensured wrongly (n = 74)	50 (67.6)	18 (24.3)	5 (6.8)	0 (0)	1 (1.4)
Relayed wrong, inaccurate or inadequate information (n = 340)	175 (51.5)	106 (31.2)	30 (8.8)	3 (0.9)	26 (7.6)
Management of patient data (documentation) (n = 3291)	*No harm*	*Mildharm*	*Moderateharm*	*Seriousharm*	*Unknown*
Inadequate, missing or incorrect information of patient (n = 1543)	901 (58.4)	383 (24.8)	88 (5.7)	5 (0.3)	166 (10.8)
Errors in personal data or contact information (n = 422)	282 (66.8)	94 (22.3)	13 (3.1)	3 (0.7)	30 (7.1)

Each of the three subcategories included incidents that led to moderate or even severe harm to patients. Most cases occurred in the subcategory coordination of care before treatment.

6. Discussion and Conclusions

Our results give evidence that the Swiss cheese model is a reality in healthcare. Patient identification is crucial at the beginning of the caring process. Especially, the amount of missing, inadequate, or incorrect information in referrals can cause serious delays in treatment or totally incorrect care planning. It is also surprising how often a patient's identity remains unchecked, despite it being the key to all patient documents and the personal code structure being familiar to all citizens. Fortunately, the consequences for patients regarding these incidents remain mostly mild. The EUGDPR is the most important change in data privacy regulation in the last 20 years. Under the GDPR, a breach notification will become mandatory in situations in which a data breach is likely to result in a risk to the rights and freedoms of individuals. This must be done within 72 hours of first having become aware of the breach. Those processing data in healthcare will also be required to notify patients without delay after first becoming aware of a data breach [3]. This requirement will have a vast impact on healthcare data processing procedures, which seemingly—based on our data—have gaps that threaten patient rights. Updated incident reporting systems are needed. Even if voluntary incident reporting is an important tool for identifying patient safety problems, these systems have limitations in terms of GDPR: a principle of anonymity causes obstacles for fulfilling GDPR requirements. The results represent only one country. However, based on previous studies, patient data privacy is an important part of high quality and safe care. Moreover, patient privacy concerns are highlighted in the use of EHRs: system breaches occur accidentally, through cyber-attacks, or, e.g., due to lapses in professional conduct [1-2,8]. The use of an incident reporting system at the national level allows for the statistical analysis of hazards, supporting confidentiality and highlighting remedial actions.

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Developing an Evidence-Based Clinical Dataset for the Comprehensive Implantable Medical Device Registry (CIMDR)

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Abstract. Medical registries are in a need of a data set that is based on clinical evidence. In 2014, the Saudi Food and Drug Administration (SFDA) launched a plan to develop the national Comprehensive Implantable Medical Device Registry (CIMDR). One of the primary goals of the CIMDR is to develop a clinical -and population- based data set. The aim of this study is to report on the process of developing the data elements for the CIMDR. We used an iterative process of multi-stakeholder consultation over a two year period (2014–2016). The goal of the multi-stakeholder consultations was to build a dataset to address the need for device traceability, effectiveness, safety, and the recall of implantable medical devices. We investigated international and local standards for implantable medical device information capture, conducted a review of the literature, and consulted expert opinions in the development of the CIMDR dataset. The CIMDR data framework includes demographics, patient history, diagnosis, procedure information, and follow-up details for orthopedic and cardiac related implantable medical devices. Most of the dataset elements are logically validated with minimal free text entry to avoid human error and facilitate ease of entry. We use the International Classification for Diseases-Australian Modification as the standardized nomenclature for the CIMDR.

Keywords. Registry, Dataset, Saudi Food and Drug Administration, Implantable, Medical Devices

1. Introduction

The goal of the registry is to capture a variety of implantable medical device information from a number of different medical fields such as orthopedics and cardiology, building a comprehensive and representative data set is one of the principal

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challenges for the SFDA. In this paper, we describe our process for building the clinical dataset for the CIMDR for the following clinical areas: percutaneous coronary intervention (PCI), implantable cardioverter defibrillators (ICD), and knee and hip implants.

2. Project Background

Little information is known about the health and safety impacts of implantable medical devices on patients in Saudi Arabia, and generally, the Arab world. Most countries in the Arab world have regulated Food and Drug Authorities to register medical devices, however, the regulatory framework lacks a cohesive framework among countries in the region. Recently, in Saudi Arabia, there has been a variety of work conducted on the development of registry and health surveillance systems. On a national level, there are three well-known national registries: the National Cancer Registry, Saudi Centre for Organ Transplantation (SCOT) registry and National Registry for Diabetes. For implantable biomedical device surveillance, no registries exist in Saudi Arabia or within the region. In 2007, a royal decree assigned the SFDA the responsibility for regulating medical devices. In 2014, the SFDA formed a consultation committee to propose a plan for CIMDR development. There were a number of experts on the committee including medical device experts, epidemiologists, information technology specialists, health informaticians, physicians and SFDA administrators. The committee met once per week for a period of 20 weeks to establish a plan for the development and implementation of the CIMDR. One of the main outcomes of the taskforce was to create a registry database based on the most up-to-date clinical evidence. The scope of the CIMDR registry is to make a registry of medical devices. In the initial stage, there was a consensus to start with cardiology (percutaneous coronary intervention and implantable cardioverter defibrillators) and orthopedics (knee and hip joints).

3. Process of Building the CIMDR Clinical Dataset

In 2016, a group of cardiology, orthopedics, and health information experts within Saudi Arabia were consulted to guide the SFDA in the formulation of the dataset for a part of the SFDA's CIMDR. The purpose of the group was to select the appropriate parameters to be included within this clinical dataset. The work was split into two phases: 1) building a common minimum data set and 2) building specific data sets relative to each area of specialty. Through multiple iterations and consultations with experts, the consultant group developed a common minimum data set that included data elements pertaining to the following areas irrespective of the clinical domain: demographics, diagnosis details, basic procedural details, and follow-up details. The ease of extraction and availability of the information was given the foremost importance along with the harmonization of the parameters with each specialty.

For building the specific data sets, a group of medical consultants working in conjunction with the SFDA developed specific clinical data sets for cardiology and orthopedics because these two areas were the primary focus for the SFDA during the first phase of CIMDR development. The approach was an iterative one with multiple stakeholder feedback. Primary source documents for the development of the clinical data sets include the following: 1) Cardiology Audit and Dataset Standards [1], 2) the

National Cardiovascular Disease Database – PCI Registry (AMERICA), 3) National Cardiovascular Data Registry – ICD Registry (AMERICA) , 4) Gulf Registry for Implantable Cardioverter Defibrillator for implantable cardioverter defibrillators implants, 5) UK National Joint Registry [2], 6) American Joint Replacement Registry, 7) Canadian Joint Registry [3], and 8) Saudi Registry for Joints.

After the selection of the parameters, to ensure the quality of the data being collected, we used the International Classification for Diseases–Australian Modification (ICD-10AM) as our disease coding standard to fill in the relevant data for the parameters relating to diagnosis, procedures, symptoms, comorbidities, and complications. However, to ensure the quality and standards of the data, we created autonomous predefined classes/lists for parameters such as the NYHA and KILLIP classification s, PCI/ICD insertion and knee/hip implant indications, the Knee Society score, and the hip score. The ICD-10AM codes for all the categories were evaluated. The most common codes were kept or added according to the category and the uncommon codes were removed, except for the ICD-10AM/ACHi codes for comorbidities and previous procedure history. The final lists were approved by the ICD-10AM expert. The aim was to keep the data entry as smooth as possible.Next, we arranged the linear data into a vertical format appropriate for data entry that consisted of the following six categories: 1) Demographics, 2) Patient History, 3) Diagnosis Information, 4) Procedure Information (with immediate and late complications), 5) Procedure Outcome, and 6) Discharge/Follow-up Information.The final step was to meet with hospital stakeholders to validate the Case Report Form (CRF), which includes both the common minimum data set and the specific clinical data sets. We scheduled multiple meetings over a six-month period (June 2016 to December 2017) with consultants, data managers, and the relevant technicians, and all feedback from the stakeholders was reviewed. Appropriate and relevant modifications were made to the CRF subsequent to the validation process with the key stakeholders. Each data element included in the CRF was validated by expert reviews, the literature, SFDA, and other stakeholders. The outcome was a data set that was divided into the following sections: 1) demographic data, 2) diagnosis information, 3) history information, 4) procedure/surgery information, and 5) follow-up information.

4. Relevant Data Elements for CIMDR Analysis

The general literature review with respect to PCI/ICD registries/databases indicated that there were no established or fixed outcomes due to missing standard end points. After a detailed study carried out by the SFDA, a basic framework was developed for the analysis of commonly reported outcomes found in the academic literature with endpoints that were divided into primary and secondary endpoints. Therefore, it was determined that researchers should focus separately on safety and effectiveness. The research team hence constructed primary endpoints for clinical studies such as death within 30 days, readmission for myocardial infarction within 30 days, cardiogenic shock, infections, and fractures during operation. In contrast, secondary end points include arrhythmias, bleeding manifestation (either requiring blood transfusion or surgical intervention), mechanical complications, duration of hospital stay, and the revision of a procedure.Specifically related to cardiology, the following outcomes should be considered in the analysis of CIMDR data: major adverse cardiac events, mortality, new stroke, new fatal myocardial infarction (MI), index revascularization,

acute coronary syndrome [4], new onset heart failure [5], sudden cardiac death, re-hospitalization for MI, coronary artery bypass graft, stent thrombosis and restenosis [6], appropriate therapy, survival analysis, device related infections [7], and lead failure [8]. Specifically for orthopedics, the primary clinical outcomes that should be studied relate to the Knee Society score and hip score, revision, fractures, and infections immediately after the procedure as well as after a specified time.

5. Conclusion

In this paper, we described the SFDA process of developing a CRF for the CIMDR for both cardiology and orthopedic implantable medical devices, which has been based on previous work [9-11]. We followed an iterative approach that included a number of stakeholder consultations, along with content area experts and the SFDA. This paper also highlighted some of the elements that would be included in an analysis of the data for reporting patient outcomes. Future work will test the generalizability of the data set to other hospitals in the Kingdom of Saudi Arabia as the CIMDR is currently being pilot tested.

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Financial Management and Spatial Geomapping of Medical Equipment: The Case of Ultrasound Scan and Respirators

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Abstract. The proposed application is based on Geographic Information Systems (GIS) and it's used for medical devices spatial mapping. The application aims at improving the efficiency of hospital units. By using appropriate software, digital maps are created. The technical and financial data of the respirators and ultrasound systems are displayed on the maps. The respirators are installed in the Intensive Care Units (ICU) of public hospitals in Peloponnese. The ultrasound scan systems are also installed in the Radiology Departments of the same units. The user is enabled to create interactive maps and visualize a large amount of real-time information. The overarching aim is to develop an integrated surveillance system of medical equipment. This process will promote the loss-making machinery replacement. Furthermore, the efficient management of revenue and expenditure operations of hospital units will be promoted. The reliable decision-making by the Ministry of Health or the Health and Social Welfare Departments will also be enhanced.

Keywords. Geographic Information Systems, Mapping, Management, Medical Equipment, Interactive Maps

1. Introduction

The worldwide health systems deal with the challenge of better health care management under resource constraints [1]. In recent years, the rapid development of digital technology has created new applications for public health expenditure control. Geographic Information Systems (GIS) are useful spatial analysis systems [2]. They are mainly used for health care units efficiency increase. There are many benefits for the Public Health sector related to GIS [3,4]. The organizational and administrative problems can easily be solved by analyzing spatially recorded data [5]. The decision makers should focus on providing high quality health care services [6]. Unified spatial data can jointly be involved in GIS systems, enabling conclusion drawing [7]. Real time information establishes an extended financial database for each hospital unit. Finally, GIS systems play a strong role in performance indicators analysis, combined with epidemiological characteristics classification [8].

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The purpose of the application is to create an online platform as a price surveillance system, in order to control the expenditure of medical equipment. The application is also expected to test the cost-effectiveness of the examinations performed in public hospitals. All data will be displayed on interactive maps.

2. Materials and Method

The application uses the ArcGIS platform of ESRI. It's based on a single database where medical devices are specially classified. The classification is carried out by using specific information. This data contains information of health units and medical devices. Data was processed in the DigiTHEA Lab in the University of Peloponnese by 5 participants for about six months. The medical equipment is classified by category, model, manufacturer and GMDN code. All data is imported from a computer, mobile or tablet. By using this application, comparative study is enabled. The maintenance contracts can easily be revised and new terms can be set. Cutting costs can also be promoted and financial data can be assessed. The total expenditure is related to the cost of supplying new medical devices, repairing faults and supplying spare parts. Useful indicators can be calculated, such as equipment age index, equipment renewal costs index, maintenance costs index, etc. By selecting the appropriate thematic background (e.g. a geographical map) [9], the spatial visualization of the above data is achieved. These data contain spatial characteristics which are displayed on maps by calculating their exact coordinates.

Data contains all the information needed for customizing ultrasound scan systems. Raw data thorough analysis is also allowed by studying the map. All data is uploaded to ArcMap, by using the ArcCatalog application, spatial data navigation and special management tools. The ArcMap software is used to modify and display data on digital maps. After ArcCatalog files processing, data is previewed and directly transferred to ArcMap for mapping and editing. The main feature of the application, compared to other medical device management systems, is the online geographic recording of the obtained information. In view of the special features of the application, users gain a large amount of information. Information is related to the number and status of the medical devices, as well as their spatial distribution. Interactive digital maps are created, enabling user's real time data access. In view of system's usability, the integration of diagrams and the export of comparative results are also allowed. Reports can be extracted in pdf, html, rdf, rtf, tif, txt, xls formats and saved in a geodatabase.

3. Results

The application functions as a response tank which executes basic user commands (e.g. revenue graph analysis of ultrasound exams in the form of "pie" charts). Digitized financial data is captured in interactive maps. In Figure 1, the average revenue of ultrasound exams performed in 2015 is displayed, as a percentage of the revenue of the same exams performed in 2012. The majority of hospitals in the Peloponnese share a 5,5% to 95% reduction of their ultrasound scan exams. The Radiology Department of the Hospital Unit of Molaoi is excluded by this result. The relative revenue increase in 2015 rates to 110% compared to the relative revenue in 2012. In Figure 2, the total cost of radiology supplies in the public hospitals in Peloponnese is displayed. All data is

available for the period 2012-2015. Radiology supplies concern disposable drugs, films, gels and consumable products, such as gauze and hospital supplies used in Radiology Departments. A general reduction between 7,5% - 40% of the cost of radiology supplies is revealed by graph analysis in the period 2012-2015. A 10% cost increase of radiology supplies of the General Hospital of Argos - Hospital Unit of Argos is displayed, as well as a 102% cost increase of the General Hospital of Messinia - Hospital Unit of Kalamata. The cost increase of radiology supplies of the General Hospital of Messinia - Hospital Unit of Kiparissia rates to 22% and the same rate of the General Hospital of Achaia - Hospital Unit of Aigio is 29%.

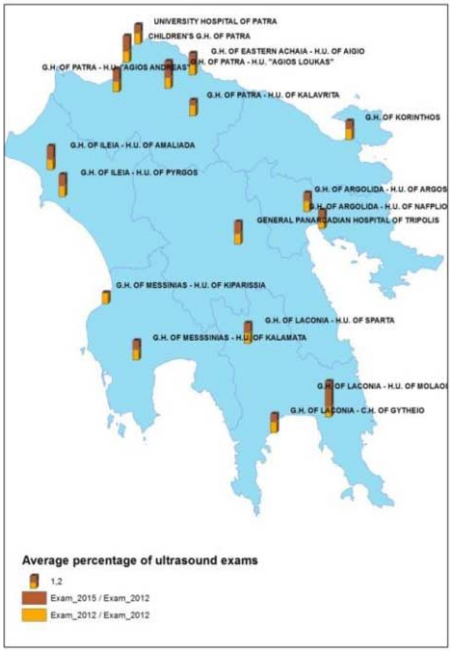

Figure 1. The average revenue of ultrasound exams in 2012 and 2015

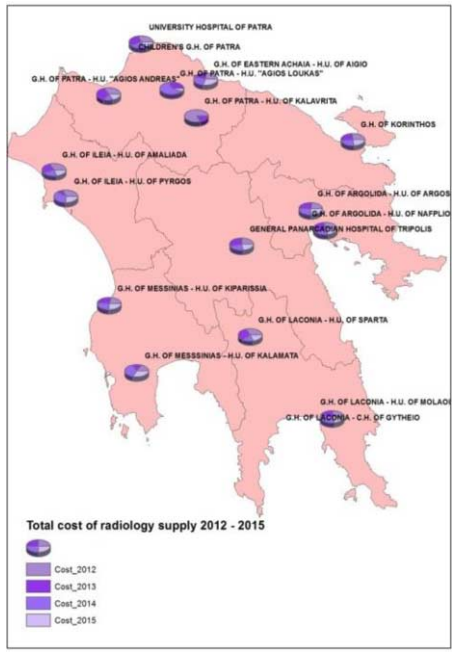

Figure 2. Total cost of radiology supply in the period 2012 – 2015

The same process is followed in the respirators in ICU of public hospitals in Peloponnese. Studying the maps, users can obtain information about the manufacturer and the model of the respirators by using HTML Popup tool (Figure 3). Data review from different hospitals is also promoted by spatial mapping of medical equipment. Biomedical Technology (BIT) departments and Public Health sector are also benefited by the spatial data recording. The application facilitates data export, dashboards creation and calculation of indicators (e.g. equipment operating time index, machine idle time index). These indicators are related to unused equipment (due to age, unprofitable repair, etc.) or under repaired equipment (number of repairs, total maintenance costs etc.). Geographical data are customized in report tables which are updated every time there is new information available.

By entering into the platform financial data from preventive maintenance contracts and from one-off (flat-rate) payments by suppliers, they can obtain corresponding aggregate or isolated results for IPM & CM costs. At the same time, if spare parts are imported, results will also come from this field.

Figure 3. Spatial mapping of respirators by using HTML Popup tool

4. Discussion

The application is useful for preventing cost overestimation in health services. It's also useful for the rational supply of medical equipment in hospital units. The application enables clinical engineers and health managers to gain more detailed spatial information. Useful statistics are collected, enabling thorough analysis by health decision - makers. Thus, data can be available to citizens, in order to guarantee transparency in transferring data procedures. The application can be established on a central data acquisition system for financial and administrative control of Radiology Departments or hospital units. The replacement of obsolete medical equipment is promoted by studying spatially analyzed data. The number of patients who use a medical device can be estimated in order to decide whether medical equipment is financially attractive. Patients can also be directed to the nearest hospital units, in case of a damaged medical device.

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GIS Platform for Management of Diagnostic Examinations

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Abstract. Greece is one of the European countries with the largest number of CT and MRI scans. Geographic Information Systems (GIS) are a useful tool for efficient cost reduction in the health sector. ArcGIS software is used to create interpretable maps. Data represents the number of imaging examinations per type and population size. All available data is acquired in 2012-2015. By using special symbols, pop up windows emerge. The windows contain a large number of data. The results are filtered and uploaded to a digital control panel. This central information system combined with the digital maps form a digital platform for estimating the exact number of diagnostic examinations. The survey confirms that the General Hospital of Tripolis performed 27.000 CT examinations in 2012-2015, corresponding to approximately 57% of the population of Tripolis. The approximate percentage of CT scans of the Hospital Unit of Pyrgos was found 55%. The implementation of this platform confirms the large number of diagnostic examinations in most areas of Peloponnese.

Keywords. Geographic Information Systems, Diagnostic Imaging Examinations, Population

1. Introduction

Health care quality improvement increases total expenditure and raises some serious problems which affect access to health care services and insurance patients' cover [1]. The cost of health care is equivalent to the total operating expenditure and includes all types of health care indicators. Quality cost describes the difference between the actual cost of health care services and the reduced cost, if patients' needs conform to health care services [2]. Imaging examinations performed for therapeutic and diagnosing purposes play a significant role in the estimating cost procedure.

The rise of digital technology creates new applications for cost reduction and limitation of radiation dose of diagnostic imaging examinations. Geographic Information Systems (GIS) are increasingly recognized tools in health sector [3]. They are used for comparing relative costs and improving outcomes [4]. They are also used for analyzing and understanding the spatial dimension of health care [5]. GIS tools enable the transformation of quantitative healthcare data to geographic objects. The

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process is known as geocoding and is used in data analysis [6]. The aim of the paper is to develop a GIS-based platform for cost control and management of diagnostic exams.

2. Materials and Method

ArcGIS software is used to edit the values of the descriptive features associated with diagnostic imaging examinations [7]. Data includes the number, the type of CT scan performed per geographic area and population size. It also includes the model of the computerized tomography system available to each hospital unit. CT examinations are selected to be spatially recorded among the other diagnostic tests because of the highly tissue absorption rate, compared to other exams e.g. X-rays. All available data is acquired in 2012 - 2015 and covers the territory of Peloponnese. It was acquired by the Department of Health Data Editing and Analysis of the Hellenic Ministry of Health.

In the first stage of the procedure, two digital maps are created. Population data for each territory is collected and combined with the corresponding data of diagnostic imaging examinations. By selecting the desired color, a specific symbol is created for each region. Focusing on specific areas on the map, the actual coordinates of each hospital unit on the map and the number of inhabitants are automatically displayed in pop-up windows. A second interactive map is created (Figure 1), displaying the number and the descriptive features of CT imaging examinations. Primary information is digitized in order to form an attribute table [8]. The user is able to divide all data by system model and type. The final stage involves the establishment of a central management system. This system, combined with the final map created, forms the web-based platform. The digital platform was established in the Digital Health Applications and Health Economics Analytics Laboratory in the University of Peloponnese.

3. Results

Spatial data recording reveals that the percentage of CT examinations performed in General Hospital of Tripolis, amounts to 31.4% of the total population of Arcadia (Table 1). This percentage also amounts to approximately 57% of the population of the capital which is the city of Tripolis! Spatial analysis also reveals that the University Hospital of Patras performed 108220 CT examinations during 2012 - 2015. This number amounts to 36% of the total population of Achaia.

"Agios Andreas" Hospital Unit, which is also located in Patras, performed 58000 CT examinations during 2012 - 2015. This amounts to 19% of the total population of Achaia and approximately 27% of the population of Patras. The corresponding percentages of "Karamandaneio" Children's Hospital were 1.36% and 1.96% respectively. Studying these results, it is clear that the three major hospitals in Achaia performed a CT scan to approximately 56% of the total population of Achaia and 80% of Patra's population during 2012 - 2015.

The percentage of the General Hospital of Argos is approximately 30% and accounts for approximately 10000 inhabitants of the city of Nafplio. In Messinia, the percentages of CT examinations are 38% of the population of the capital and 17% of Messinia's total population. The same remarks are made about the General Hospital of Pyrgos and the General Hospital of Sparta. The percentage per capita amounts to approximately 16% and 15% respectively. In conclusion, it is realized that during 2012

- 2015 the public hospitals of Peloponnese performed a great number of CT diagnostic examinations. In most cases, CT exams exceeded the total size of the population of the capital. In particular, the total number of CT examinations performed in Hospital Units of Achaia exceeded the total population of the entire county.

Table 1. Number of diagnostic imaging examinations performed in the Hospital Units of Peloponnese, 2012-2015. Pop. stands for population

Hospital Unit	County	Capital	Total pop.	Pop. of the capital	Total CT	CT / Total pop. (%)	CT / Capital's pop. (%)
General Panarcadian Hospital of Tripolis	Arcadia	Tripolis	86685	47254	27080	31.24	57.31
H.U. of Argos	Argolida	Nafplio	97044	33356	10092	10.40	30.26
H.U. of Kalamata	Messinia	Kalamata	159954	69849	26693	16.69	38.22
G.H of Korinthos	Korinthia	Korinthos	145082	58192	13953	9.62	23.98
H.U. of Pyrgos	Ilia	Pyrgos	159300	47995	26310	16.52	54.82
H.U. of Sparta	Laconia	Sparta	89138	35259	13768	15.45	39.05
H.U. of Patra	Achaia	Patra	303694	213984	108622	35.77	50.76
H.U. "Agios Andreas"	Achaia	Patra	303694	213984	57997	19.10	27.10
H.U."Karamandaneio"	Achaia	Patra	309694	213984	4.197	1.36	1.96

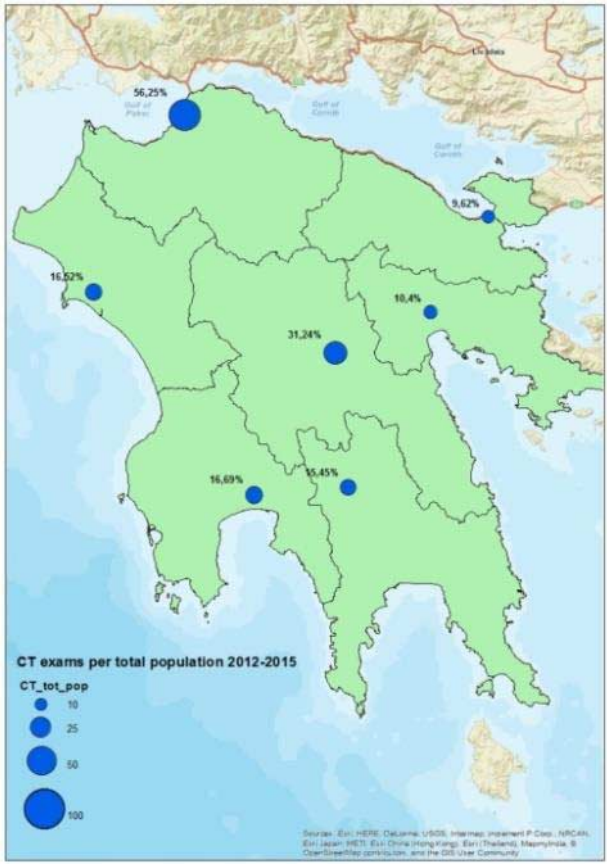

Figure 1. A GIS-based map is displayed containing the number of CT exams per population data

The high prevalence of CT exams in Greek hospitals is also confirmed by the Organization of Economic Cooperation and Development's (OECD). Most recent report on healthcare reveals that Greeks had 180.3 CT scans per 1000 people per year. The OECD average was 125.5, even though Greeks were less likely to go to a doctor [9]. According to EOPYY, the National Health Insurance Provider in Greece, between August 2013 and July 2014, Greeks had 1.01 million CT scans and more than 581000 MRI scans. This amounts to 4334 exams performed daily. The cost is estimated to more than 144 million euros. The numbers seem to be excessive but they are completely justified by the specific statistic data, related to the annual number of visits to the doctors per capita. In Greece there are just four visits to the doctor per capita per annum. In OECD countries the average number is 6.7 [10].

4. Discussion

GIS is a useful tool that enables both spatial and statistical analysis. The specific application is an effective method for the financial analysis of polices initiatives and health care system. It will form the basis of creating a control mechanism for limiting excessive diagnostic imaging examinations. Focusing on geographic areas, where the size of population is far smaller than the number of diagnostic imaging examinations, efficient decision making is supported. A digital file of big financial data [11] is also created for all hospital units by using this digital platform. The whole process will reduce costs and increase efficient funding for services and programmes worldwide.

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How Connected Insurance Is Reshaping the Health Insurance Industry

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Abstract. The role of today's insurer is changing towards a more preventive and digital or connected approach. In this context, connected health insurance has the potential to contribute towards the general wellbeing of the population. New technologies put to use by the insurance industry might even help deal with major issues related to the rising number of people globally, of chronic disease patients and that of elders while keeping them healthier and the same time protected by insurance.

Keywords. health insurance, connected insurance, health, wearables, iot.

1. Introduction

The current role of the insurer is extremely different according to country specific health & welfare policies. Nevertheless, health insurance could contribute to improve current conditions or even solve dilemmas such as how to cope with a rising number of people while keeping them in a good health state and at the same time protected. There are examples of insurers that have started to use the "Insurer as Partner" approach which implies an active role in prevention rather than reaction and claims payment. This new approach has been made possible by what we now call "connected insurance" which encompasses wearables and other devices. The re-shaping of the insurance industry has already begun, and it will continue based on new technologies at hand. The aim of this paper is to briefly illustrate the concept of "connected insurance" with specific focus on "connected health" and to present the Vitality case study in parallel with the model created by Matteo Carbone of "the five value creation levers", showing how there are benefits for all parties involved: insureds, insurers and the medical system.

2. Method

"Mobile is the future" said Eric Schmidt [1], CEO of Google in 2011. He is now Chairman of Alphabet and he understood there was no return from the smartphone "invasion". We all live surrounded by dozens of different devices, and the screen of the smartphone has become the main reference for all our activities.

Connected health insurance presents great potential for both insurer and insured. But let's define the term in a more accurate way. Connected health, as defined in a

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paper by Deloitte [2], is the convergence of health technology, digital media and mobile devices and has the aim of helping patients, care givers and healthcare professionals to access data in a swifter way while improving the outcomes of health and social care. Connected insurance on the other hand refers to an evolution of the Insurance business model based on the adoption of IoT technologies which allow the direct connection between all actors of the ecosystem: customers, Insurers and players from other industries [3]. Based on the above we can say that Connected health insurance is a mix of different types of technologies used in health insurance in order to collect data, determine patterns and create effective incentives and engagement programs aimed at reducing costs related to healthcare and at improving the quality of life of the insureds.

The question is how can innovation through connected health insurance transform the insurance company from a simple Payer to a proactive Player in the customer health journey? There are five main value creation levers to take into consideration according to the theory proposed by Carbone and explained in the book "All the insurance players will be insurtech" [4,5].

1) Risk selection: enhancing the underwriting phase with a temporary monitoring based on dedicated devices. As far as the risk selection layer is concerned, connected devices can be indirectly or directly used to select risks at an underwriting stage resulting in low risk customers acquisition and connected reduction in fraudulent intents.

2) Loyalty and behaviour modification programs lead the client toward risk free behaviour. Behavioral programs are basically approaches that exploit information gathered on behavior to direct clients towards less risky solutions.

3) Value added services: developing client tailored ancillary services that allow the Insurer to play the role of a medical concierge relying of course on primary care providers.

4) Loss control: developing a broad approach to mitigate claims. Connected insurance allows to use registered data in order to limit the portfolio loss ratio and it enables the development of claims management processes that permits the Insurance Company to act more proactively an efficiently.

5) Risk-based pricing: developing insurance policies with pricing linked to client behaviors.

3. Results

In order to better grasp the actual benefits for clients and not just for Insurers that adopt such an innovative approach, we should take a closer look at the South African insurance player Discovery that can be considered the benchmark when it comes to engaging and improving the life quality for members. Its Vitality program has managed to create a system that not only raises the loyalty of customers but improves their lifestyle and overall state from a health point of view. They apply the five value creation levers mentioned above in a way that brings concrete results for the company and for the insureds.

Loyalty and behaviour modification. In the case of Vitality it is applied as a reward system that stimulates safer client behavior through gamification to keep customers engaged. The gamification strategy which used by Vitality is run with the support of an extended network of partners and with the help of wearables and smart

objects alongside the well know smartphone. They create mini challenges related to shopping for food, physical and sporting activities, medical checkups and so on, that if accomplished are rewarded with cash-back, discounts or other types of incentives. As a consequence, the individuals end up having a more active life (Engaged Vitality members exercise 25% more than non-Vitality members) and according to a study released by Discovery [6] they live longer than non-Vitality members: to be more precise the average life expectance of an insured South African is 67 years while the average life expectancy of an insured Vitality member is 81 years. Customer loyalty is also intertwined, in Vitality, with **value added services.** Vitality offers extra services linked to the insurance cover, which have a double aim: on the one hand to guide clients towards desired behavior, on the other hand to offer perceived value through services to clients. Very often these services are provided by means of specialized partners.

Risk selection. Although it is easier to apply this lever to telematics-based auto insurance where monitoring objective data about driving style is relatively easy, the method can also be used when referring to health insurance. The use of connected devices gives the insurer (Discovery) precious data on people's lifestyle and health condition. This helps create a clearer segmentation and thus the ability to select risk in a more effective way. But maybe even more important, the Vitality program attracts younger and healthier people to start with, precisely because this category is proportionately more attracted by the technological, more digital towards insurance.

Risk-based pricing. Monitoring the "quantity" and "level" of risk exposure during the coverage period has now become possible. In this sense, the risk can be calculated on the basis of gathered information with a direct impact on pricing applied to the single customer. We do not have enough data to confirm that this is being applied through the Vitality program, but it is becoming a standard practice for telematics-based car insurance where the object of the insurance coverage is easier to evaluate than in the case of a living breathing person.

Loss control. By using connected devices with their customers, Discovery possesses an "early warning" mechanism that is capable of anticipating serious health problems and more expensive claims.

Another interesting claim coming from a recent presentation by Discovery Vitality at DIA Amsterdam 2018 deserves our attention. According to the results, there is 18% reduction of hospital and chronic claim costs for the batch of Vitality members that use the Active Rewards System alongside the Apple Watch, compared to the group of insured who do not use an Apple Watch. Although they specify that it is based on a cross-sectional view of the relative claims experience and it is premature to show the improvement over time given the lower frequency of health claim events. Nevertheless, it is a confirmation of the fact that certain wearables together with the right reward system may have significantly positive results but has yet to be observed over a longer period of time.

4. Discussion

The implications of the results obtained through the Vitality programme for the efficient encouragement of healthy lifestyles and wellbeing are significant. Their model should be further investigated in order to understand if and how it could work for the general population not only specific segments and to see to what degree innovation

driven by Insurers and technology companies can be used to benefit citizens in general. The transition to a "prevention-centered" approach is actually a pragmatic decision for insurers because in time, the portfolio tends to change its structure, passing from a majority of so called "sick" clients to a majority of relatively "in good health" clients [7,8].

5. Conclusion

The insurance industry is slowly passing from a one-size-fits-all approach towards a personalized approach that looks at individuals and their habits, needs and their environment. As the World Health Organization predicts a 13 million doctors deficit at worldwide level by 2035 [9], it's essential for connected health and connected health insurance to evolve in such a way that will allow primary healthcare providers to be much more versatile and flexible in reaching their patients. Clearly the new paradigm in connected insurance will face several challenges posed by rate of adoption, cost barriers, resistance to change, and privacy aspects, but nevertheless the potential benefits could be significant based on Discovery Vitality case study, for both insurance companies and customers alike. On the one hand insurance carriers could be able to reduce their costs and at the same time positively influence the health state of their customers. On the other hand, citizens will have improved access to better medical care and health advices at a convenient cost. Further research needs to be done: 1) of Discovery Vitality programs worldwide in order to understand how results vary over time and from country to country; 2) of similar connected insurance programs promoted by other insurance companies with the objective of understanding how changes in the rewards/engagement system reflect on the results.

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IT Infrastructure for Registries in Health Services Research: A Market Study in Germany

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Abstract. Registries are increasingly implemented to record the practice of health care. Within a national funding scheme for registries, an accompanying project was launched to support the design of the registries' IT infrastructure amongst other tasks for 16 projects. A challenge of data management systems was organized by the accompanying project in order to enable the projects to define realistic expectations towards IT support in their research protocols. Twelve vendors participated in the challenge. They presented their solutions for selected use cases. In advance, the projects considered a sufficient authorization concept and the possibility to export data to be of highest importance. However, the systems covered mainly core processes of electronic data capture. The accompanying project will continue its support for the next stage of the funding scheme, which will be the implementation of the registries that win a competitive review of their research protocols prepared in the concept development stage.

Keywords. Data management, electronic data capture, infrastructure, registry

1. Introduction

Registries play an important role in health service research [1]. They offer insights into the practice of health care enabling the evaluation of interventions' efficiencies as well as quality research. A registry could be defined as a medical documentation used for the assessment of research questions related to groups of patients. Registries are projects or institutions with an organizational structure, rooms, and staff. Consequently, registries as organized systems should be clearly distinguished from the registry database and from the IT equipment as part of the registries' infrastructure [2]. Core processes of registries are data management from data recording to data monitoring, data analysis responsible for statistics, management of subjects including consent administration, and study site administration. The core processes are supported by assistant processes like management of IT services, book keeping, and others [3].

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In 2017, the German Ministry of Education and Research launched a funding scheme for registries in health services research. The set-up of exemplary projects should foster the quality of registry research in Germany. Sixteen projects received a funding for concept development until the end of May 2018 supported by an accompanying project (REGISVF-AP). REGISVF-AP was carried out in cooperation between the TMF – Technology, Methods, and Infrastructure for Networked Medical Research and the German Network Health Services Research (DNVF). Four main topics had been identified for REGISVF-AP, implementation counseling, quality management, IT requirements, and metadata catalogue. In the following, the support of the 16 projects in concept development with regard to IT requirements will be introduced. A list of the projects is available at https://www.gesundheitsforschung-bmbf.de/de/modellhafte-register-konzeptentwicklungsphase-7167.php.

2. Methods

The support in concept development with regard to IT requirements focused on two aims. Firstly, the projects should be enabled to define realistic expectations concerning the performance of data management software. This software is usually denoted as electronic data capture software. Realistic expectations would influence the registry design described in the research protocol, for example concerning interfaces to hospital information system, integration of health apps or online reporting functions. Secondly, the projects should obtain an impression about the strengths and weaknesses of products available on the market in order to systemize their upcoming communication with vendors or suppliers. Some of the projects had already been in contact with commercial companies, others not. A few projects intended an in-house development.

REGISVF-AP decided to organize a challenge inviting commercial and non-commercial vendors and suppliers to present their solutions along a predefined schedule. Additionally, the conclusions should be underpinned by a systematic assessment of needs and functionalities. The organizers adapted two former approaches. A group within the German Association of Medical Informatics, Biometry and Epidemiology organized open clinical documentation challenges for years. Although the results were not published, respective documents were available due to a participation of one of the authors. The same author organized challenges in a selection process for clinical applications in a university clinic two decades ago [4]. From the latter, experiences in a systematic assessment of needs and functionalities were available.

A pathway was defined for each presentation: 5 minutes introduction, followed during 30 minutes by a sequence of predefined use cases, and 10 minutes discussion. The use cases were selected from a comprehensive catalogue of requirements and tasks of cohorts and registers [5]. Selected use cases were form design, definition of authorization concept, and user management from the development phase of a registry, furthermore patient registration, editing, visit presentation, visit creation, patient data deactivation, reporting, central monitoring, and data export from the operational phase of a registry. About 30 vendors were invited to join the challenge with their data management software along with an open call for participation on the project's website. There was neither an attendance fee nor any cost compensation for participation.

Forms for the assessment of use case importance, for the verification of use case coverage, and for a subjective evaluation of usability were developed by REGISVF-AP

and consented with the 16 projects. Twelve (12) out of the 16 projects attended the challenge at least one day. After the first two presentations, the projects decided to skip the subjective valuation of usability. The forms were filled in on paper.

3. Results

3.1. Use case importance

Twelve projects attending the challenge weighted the use cases importance in advance. Table 1 shows the results for the top level. For some use cases, detailed process steps were assessed additionally. The definition of an authorization concept and data export were ranked highest with a mean of 3.0. Reporting received the lowest rank with a mean of 1.9.

Table 1. Assessment of use case importance. The number of projects with the respective weight is shown.

Use Case	Very important (3)	Important (2)	Less important (1)	Not important (0)	Mean
Form design	8	1	2	0	2.5
Definition of an authorization concept	12	0	0	0	3.0
User management	8	3	1	0	2.6
Patient registration	11	0	1	0	2.8
Editing	11	1	0	0	2.9
Visit presentation	8	2	0	2	2.3
Visit creation	9	1	1	1	2.5
Data deactivation	8	3	0	1	2.5
Reporting	2	6	3	0	1.9
Central monitoring	10	2	0	0	2.8
Data export	12	0	0	0	3.0

3.2. Use cases coverage

Fourteen vendors applied for participation. Two systems were represented twice. Therefore, twelve systems remained for presentation. The challenge took place during 1.5 days in March 2018. The use cases coverage was logged by one member of the project team (cf. table 2). Electronic data capture functionalities were supported by all projects. Five and two systems did not support the use cases reporting and data export respectively

Table 2. Logging of use case coverage. The number of systems offering the respective functionality is shown.

Use Case	Fully available	Partially available	Unclear	Not available
Form design	12	0	0	0
Definition of an authorization concept	12	0	0	0
User management	9	1	2	0
Patient registration	12	0	0	0
Editing	12	0	0	0
Visit presentation	12	0	0	0
Visit creation	12	0	0	0
Data deactivation	9	0	3	0
Reporting	5	1	1	5
Central monitoring	9	3	0	0
Data export	9	0	1	2

4. Discussion and Conclusions

Within the support for 16 projects in defining registry concepts a challenge regarding data management systems was organized. Twelve systems presented their solutions for the selected use cases. Whereas all systems offered support for electronic data capture, supplementary use cases such as reporting were only partially covered. Unfortunately, most projects felt not prepared for a usability assessment based on the presentations alone. Therefore, the planned analysis could not be undertaken.

Within the funding scheme, the German Ministry of Education and Research conducts a competition regarding an ongoing funding for the implementation of the registers based on the results achieved in the concept development stage. REGISVF-AP will continue to support the remaining projects in the setup of their IT infrastructure. This will include templates for tender documents, the supervision of the selection procedures, and the establishment of collaboration structures between the projects [6]. Usability issues will be considered as well [7].

Vendors and suppliers of registry software are listed and described in the Toolpool Medical Research maintained by the TMF at https://www.toolpool-gesundheitsforschung.de/.

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Facilitators and Barriers of Electronic Medical Records Systems Implementation in Low Resource Settings: A Holistic View

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Abstract. Electronic Medical Records (EMR) systems show promise for facilitating health care improvement in quality patient care, patient safety and cost reduction. Nevertheless, their adoption requires careful planning and execution for successful implementation and optimal benefits. The main objective of this review was to identify, analyse and categorize facilitators and barriers to the implementation of EMRs in resource constrained settings in order to gain insight for successful EMR implementation. A literature review on papers from 2007 to 2017 concerning facilitators and barriers to EMRs implementation was conducted. The study included 18 articles that met selection criteria. Four categories of facilitators and barriers including a total of 28 sub-categories were identified from content analysis. These are *technical, human, processes and organizational*. EMR implementers should pay attention to these issues and adopt a change management strategy for sustainable EMR use in resource-constrained settings.

Keywords. Electronic medical recordsimplementation, facilitators, barriers, low resource settings.

1. Introduction

The adoption of Electronic Medical Records (EMR) systems in the healthcare industry has been on the rise in recent years, resulting in digitization of patient records and hence making patient data readily available for treatment, care and analysis [1,2]. These implementations have been escalated by the promises of improved quality patient care, patient safety and cost reduction [3,4]. In the US, the adoption was driven by a presidential executive order 'Electronic Health Records for All Americans' in 2004 [5]. In developing countries, adoption of these systems has largely been driven by the need for better data management systems to support care and reporting for patients with *Human Immunodeficiency Virus*(*HIV*) *and Tuberculosis* (*TB*) [6]. Despite the benefits of EMR systems use in health care practices, the adoption rate remains low in developing countries [7].

Implementation of EMR systems is complex, costly and can be highly disruptive to conventional workflow [8]. Successful EMR implementation requires careful planning

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and balancing of service delivery needs in order to optimize the anticipated benefits. Several publications highlight the various strategies undertaken at diverse levels and settings to ensure successful implementations[9]. While these factors could be generalized regardless of the settings, organizational and user needs can be different due to cultural factors and issues like lack of computer skills.

This paper provides an overall impression on current determinants of EMR system implementation success in resource constrained settings with a view to advance successful implementations and scale-up sustainable initiatives.

2. Methods

Literature searches were performed in several databases, including PubMed, HINARI, SCOPUS, AJOL and Google Scholar for papers referencing digital health records systems, barriers and facilitators of EMR implementation and other studies related to eHealth and EMR implementations in low resource settings. Terms for digital health records systems used included: electronic health record, electronic patient record, electronic medical record and patient health record. Databases were systematically searched for papers in English between January 2007 and December 2017.

Our search yielded 140 eligible studies, which were appraised using PRISMA guideline. 25 duplicates were removed while the remaining 115 were further assessed in relevance to the study. 18articles remained for content analysis. Papers on mHealth systems used for data capture were excluded.

3. Results

18studies met the inclusion criteria. The observed facilitators and barriers from the relevance-filtered publications were reported either as original observations or from systematic reviews. Thematic analysis coding identified four categories of critical factors pertaining EMR implementations in low resource settings: *technical, human, processes and organizational.* These categories are represented in the developed conceptual framework in Table 1, with elements within these categories identified as being important for EMR implementation in low resource settings based on the review. The frequency with which these elements appear in the literature is included next to each element listed in Table 1.

From the literature, a majority of the critical factors in EMR were observed to be technically related. Despite the drop in costs of computers and internet, the prices still account for a significant barrier in resource-constrained settings [10]. A number of authors pointed the importance of systems interoperability to facilitate seamless data sharing even within departments in a facility [1,7].

While most studies underscored the importance of training as a major EMR implementation factor, subsequent technical support and computer skills are as important. Pole, in the EMR implementation in Sri Lanka states that '*the main secret of success was continuous training of hospital staff over a 2 to 3 year period*' [11]. Holden on other hand emphasized the importance of social environment where colleague support is present [12]. Most studies stressed training should involve all the actors in the health care systems; users, management and technical support team.

Table 1. Categorization of EMR implementation critical factors with frequency of citations.

Technical	Human
- Internet/Interoperability (7) - Stable electricity (8) - System customization/open source (5) - Availability of standards (4) - System usability/learn/use (5) - Infrastructure/hardware (3) - Data storage backup (3) - System security (physical/logical)(2) - Software upgrades (1) - System complexity (1)	- Computer skills (9) - User acceptance (3) - High expectations (3) - Experience (1) - Staff turnover (1) - Workload (2) - Patient-provider relationship (1)
Processes	**Organizational**
- Training (12) - Technical support (8) - User involvement (5) - System champions (2) - Incentives/motivation (3)	- Funding (7) - Project leadership (5) - Procurement issues (1) - Selection of the system (1) - EMR adoption plan (2)

The most commonly emphasized issues under organizational category relate to funding and leadership. Most of the implemented EMR systems in sub-Saharan Africa are a result of donor-funded projects with unclear sustainability plans [6]. One study in Kenya shares strategies it deployed to assure meaningful and sustainable EMR implementation [13]. This includes good will from the government, sensitization of leadership, user training, and formation of health facility-level multi-disciplinary teams, stable electricity provision and leadership from the county management. Evidently, this strategy cuts across all the implementation issues emphasized by most authors. Three studies suggested the need for incentives to keep the users of the system motivated, which should not necessarily be monetary.

4. Discussion and Conclusion

Healthcare organizations are complex and hence introduction of EMR system can bring further complications especially to the workflow, which can lead to rejection of the system regardless of the setting. Users are likely to embrace systems that do not interfere with their workflow [11]. Thus, EMR systems designed or customized to fit the intended environment is important. In addition, simplicity/usability of a system act as a great support to sceptical users and those lacking IT skills. How the organization manages change is a panacea to system acceptance. It was shown that individuals' attitudinal-behavioural limitations or resistance to change plays a greater role than other limitations [14].

Shortage of qualified human resource challenge demands for staff training as well as employment of skilled staff. However, Were *et al* [15] argue that an EMR implementation model that relies on employing highly trained full-time IT staff or dependence on foreign experts is not scalable due to the associated costs and limited available skilled personnel. Instead, they proposed a model that uses a national Technical Expertise Center (TEC), a global developer, and implementer networks to support multiple local implementations.

Availability of free open source systems such as OpenMRS, Bahmni, FreeMED, GNUHealth and OpenEMR overcomes the upfront system acquisition barrier with only

feature customization and local adaptation to consider[16,17]. It is important to note that sufficient funds are paramount not just for implementation phase but also for subsequent maintenance in terms of supervision and continuous training.

Despite the differing EMR capabilities/versions from country to country, major critical factors of EMR implementation for low resource settings were identified. Successful implementation of EMRs in the complex healthcare organization requires social-technical approach and system design adapted specifically to the organization. This sets the stage for more comprehensive evaluation of how these critical factors apply within specific country settings.

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Adoption of ICT by Elderly with Hip Fracture After a Fall

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Abstract. The purpose of this study is to investigate the adoption of Information and Communication Technologies (ICTs) of elderly with hip fracture after a fall. Demographic and clinical data using a general questionnaire were obtained from 67 elderly patients with a hip fracture after fall and compared with 67 gender-age matched elderly healthy controls regarding their knowledge and use of ICT-based devices. Univariate and multivariate analyses were conducted at p=0.05. 25.4% of the patients vs 10.5% of the controls uses ICT-based devices (p=0.024). Among patients, the demographic factors significantly associated with the use of ICT-based devices included area of residence, educational level and financial status (p<0.001 to p=0.045). In conclusion, based on a small sample, it seems that the adoption of ICT by the elderly vulnerable populations is limited.

Keywords. Elderly, Injurious Falls, Hip Fractures, Information and Communications Technology.

1. Introduction

Falls occur in about 30% of the elderly at least once a year, with 1/3 of them leading to injuries and fractures (requiring hospitalization) and disability [1]. The most common cause of hospitalization is hip fracture [2]. The economic and social burden resulting from these injuries is high, making it a challenge for health care systems [3]. In addition, patients who have suffered a fall and fracture are vulnerable to recurrent fall and injury [2]. Research has shown that these injuries can be prevented primarily by identifying people at risk and secondary by reducing the consequences of an existing fall, with the use of ICT. More specifically, new technology, such as inertial sensors, smartphone, low cost video/depth camera, pressure sensors and motion ambient sensor, offer an alternative approach that can efficiently record and analyze motion data such as balance and mobility and can provide an easy-to-implement objective fall risk assessment [4]. Furthermore, early detection of a fall and ensure immediate relief, is vital for the elderly, because the time spent is a determining factor affecting the severity of the consequences such as hypothermia, dehydration and bronchopneumonia

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[5,6]. Despite the recognized and significant public health burden of injurious falls, the use of ICT for prevention and safety in the elderly daily living is limited not only in this field [7] but also in other chronic conditions [8]. The purpose of this study was to investigate the knowledge about the ICTs available for falls and their adoption by seniors who have already suffered a hip fracture, but also their correlation with demographic characteristics.

2. Methods

This research is part of a case-control study of public hospitals in the 6th Health District. The data were obtained for the year 2016 from the electronic records of a regional "medium" hospital. The patients selected were over 65 years of age who were hospitalized with hip fracture (S72.1/diagnostic code) after fall, into the orthopedic clinic. As controls, seniors who visited primary health care structures without a fracture history were selected. A general questionnaire was used which included demographic, clinical, financial data, history of fracture and data relating to ICTs for falls. Continuous variables are presented as mean ± SD or median and quartiles. Categorical variables are presented as absolute (N) and relative frequencies (%). Chi square test (X^2), Fisher's exact test and t-test for independent samples were used to evaluate the association of history of falling between cases and controls. Moreover, the same statistical tests were used to investigate whether the use of ICT-based devices varied according to the patient's demographic, social and economic characteristics. The Tinetti Performance Oriented Mobility Assessment (POMA) was calculated for both cases and controls. Cronbach's alpha was used to assess the internal consistency of the participants' answers. Also, t-test for independent samples was used to assess the mean difference in the Tinetti assessment tool (Balance, Gait & Total score). All reported P-values are based on two-sided hypotheses and P-values less than 0.05 are considered as statistically significant. All statistical analysis was performed using IBM SPSS v.23 statistical software (Statistical Package for Social Sciences Inc., 2003, Chicago, USA).

3. Results

The study included 67 patients with a mean age of 79 years and 67 controls with a mean age of 76 years. As regards the area of residence, 52.2% of the patients and 50.7% of the controls live in urban areas, while in rural areas 40.3% of the patients and 40.3% of the controls respectively. 25.4% of the patients vs 10.5% of the controls uses ICT-based devices (p=0.024). Among patients, the demographic factors significantly associated with the use of ICT-based devices included family status, area of residence, educational level and financial status ($p<0.001$ to $p=0.045$) (Table 1). The same variables, were found to be significant predictors when using a multivariate model. The devices used were wearable sensors with the form of a pendant, or watch. Regarding the Tinetti score (balance, gait & total score) displayed good internal consistency ($a>0.80$). Moreover, a statistical significant difference is found when comparing the mean value of the Tinetti scores between cases and controls (p-value<0.001). Specifically, the balance, gait and total scores are on the average lower for cases

compared to controls. Regarding the total score the cases have a high falling risk, while the controls a medium falling risk and the difference is significant.

Table 1. Univariate analysis of differences in demographic, social and economic characteristics and the use of ICTs, within patients.

Demographic, social and economic characteristics	Use of ICTs		Total	p-value
	Yes (n=17)	No (n=50)		
Gender (n, %)				
Female	9 (52.9)	33 (66.0)	42 (62.7)	0.3361
Age (mean, SD; years)	79.9 (5.3)	79.2 (6.1)	79.4 (5.9)	0.7012
Living conditions (before falling) (n, %)				
Alone	0 (0)	1 (2.0)	1 (1.5)	
Spouse/Companion	5 (29.4)	19 (38.0)	24 (35.8)	
Children	1 (5.9)	13 (26.0)	14 (20.9)	0.045*3
Other relatives	0 (0)	4 (8.0)	4 (6.0)	
Carer / House keeper	11 (64.7)	13 (26.0)	24 (35.8)	
Owner of residence (n, %)				
Own house	16 (94.1)	47 (94.0)	63 (94.0)	0.9861
Guest	1 (5.9)	3 (6.0)	4 (6.0)	
Residence area (n, %)				
Urban > 10,000 inhabitants	17 (100.0)	19 (38.0)	36 (53.7)	
Suburban 2,000 – 10,000 inhabitants	0 (0)	7 (14.0)	7 (10.5)	
Rural < 2,000 inhabitants	0 (0)	24 (48.0)	24 (35.8)	<0.001*3
Education (n, %)				
None	4 (23.5)	29 (58.0)	33 (49.3)	
Elementary	7 (41.2)	17 (34.0)	24 (35.8)	
Secondary	4 (23.5)	4 (8.0)	8 (11.9)	0.008*3
Tertiary	2 (11.8)	0 (0)	2 (3.0)	
Economic level (personal annual income; euros) (n, %)				
0 – 6,000	0 (0)	9 (18.0)	9 (13.4)	
6,001 – 12,000	6 (35.3)	31 (62.0)	37 (55.2)	
12,001 – 24,000	7 (41.2)	9 (18.0)	16 (23.9)	0.002*3
24,001 – 40,000	4 (23.5)	1 (2.0)	5 (7.5)	

1X2 test
2t-test for independent samples
3Fisher's exact test
*statistically significant result at statistical significance level of a=5%

4. Discussion

According to the results of our study, despite the high risk of recurrent fall, the adoption of ICTs by the elderly is relatively low and is limited to the use of fall detection devices. Study reports that elderly people living in the community claimed that they feel more confident and independent using such devices, and that the "detector" improved their safety [6]. Patients with higher education and better financial status, as well as those living in urban areas, are mainly users. Previous studies have linked urban residence and high economic status with the adoption and use of technology by elderly living in the community [8,9]. The limited adoption and use of these technologies by the elderly includes factors such as familiarity with technology, usability (user friendliness), cost, privacy, lack of information [10,11]. Another important factor is the functional and cognitive status of the elderly (aging is linked to a change of cognitive and functional abilities) that might affect their handling of the technology [12]. It has also been noted that the minimal and faulty use of fall detection

systems in community-dwelling older people is due to their non-participation in the development of such systems. Minimal attention is given to the specific needs of the elderly views and expectations, and their involvement in the various stages of system development is proposed [5]. According to Ward et al. (2012), the use of ICT, which is also available through health and social services, is limited, with health professionals not convinced of their benefits [7]. Limitation of our study is the small size of the sample, which does not allow generalization of results.

5. Conclusions

Independent and safe living of the elderly in the community, which could be ensured through the widespread use of ICTs, is a challenge for healthcare systems, which should provide adequate support for healthy aging populations. Informing the population, especially those at a low socio-economic level and in remote areas and facilitating their access to ICT is vital.

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Smart Oncology Care Networks: An Approach in Information Systems to Support Brazilian National Cancer Institute

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Abstract. In last decades Information Technology (IT) has been established as the main tool to support processes. Medical area has noticed the opportunity for improvement and interacting with IT has enabled solid interdisciplinary instruments for improvement. The aim in this project is composed by an analysis of the relationship between the application of information technologies, oncological assistance and innovation. Next, the project will focus to present the case of a proposal to reformulate the national cancer care system, with IT and Innovation being the base instrument for this process.

Keywords. Information Systems, Oncology Care Networks.

1. Introduction

In last decades Information Technology (IT) has been established as the main tool to support processes, regardless of the nature of activity. Medical area perceived an opportunity for improvement and interacting with IT enabled solid interdisciplinary instruments for improvements, such as electronic medical record systems, tele radiology, medical knowledge portals and others. These evolutions, which in most cases, still have high costs, have brought positive impacts to the clinical hospital reality, but it is necessary to go further. In the study field of oncology still needing innovative products, mainly in the underdeveloped countries, responsible for 70% of the deaths caused by the disease [1].

More and more, it is necessary the detachment by outdated methods and incorporation of new technologies to the hospital reality, and the integration between several areas as an indispensable to create a high-performance environment. For this interdisciplinary relationship occur in a harmonious way, the concept of traditional hospital need to be rethought and as involving parts, consider the need for smarter

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hospitals that work better, with insight to the level of needs of doctors and patients, the field of care.

In the field of cancer, the perspectives could be used as the basis for the development of treatment methods and standards throughout the world. Cancer impact and related costs have been highlighted by health systems, especially those with universal access. When dealing with the Brazilian reality, the knowledge and publicity in the distribution of costs is a challenge, since the units of the public network do not have integrated systems, which makes it difficult to trace patient profiles making it difficult to formulate targeted policies [2].

The results are known as health units of the country, highlighting a drop in the quality of services and the exhaustion of the fragmented vision of health systems, without a more comprehensive and integrated evaluation of the results of public and private organizations that make up the system [3].

On the other hand, the range of technological solutions specifically linked to the field of health, especially in systems, has been growing too much, emerging of new machines and equipment for diagnosis and intervention, surgical robots, information and instantaneous communication are examples of fields of investment and work of thousands of technicians and scientists [4].

Given the great offer of new technologies, it is vital to question the development of this research proposal: Why is there no incorporation in the short, medium or long term of technological innovations, especially systems, to meet the demands of society?

For service managers, the development in Science and Technology, and the incorporation of strategic innovations, are increasingly becoming a concern. Although in an incipient and marginal way to the decision-making process, the demand for transparent and secure policies of incorporation, management and technology transfer and knowledge grows [5]. The smart oncologic care network concept, therefore, intends to elaborate the proposal based on bibliographical concepts of quality [6].

Therefore, the aim in this project is composed by an analysis of the relationship between the application of information technologies, oncological assistance and innovation.

2. Method

The work was divided into 3 stages: Scenario Survey, Technological Prospecting and Concept Development. Figure 1 shows the proposed workflow:

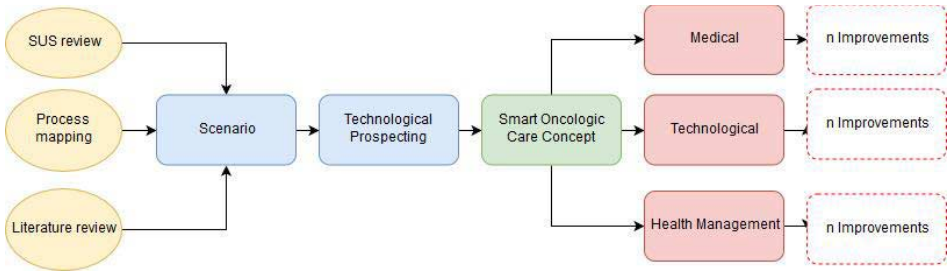

Figure 1. Method Workflow

3. INCA's Case and Results

The National Cancer Institute (INCA) plays a multiple role in all areas of cancer prevention and control in Brazil – prevention, epidemiological surveillance, treatment, information, education and research. As a technical division of the Federal Government, under the direct administration of the Ministry of Health, the Institute provides cancer care within the Integrated Public Health System (SUS) [7].

Moreover, INCA formulates and coordinates public policies, develops research activities and disseminates practices and knowledge on medical oncology. Every day, new demands has been present in volume and complexity resulting from more specific technological solutions of the hospital area which being installed in INCA units; growth INCA workforce with new members and employees and automation of hospital procedures. In this paper, was chase two examples and they will be presented with alternatives implanted based on smart oncology care networks model: Telemedicine and Palliative Care Cancer Information System.

Telemedicine is already a reality on health care, but a different perspective at cancer studies is necessary. That technology continually decreases the number of admissions and medical appointments, while the costs of this innovation adoption can be covered by savings generated from reductions in unnecessary hospital visits. Telemedicine, additionally, improves communication between remote healthcare professionals and specialists. These are advantages that impact not only on the patient and caregivers but affect all the stakeholders.

Telemedicine has been supporting the Oncologic Attention Network which is the strategic vehicle through which the INCA bases its national integration plan on. Its purpose is to create a partnership between organizations in charge for research and services in the cancer area. This network leads into a cooperation environment which makes possible to congregate doctors, administrators and society segments that represent patients. Its goals are the following: i) to make the access to information and knowledge easy on all spheres – doctors, hospital administrators and patients; ii) to establish a community for the practice of research and treatment; iii) to deploy an integrated *collaboration environment* with easy access to useful information to support clinical and executive decision-making processes.

In this context, collaboration is very important between physicians and other healthcare specialists. There are also new research challenges and opportunities in the development of collaborative knowledge modeling using telemedicine services.

Despite the great number of studies about the use of the new ICT tools in healthcare services, few researchers analyze the potential of these innovative technologies in the palliative care units. The implementation of these new applications can bridge the gap between palliative care services and the other clinical specialties.

The case study confirmed the importance of accessible care for a group of clinically vulnerable, dying cancer patients and their family caregivers. When interviewed, patients and family caregivers attest the difficulty in obtaining care via traditional treatments protocols. One of the greatest advantages of telehealth is the quick access to the palliative care team that patients can experience via mobile devices.

The system deployed at INCA can be considered a disruptive innovation in the Brazilian public health system, considering the radical improvement of palliative cancer care processes, through features like the pain management module and the

patients monitoring. These kinds of ICT tools are emerging as enablers for a ubiquitous and pervasive healthcare.

More research is essential to investigate the strategies of development and deployment of palliative care information systems and to study the ICT tools impact on patient clinical outcomes. With the support of mobile technologies, terminal cancer patients will be able to provide current information to their physicians and caregivers and collect data more accurately to support their needs and wellness.

4. Discussion

This research pretends to be a basic instrument for the management of the environment, to allow the management of sustainable hospital processes, contemplating the optimal use of resources and meeting the social demands of aiding cancer cases in Brazil, continues and seeks to compile these concepts and cases, to contribute to the creation of a great model that can be used in other hospital realities. As a secondary intention, it is intended to carry out a deep reflection on the mechanisms of cancer care provided in the country. In addition, the project intends to produce small modules of improvements, from the medical, technological or process fields, that allow the isolated implantation in existing structures.

The Smart Oncology Care Concept is an indispensable approach especially in developing countries such as Brazil. In countries with great territorial extension alternatives for cost reduction with medical treatments may be the main mechanism to access this service.

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Decision Support Systems in Cancer Treatment: A Case Study at Brazilian National Cancer Institute

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Abstract. Nowadays Brazil has a complex cancer care scenario. There are nearly 600.000 new cancer cases each year in Brazil, and the huge majority of patients have some contact with hospital services. However, long waiting queues for diagnostics and treatments have become common. One of the critical success factors in a cancer treatment is early diagnosis. The reduction of waiting time to start therapeutic procedures is one of the main issues for improvement of patient's quality of life and possibilities of cure. The objective of this work is to describe the development of a decision support system that improves the identification of access alternatives, appointment scheduling and employment of available resources. The Theory of Constraints was used to identify bottlenecks in patient treatment flow and a Discrete Events Simulation model was used to reduce patients' waiting time to start cancer treatment.

Keywords. Decision Support System, Theory of Constraints, Discrete Event Simulation.

1. Introduction

Brazil presents a complex scenario in cancer treatment. The occurrences and rates of death have been increasing, around 600.000 cases every year: they are mainly increasing when it comes to prostate cancer in men and breast cancer in women. Research has found that waiting lines for treatment and diagnosis have turn into routine in many regions of the country, resulting in patients being diagnosed at advanced stages of the disease [1]. Cancer-related research and treatment is a long, complex and high-risk process and involves a myriad of activities. Brazilian cancer patients have experienced long waiting times for many years [2]. Lengthy waiting times for treatment may have a negative clinical impact. Delayed treatment may increase the risk of local recurrence and poor survival.

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Despite huge technological advances in treatments, over the recent years, cancer is still responsible for over 130.000 deaths per year in Brazil. Advances in life quality increased citizens life expectations. However, because of limited resources, cancer in Brazil still be considered a severe public health problem. The management of cancer treatment is a long and complex process. The reduction of the patient's waiting time to start cancer treatment plays an increasingly important role in the treatment of this chronic illness [1,2].

Healthcare simulation models generally requires the implementation of systems with complex activities, involving stakeholders with diversity of views and intentions [3]. It is thought that the active involvement of stakeholders throughout the study can decrease these problems, creating solid ownership of the model formulation and acceptance of charge for actions to be taken [4].

Organizations rely on data analytics to strategic decisions making. Descriptive analytics is commonly used to provide insight into past behavior. However, greater value can be achieved by predicting future behavior through predictive analytics. Simulation plays a vital role in facilitating predictive-prescriptive analytics [5].

The objective of this article is to describe the development of a decision support system for cancer treatment management that contributes to the identification of access alternatives, appointment scheduling and the use of available human and material resources. The adopted methodology is focused on the patient treatment flow and on the early start of cancer treatment. The Theory of Constraints is used to identify bottlenecks in patient treatment flows and a Discrete Event Simulation model is used to allow short-term booking.

2. Methods

Over the last few years, the Brazilian National Cancer Institute (INCA) has been investing significantly in the implementation of an IT architecture that integrates the organization´s main processes and provides Decision Support Systems which contains the following components:

2.1. Clinical Information System

INCA has five specific hospital units with different stakeholders, but which share the same processes and technologies based on a common patient database and standardized information systems. To support the physicians' activities, several tools, such as tracking mechanisms for keeping the longitudinal patient history, on-line tools for gathering clinical information and the traditional medical record, are used. Most of these are patient-centric and make the hospital environment amenable to the kind of knowledge management system framework, such as presented in Figure 1.

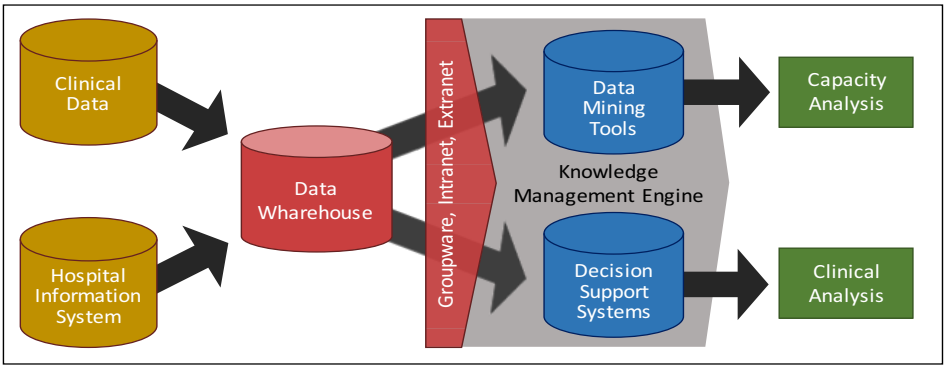

Figure 1. The INCA Information Architecture

The system was developed using INCA's intranet network that provides a safe access to applications developed to improve healthcare. This solution includes a collaboration environment between physicians and managers, simplifying the physician work, and empowering managers involved in the decision-making processes. The legacy systems feed the clinical data repository, which is the basis to build the decision support system.

2.2. Electronic Treatment Flow

The electronic flow component is a new interesting feature. It offers the possibility to electronically create the patient's treatment flow from the clinical data repository. Therefore, the users are able to examine, in a visual fashion, the evolution of the treatment. This component is a very useful tool to support decision-making with regards to the care provided. The doctors can blend, in one screen, the past, the present and the future events of the patient treatment history.

This component increases the traceability and is totally patient-oriented. It is possible to see, in an animated fashion, the details of the flow of a particular patient over the treatment process. Understanding the flow of the treatment, evaluating the constraints and managing the bottlenecks can be a possible way to improve quality.

2.3. Simulation Model

A simulation model was developed at the image examination sector of one of the hospitals of the INCA. The objective of the model was to contribute to the reduction of the patient's waiting time to start the treatment. The patient's flow was analyzed, and the access alternatives focused.

In this way, the simulation model was used to examine alternative scenarios. The objective was the reduction of the waiting time between the image exam schedule, its execution and the dimensioning of the human and material resources. The target was to increase the capacity to complete image exams. Simulation was used to investigate several "what- if" scenarios. The experiment showed that to reduce overall exam execution time was necessary to remove the phase of film production. The recommendation was to implement a Picture Archiving and Communication system (PACS).

3. Results

The use of simulation model recommendations has made a significant impact in terms of reduction of the waiting time to obtain image diagnosis at the Hospital of Cancer. A comparative study has evaluated this indicator before and after the implementation of the Picture Archiving and Communication system (PACS). Figure 2 shows that the interval was reduced from 30 to 22 days with a reduction of 25% of the waiting time, proving the effectiveness of the process.

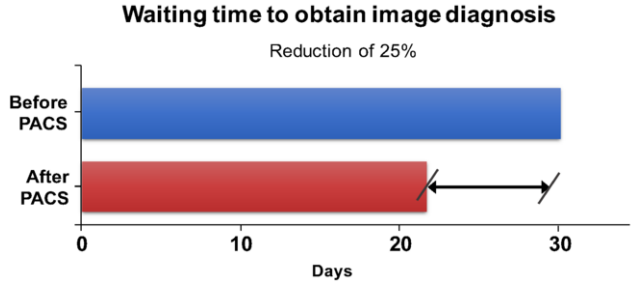

Figure 2. Patients' average waiting time to obtain image diagnosis.

4. Discussion

This paper shows how decision making in a cancer treatment center can be improved using an Integrated Information Support System. The use of this environment provides the necessary analytic support and insight into such operational decisions. The central feature is a suite of programs which selects information about clinical history of patients, identifies process bottlenecks and uses discrete simulation technique to investigate alternative scenarios to support the schedule of CT's exams. The alternative which is provided by PACS implementation has reduced patients' waiting time for cancer treatment. Its implementation shows, therefore, that good clinical information system can effect positive change. This research demonstrates the potential of combining theory of constraints with discrete event simulation (DES) to develop a decision support system to overcome the challenge of the reduction of patient´s waiting time to start cancer treatment. Further research can be concentrate in applying these concepts in other types of diseases.

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A Hospital Information System Application May Facilitate Staff Compliance with Quality Protocols in a Medical Unit: A Case Study

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Abstract. Quality standards have been widely adopted in healthcare, while the Hospital Information Systems (HIS) support quality management in modern hospitals. However, staff compliance lags behind. In this study, we investigated the effect of a novel application, implemented in the HIS, on staff compliance in the Intensive Care Unit of a tertiary teaching hospital. This application integrates quality protocols to the HIS, which is routinely used by the nursing staff. Demographic data and self-reported compliance were recorded before and after the intervention. We found that the compliance rate was significantly increased and the application was well accepted by the majority of the staff. We also showed that previous ICU working experience is independently and positively associated with compliance (p=0.02, OR=2.86; 95% CI: 1.16 – 7.06), after adjustment for age and total nursing experience In conclusion, we developed an effective application for quality improvement aiming at facilitating educational processes and enhancing staff compliance.

Keywords. Quality protocol, Compliance, Hospital Information System, Intensive Care Unit

1. Introduction

Improving quality in healthcare is a fundamental contributor to healthcare performance. As contemporary healthcare organizations aim at effectiveness and efficiency, substantial efforts are made to achieve high quality [1]. However, meaningful and sustainable quality improvement remains challenging [2,3]. Multiple approaches have been adopted in this effort and quality improvement initiatives usually focus on

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collaboration, education and culture change, while outcomes very much depend upon staff efforts and availability of resources [1,4]. The Hospital Information Systems (HIS), designed to manage all aspects of a hospital's operation, support quality management as well [5].

Quality standards (QS) protocols have been implemented in the multivalent Intensive Care Unit (ICU) of the Attikon University Hospital, a tertiary teaching hospital in Athens. Despite the initial zeal, implementation waned over time and staff compliance diminished substantially. Aiming to enhance ICU staff compliance to QS protocols, we implemented a HIS application and we conducted a longitudinal pre-post survey to investigate the effect of this intervention on staff compliance.

2. Methods

The HIS that is currently running in our hospital integrates all standardized administrative procedures. ICU nursing staff is authorized to access the patient electronic record for routine administration and services. According to previous research, employment of specific tools may increase conformance quality in patient care [6]. In order to facilitate educational processes and enhance staff compliance, we developed an add-on application, integrating the ICU QS nursing protocols to the HIS, which has been presented in detail in our previous report [7]. We also incorporated a checklist for the staff to fill-in, after implementing a protocol, for filing purposes.

The target population of this pilot study was the ICU nursing staff of the Attikon University Hospital. The survey was conducted in 2 stages: before (April 2017) and after the intervention (April 2018). We developed a semi-structured questionnaire consisting of 3 four-point Likert scale and 1 open-ended question to explore the staff's knowledge and opinion about QS, the self-reported compliance to the protocols and the reasons for not complying. We also recorded demographic data (age, gender) and length of total nursing and ICU working experience. After implementation, we presented the application to the staff, communicating clearly the aim of this intervention and explaining that usage is optional. One month later, we repeated the survey using a semi-structured questionnaire consisting of 3 four-point Likert scale to explore the staff's opinion about the application and the self-reported compliance rate. The questionnaires were completed anonymously, and confidentiality of the data was ensured. No other quality improvement initiative was undertaken during the study period.

Statistical analysis was performed using IBM-SPSS® version 24. Initially, data were assessed through simple cross-tabulations. Internal reliability, test-retest reliability and construct validity of the questionnaire were determined using Cronbach's alpha and Pearson's correlation, respectively. Overall, internal reliability (Cronbach's alpha = 0.715), test-retest reliability ($r= 0{,}768$, $p<0.001$) and validity ($r > 0.551$, $p<0.002$) were high. Nonparametric tests for 2-related samples were used to assess the significance of the results before and after the intervention. Normality hypothesis was examined using the Shapiro-Wilk test. Spearman correlation coefficients were used as measurements of correlation for continuous and ordinal variables. Multiple logistic regression analysis was used to identify independent determinants of compliance (transformed as a binary outcome). For all tests, a p value of <0.05 was considered significant.

3. Results

3.1. Before intervention

The study population consists of 30 nurses (9 male /21 female), aged (mean ± SD) 35 ± 3 years (range 32-44). The length of total nursing experience was 9 ± 3 years and the ICU working experience was 7 ± 3 years. The questionnaires were filled in by the entire nursing staff (N=30), except for the open-ended question (N=19). Twenty-eight (93%) responded that they had knowledge of the QS protocols adopted by the ICU and 27 (90%) expressed positively about them. The self-reported compliance rate was 53%, while 7% reported not following the protocols and 40% following them partially. The reasons were reported by 19 nurses as follows: one disagreed with this practice, two reported that they didn't know the protocols, five reported that personnel and material shortage were the main reasons for noncompliance and eleven stated that heavy workload was a barrier to comply. There was a significant positive correlation between ICU working experience and compliance ($r= 0.406$, $p<0.03$). We also found that only ICU working experience was an independent predictor of compliance ($p= 0.02$, OR= 2.86; 95% CI: 1.16-7.06), after adjustment for age and total nursing experience.

3.2. After intervention

Regarding the completion of the questionnaires, the response rate was 100%. Twenty-six nurses (87%) responded that they were informed about the application and twenty (85%) felt positive about it. The self-reported compliance rate was 70%. We recorded a statistically significant increase in compliance rate of 32% ($p<0.001$). Finally, 80% considered the application educational and 73% considered the electronic check-list useful in every day work.

4. Discussion

This survey revealed that ICU nursing staff compliance rate was suboptimal, in a teaching hospital with a previously established practice according to QS. However, implementation of a simple application, integrating the QS protocols in the HIS, resulted in a significant increase in compliance rate by 32% and it was well accepted by the staff. We also showed that ICU working experience was associated with better compliance. To the best of our knowledge, there are no similar reports about integration of clinical protocols to the HIS, although there are scant reports for the successful application of computerized protocols in medical units [6,8]. Previous studies have questioned the usefulness of traditionally used tools, like rounding checklists, as reminders for evidence-based practices [9]. These practices seem to be outdated, and information technology has provided supporting tools to quality improvement.

Our application is original, simple and easy to apply. Additionally, the requirements in resources for this application were minimal. Furthermore, we organized only one staff meeting for the presentation of this application, with no additional time-consuming interventions. The added value of our intervention is the provision of an educational tool to help staff familiarize with the protocols in a quick

and easy way. At the same time, this intervention may serve as a reminder to enhance compliance, as a self-audit tool to facilitate self-improvement and as a monitoring tool.

Certain limitations merit discussion. Our study was performed in a single center, thus our findings may not apply to every medical unit. However, HIS has been widely adopted and shares common properties. The recording of the self-reported compliance anonymously using a questionnaire may be inherently biased. Nevertheless, the same method was used before and after the intervention, serving the purposes of our study. Our aim was not to perform an internal audit of staff performance. Additionally, our results may have been influenced by the short time period after the intervention. It is possible that optimal effects will subside over time. We acknowledge that quality improvement is an ongoing process. Finally, for the successful implementation of every quality initiative, it is necessary to consider its acceptance by the staff and highlight certain barriers to its effective use, like knowledge and training deficits and reluctance to change [10]. To this end, organizational support for education, training and cultural change is fundamental. Proper communication of every initiative along with the simplicity of any intervention warrant better outcomes. Aiming at improving quality of ICU care, our future goal is to establish this practice and to extend this application by including medical and other procedural quality protocols.

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Healthcare IT Strategic Alignment: Challenges and Recommendations

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Abstract. Information technology (IT) has dramatically transformed business processes in many industries including healthcare, where electronic health records, electronic prescribing and computerized provider order entry systems have positively changed the practice of healthcare. Recently, King Faisal Specialist Hospital and Research Center, Saudi Arabia, implemented various IT systems in multiple clinical and administrative departments leading to major transformation in healthcare workflows and business processes. At the pharmacy department, many Healthcare-IT alignment challenges are still perceived. Information about challenges of strategic alignment were gathered using qualitative survey methods, through conducting semi-structures interviews, to collect opinions, experiences and suggestions. Findings were first validated, according to published literature and research work, then sorted into fourteen challenges categorized into four main areas and recommended solutions: 1) Improving organizational communication, 2) Enhancing organizational governance, 3) Specifying the alignment scope and building the architecture and 4) Developing organizational and human skills.

Keywords. Healthcare, Information Technology, Strategic Alignment, Hospitals.

1. Introduction

Information technology (IT) has dramatically transformed business processes in many industries, including healthcare, where electronic health records, electronic prescribing and computerized provider order entry have positively changed the practice of healthcare [1]. The huge influx of healthcare data that need to be shared between various providers in a timely manner adds pressures to adopt IT solutions that would assist in providing safe and effective healthcare services in an efficient way. Therefore, reaching a high level of strategic alignment between IT and business will have significant impact on the performance of organizations, provide new opportunities for improvement, gain return on investment in IT application and achieve a competitive advantage [2]. Strategic IT-business alignment can be defined as fitting or integrating the IT and business strategies together. It can also be defined as the integration of external and internal domains. The external domain includes the main characteristics of the business that makes it unique among different competitors and the internal domain

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includes the services or products that are produced by the business [3]. There are various models and frameworks that are used to provide a practical guidance to measure the IT-business alignment. One model proposed by Henderson and Venkatraman (1993) measures two types of integration: the strategic integration between IT and business and the functional integration concerned with various business and IT processes and links it to the infrastructure [3]. Another model developed by Luftman (2003) focuses on the relationship between the business and IT through measuring six main alignment criteria: communication, competency, governance, partnership, scope, and skills [4]. Successful IT-business alignment provides organizations with the stability and flexibility to adapt to environment dynamics [5]. Recently, King Faisal Specialist Hospital and Research Center, Saudi Arabia, implemented various IT systems in multiple clinical and administrative departments that lead to major transformation in the workflow and processes. At the pharmacy department, many challenges are still perceived, so we decided to explore these challenges and provide recommendations to assist decision makers in closing the gaps between business and IT to improve healthcare performance.

2. Methods and Results

Detailed information about perceived challenges aligning Pharmacy and IT processes were gathered from the two departments, the services and staff members. Qualitative survey methods were used, through conducting semi-structures interviews, to collect opinions, experiences and suggestions. Findings of interviews were first validated, according to published literature and research work, then sorted by researchers into fourteen challenges, categorized into four main areas and recommended solutions. Figure 1 shows the four main areas of challenges and Table 1 lists the detailed fourteen challenges within the four areas.

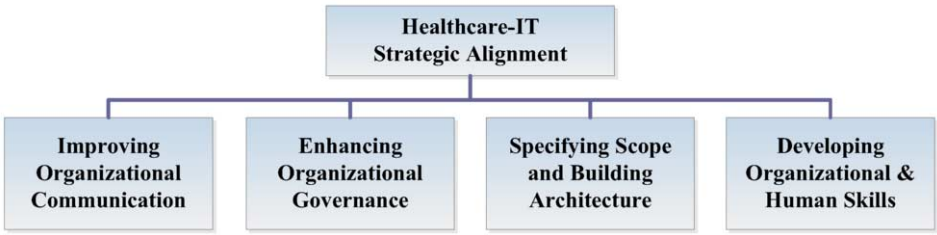

Figure 1. Healthcare IT Strategic Alignment Four Challenge Areas

3. Results and Discussion

3.1. Improving Organizational Communication

Study participants agreed that business and IT sides should have a proper level of communication through which both parties can understand each other, using common language, and where knowledge sharing is practiced within the organization. Many studies report that within different organizations there are gaps in communication that requires being addressed [6,7]. The main challenges that could be identified and

validated within communication includes 1) Partnership between departments and overcoming differences of views, due to different and sometimes conflicting priorities, 2) Mutual understanding of the roles of other departments, where each department might understand their role clearly but either do not understand the role of other departments or the role of their own departments in supporting other departments, 3) Sufficient knowledge sharing though different media, such as e-mails, meetings, and announcements to avoid miscommunication and 4) Availability and effectiveness of IT-business liaison to coordinate communication and tasks between departments [8].

Table 1. Healthcare IT Strategic Alignment 4 Areas and Summary of the 14 Perceived Challenges.

Areas	Challenges
Organizational Communication	Interdepartmental partnership Mutual understanding Sufficient knowledge sharing Availability and effectiveness of IT-business liaison
Organizational Governance	Involvement in strategic planning Involvement in executive committees Availability of a structured reporting hierarchy Authorization for decision making and understanding the role Availability of criteria to prioritize IT projects
Alignment Scope and Architecture	Automating business processes IT solutions effectiveness/customization
Organizational and Human skills	Readiness to face changes Management style Learning from previous experiences

3.2. Enhancing Organizational Governance

Organizational governance is based on achieving a certain level of authority for decision making, where managers from all contributing departments should be involved. It also includes having a clear process for prioritizing IT projects and utilizing resources in an effective way [9]. Based on our findings and validation, organizational governance includes five main challenges: 1) Involvement of all departments in strategic planning, 2) Involvement of departments in steering executive committees managing projects, 3) Availability of a structured hierarchy to report achievements and escalate challenges and, 4) Authorization to provide decision making in IT projects selection and understanding of the role or position in decision making and 5) Availability of criteria that prioritize IT projects based on the actual needs of processes and patients [10].

3.3. Specifying Alignment Scope and Building the Architecture

The IT department should be able to support the businesses in their requirements through providing effective IT solutions that are customized to their needs. IT should also provide a supportive infrastructure for implementing IT solutions that facilitate business processes [11]. Findings show that scope and architecture can be evaluated through analyzing two main challenges: 1) Level and degree of automating business processes, which performance is influenced by, then 2) IT solutions effectiveness and customization, in the form of influence on outcomes and results [12].

3.4. Developing Organizational and Human skills

Skills can be defined as the ability of the organization and personnel to accept changes and adopt cultures that promote readiness to face expected and unexpected changes. It also includes the presence of a formal management style within the departments which encourage learning from previous experiences [13]. Based on findings, development of skills is based on three main challenges: 1) Readiness to face expected and unexpected changes, 2) The management style that promote change acceptance and readiness and 3) Learning from previous experiences [14].

4. Conclusion

Strategic alignment between business and IT is important for improving organizational performance and achieving competitive advantage within any given industry. In a highly dynamic environment, such as healthcare, it is crucial to have a balanced fit between the business and IT processes and strategies to support changes and modify strategic planning; this could minimize negative effects of change and improve effectiveness and efficiency of performance.

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Human Based Digital Intelligence Analyses for Health Care Ecosystems

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Abstract. The maturity level of the digital transformation in health care ecosystems is heavily depending on human factors. Primarily the digital intelligence of the human beings - e.g. medical or nursing staff - should be taken seriously in the transformation processes. To derive sustainable strategies in a holistic manner an innovative, multi-dimensionaland human centred socio-economic capability model had to be developed and applied. By the use of our model health care ecosystems can be analysed, scored and benchmarked successfully. Furthermore, each ecosystems' digital intelligence based on their employees can be derived holistically from our four scoring scopes.

Keywords. Socio-Economic Capability Model, Human Based Digital Intelligence, Health Care Ecosystems

1. Introduction

To be attractive to patients, hospitals benchmark each other regarding quality of treatment or exclusiveness of their facilities. Efficient operation and sustainable evolution of health care ecosystems, like hospitals or care centres, will be influenced by many factors, like the digital transformation. This is one of the biggest challenges, beside the cost cut in public funding or the realization of data protection regulations. To strategically adapt socio-economic models as well as to optimize medical and nursing treatment methods health care ecosystems have to be streamlined also in a digital manner. According to the Digital Process Index Healthcare the digitalization is compulsory [1].

Neither health care ecosystems can be developed just by looking at technology nor can it be realized completely without technology. It is a fact that those ecosystems need more efficient technologies to support the clinical pathways. In several papers, like published in [2] or [3], it can be seen that also processes, culture, organizational structure needs to be focused on. Digital transformation in health care ecosystems needs to be evolved from a technical into a socio-economic perspective. In this paper we present our research on a transformation model that can be obtained by focusing on the multi-factorial analyses of the human based digital intelligence. Furthermore, we

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derive various capability levels on the basis of our transformation model that can be used for positioning and benchmarking in digital transformation.

2. Methods

Currently in health care ecosystems several problems have to be solved: on the one hand the limitations in public funding by reducing the internal costs and on the other hand the achievement of a competitive advantage by providing an additional value for patients. This point of view is just extrinsic, but we have recognized that in digital transformation two scopes seem relevant for a holistic view: the extrinsic view, which centres on the patients and the intrinsic view centring the employees. In order to achieve excellence in the extrinsic dimension, a valid intrinsic dimension must exist. After analysing different maturity models, like [4] or [5], we have recognized the missing focus on the employees and taken it into account in the development of our socio-economic transformation model. An advanced maturity model containing more scopes and maturity levels was published in [6].

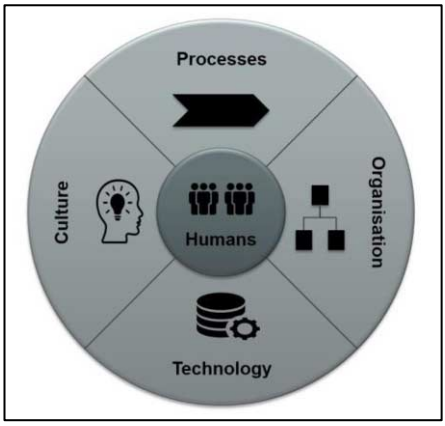

Figure 1. Socio-Economic Transformation Model

Figure 1 illustrates our socio-economic transformation model containing five scopes. Four of them are similarly known from other publications: Processes, Organisation, Technology and Culture. Further work concerning centring users in a process of organizational change was proposed in [7]. In our model the fifth scope focuses on the humans, with emphasis on the intrinsic view - the employees. Their digital intelligence needs to be measured in combination with each of the other scopes to achieve a holistic view. We define digital intelligence as the ability of humans to naturally deal with digital environments.

3. Results

The digital intelligence in combination with all scopes is the most important factor in our model, because the employees hold the reins. For this reason, the analyses of the human based intelligence needs a deep dive into every single scope. It's necessary to identify the status quo and to define the future target state of each health care

ecosystem concerning the parameters in all scopes. We deducted our Socio-Economic Capability Model (shown in Figure 2) from the basics of radar [8] to accomplish a familiar illustration. We propose the following three steps to derive a digital transformation path:

- Detect
- Position
- Transform

Firstly, the model splits up the process scope into four parameters: lean tailoring, end-to-end responsibility, certification and automation. Every single scope can be measured, concerning the achievement of objectives in the organization. For example, a question that is focused in automation can be: "How many processes are already be automated in the ecosystem?" Lean tailoring focuses the fact that lean health care is patient centred but also needs to be aligned with the needs of the employees. Secondly, our model measures the organization scope with four parameters: globalisation, cooperation, economic situation and know-how & experience. Thirdly, the technology scope comes into focus by taking a deep look at efficiency, sourcing, mobility and security. The last, culture, analyses the maturity of the scopes, collaboration governance, data protection awareness and documentation. A well-known topic for digital intelligence is documentation, because digital transformation projects can't last for a long time if this would not be well done.

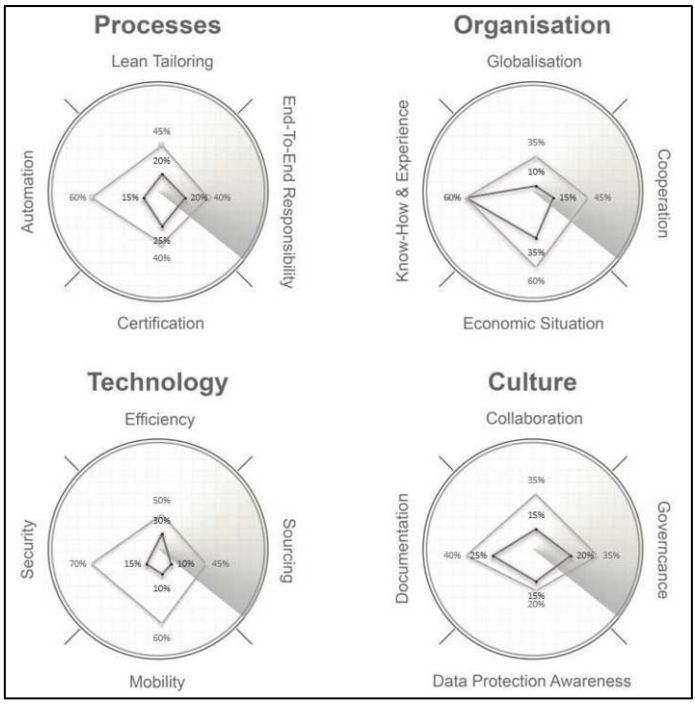

Figure 2. Socio-Economic Capability Model

4. Discussion

Our research gains a valuable insight into the specific considerations from different digital maturity models. The results centre the analysis of the human based intelligence and provides sustainable paths for health care organizations to plan their digital transformation involving their employees.

We clarify the coherences of all scopes and their parameters with an example of an international health care organization. The more global a health care organisation is located, the better collaboration, regarding our scope culture, need to exist. The security in the technical scope has to be focused concerning the international transfer of highly sensitive data. Furthermore, the processes have to be automated and an end-to-end responsibility is a necessity. A cultural fact, like documentation, is also important in globalisation, because the information has to be omnipresent and comprehensible. To conclude, all scopes and parameters of our model influence each other and show that the humans wield massive influence in the digital transformation.

Although our model can offer health care organizations a way to compare, how well they perform in digital transformation focusing digital intelligence, there are also some limitations. At the moment our Socio-Economic Capability Model just focuses on large health care organizations and ignores small doctor's offices. Furthermore, standardised digitalization paths for all health care ecosystems do not exist.

Prospectively we are going to apply and attempt our Socio-Economic Capability Model in different health care ecosystems. Consequently, we anticipate to get a sharper focus on the human factor by refining the parameters of all scopes. The value of educating employees were discussed in [9] and [10] and will also be considered in our future research.

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Developing a Policy and Procedure Framework and Manual for a National Comprehensive Implantable Medical Device Registry in Saudi Arabia

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Abstract. Policy and procedure manuals provide guidance on the operation and governance of medical device registries. In Saudi Arabia, the Saudi Food and Drug Authority (SFDA) has been developing and implementing a comprehensive national registry for implantable medical devices to facilitate the monitoring of device outcomes through post-market surveillance studies. To help guide the operations of this registry, the SFDA developed a policy and procedure manual. This paper reports on the design of the framework used to develop that manual over the course of one year (2015–2016), using a variety of literature sources, and working with medical device registry and health systems experts. The policy and procedure manual included five key principal level categories, which led to the subsequent creation of seven policies and 28 relevant procedures. The five principal categories were: Staff Engagement, Information Governance, Quality and Auditing, Research, and Reporting. The results of this work could be used to guide the development of policies and procedures for other implantable medical device registries.

Keywords. Health Informatics, Medical Registries, Policy and Procedures

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1. Introduction

The primary purpose of an implantable medical device registry is to monitor device outcomes for the purposes of surveillance, post-market observational studies, and evaluations of safety and effectiveness [1]. Overall, there is a lack of surveillance data on implantable medical devices, and only limited information is available on surveillance and the types of registries currently deployed worldwide [2]. In Saudi Arabia, where there have been no implantable medical device registries, the Saudi Food Drug Authority (SFDA) has only recently begun to develop a Comprehensive Implantable Medical Device Registry (CIMDR) to monitor the outcomes of orthopedic, cardiac, and breast implants, neurostimulators, and other implantable medical devices. The SFDA anticipates that the CIMDR will help improve outcome-based research related to implantable medical devices, and patient safety within the country [3-5].

A fundamental step in creating the CIMDR is the development of clear policies and procedures that govern its operations. To do so, major issues to be addressed involve studying hospitals' readiness, staff engagement, confidentiality and privacy of patient information, data entry and validation, auditing, and reporting. The present article aims to describe the CIMDR policies and procedures that have been developed by the SFDA. The work reported in this paper is part of a larger study, funded by the SFDA, to build and deploy the CIMDR.

2. Methods

An iterative approach was employed in the planning, development and refinement of the CIMDR policy and procedures manual. In the planning phase, a PubMed and Google Scholar search was conducted, identifying approximately 50 research articles, five books, and six government-related works on the topic of medical device registries. These publications included a wide range of topics relating to cardiology, orthopedics, clinical trial registries, and others. The literature was reviewed and examined by a health systems and quality expert, a medical device expert, an information technology specialist, a medical physician, and a policy and procedures expert. Once the review was complete, the experts developed a policy and procedure framework based on multiple sessions and feedback over a four-month period (February to May 2016).

3. Results

The research identified over 100 relevant policies and procedures. Based on feedback from and consultation with the content experts, 28 procedures and seven policies were found, organized around the five key principal level categories: Staff Engagement, Information Governance, Quality and Auditing, Research, and Reporting. Procedures relevant to the SFDA were labeled as 'internal procedures', and those related to hospitals were labeled as 'external procedures'. The five key principal level categories were dependent on one another. For example, without staff being engaged in entering data into the CIMDR (Staff Engagement), it would not be possible to have an Information Governance framework guiding the ways in which data is entered, validated, and archived. The principal level category relating to data Quality and Auditing relies on the Information Governance principal level category because, for

example, if there is no data in the CIMDR, Quality and Auditing checks cannot be conducted. Furthermore, without Quality and Auditing of the data, it would be difficult to conduct valid and reliable research, or to report on the research produced (Reporting) (See Figure 1).

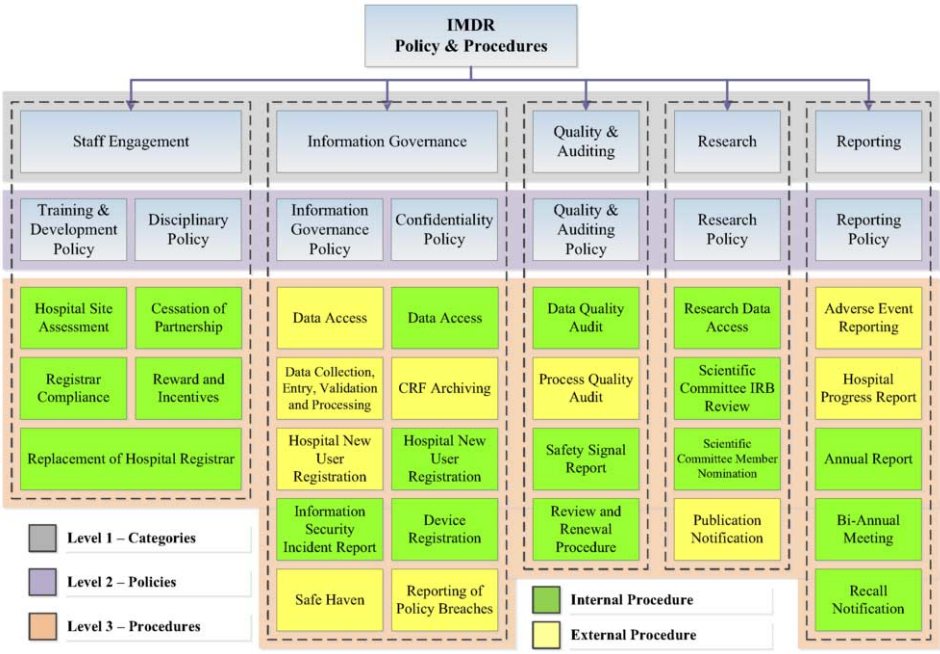

Figure 1. CIMDR Policy and Procedure Framework

3.1. Staff Engagement

Staff Engagement includes two policies and five SFDA-related internal procedures. Their purpose is to ensure that only hospitals that are ready to adopt the registry are included as CIMDR participants, and to follow up on research registry compliance.

3.2. Information Governance

For Information Governance, a total of two policies, four SFDA and six hospital related procedures were developed. The policies and procedures provided guidance on confidentiality of patient information and how to protect it and other procedures relating to data collection, data entry, data validation. Other procedures providing secure access, reporting of confidentiality breeches, and the registration of new users to access the CIMDR were also included.

3.3. Quality and Auditing

One policy, three SFDA-related procedures and one hospital-related procedure were developed for Quality and Auditing. Their primary purpose is to ensure that quality standards and requirements for data collection, entry and validation for the CIMDR were established regularly met.

3.4. Research

For Research, one policy, three SFDA-related procedures and one hospital-related procedure were developed. The research policy offers guidance on how to provide data to research projects, conduct an ethical review, take part in membership of scientific committees, and notification of research publications of studies conducted using CIMDR data.

3.5. Reporting

For Reporting, one policy, three SFDA-related procedures and two hospital-related procedures were developed. The reporting policy offers guidance for hospitals on how to report adverse events and how to develop progress reports for the SFDA. The SFDA-related procedures provide guidance on how the SFDA should conduct annual reports, host biannual meetings, and provide recall notifications to hospitals.

4. Discussion and Conclusion

The failure of implantable medical devices, although rare, can carry a substantial risk of serious patient injury. Since it is impossible to design an implantable medical device with no risk of failure, effective systems for monitoring outcomes and safety after a device is put on the market are essential to protect the health of members of the public.[6] Accordingly, implementing a national CIMDR and the prospective, active surveillance of this registry is crucial for monitoring the outcomes and safety of implantable medical devices. Having a policy and procedure framework and a manual can help guide the operations of such a registry to achieve its objectives.

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Designing and Developing a Multi-Center/ Multi-Device National Registry for Implantable Medical Devices

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Abstract. Designing, developing, and establishing the multi-device/multi-center Comprehensive Implantable Medical Device Registry (CIMDR) for Saudi Arabia is a strategic objective of the Saudi Food and Drug Administration (SFDA). The goal of the CIMDR is to capture all related clinical data along with device related information for implantable medical devices and study population-related outcomes. There is an immediate need in Saudi Arabia to establish the CIMDR to carryout device surveillance, gauge the efficiency and efficacy of various implantable medical devices, and track and recall implantable medical devices.In this work, we report on the development of the SFDA's CIMDR. We specifically focus on the project organization, five primary modules of the CIMDR, and development of the CIMDR through dynamic forms. We anticipate that the collected information in the CIMDR will be used by hospitals and the SFDA to improve patient safety relating to implantable medical devices in Saudi Arabia. Future development of the CIMDR will include a wide range of reporting and embedded analytical tools that will help researchers improve clinical standards and contribute to the research and development of implantable medical device technology.

Keywords. Clinical registry, registry electronic system, registry analytics, registry data capture, electronic data capture, medical device registry.

1. Introduction

Medical registries have been identified as a source of information and evidence for patient monitoring and the generation of clinical decision-making about implants since

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the late 1980s [1]. A national medical registry is an "organized system that uses observational study methods to collect health related uniform longitudinal data to evaluate specified outcomes for a population defined by an exposure, and that serves one or more predetermined scientific, clinical, or policy purposes" [2]. Since 2014, the Saudi Food and Drug Administration (SFDA) has been working on the development of the Comprehensive Implantable Medical Device Registry (CIMDR). The CIMDR is a registry application that will be used by hospitals across the Kingdom of Saudi Arabia. Its key purpose is to record information regarding different devices that are implanted in patients. The registry application will record patient information,including basic demographic data, patient previous history, diagnosis, surgery, and follow-up information. Building a comprehensive implantable medical device registry that includes a numberof implantable medical devices (e.g., cardiovascular, craniofacial, joint, cosmetic, and neurosimulatordevices) willcreate multiple registries under the same database that will need to be managed through a common and single registry system. In this work, we report on the development of the SFDA CIMDR, itsorganization, infrastructure, primary data elements, and data analytic tools.

2. Methodology

An iterative software building approach was used in the development of the CIMDR. In 2014, a taskforce setup by the SFDA developed a plan for the development of the CIMDR. The primary step, prior to building the CIMDR, was to develop a common minimum data set for all possible implantable medical devices. In 2015, the development of the common minimum data set was complete, and a CIMDR technical development taskforce was created to build the CIMDR. The first iteration of the CIMDR development was based on the common minimum data set, which included information related to demographics, surgery details, and medical device information. Once the initial CIMDR was built, recommendations for technical, usability, and functionality improvements were suggested to the CIMDR technical team based on consultant reviews and SFDA staff feedback. Further additions to complete the data set were then sent to the CIMDR technical team for implementation. Multiple iterations occurred over a two yearperiod leading up to February 2017, where the initial CIMDR was finalized and piloted in a number of local Saudi hospitals. In its current stage of development, the CIMDR includes a number of multiple and distinct instances of the registry for cardiology and orthopedics.

3. Results

3.1. Project Organization

The CIMDR electronic data capture system was organized around the following five technical topics.

Project Organization:Project organization involves initial studies, surveys, a literature review, and assessment. Various data capture techniques (data entry, data import, and system integration) were defined and designed.

Infrastructure:This aspect includesa document defining the required infrastructure to run the program.

Software/Registry Application/Database:This topic coversthe documentation of the complete requirements for designing and developing the registry. The data elements include data form designs derived from case report forms, data definitions, inventory fields, and workflow.
Data Analytics: Analytical standards and software were developed for the CIMDR.
Reporting:The CIMDR embeds report functions such as dash boards and basic cross-tabbing tools.

3.2. Five Primary Modules of the CIMDR

The CIMDR covers five primary modules relating to implantable medical devices, with most modules including the common elements and other modules, such as surgery, having different data elements. High-level descriptions of the primary modules are given below.
Demographic Information: patient demographic information relating to name, age, address, phone, education, and employment. These elements are included as common elements among all instances of the CIMDR, i.e., cardiology, orthopedics, cosmetics, and neurosimulators.
Diagnosis Information: diagnosis, date of diagnosis, and procedure used for diagnosis, e.g., lab, pathology, or radiology. The Standardized International Classification for Diseases 10, Australian Modification (ICD-10-AM) is used for recording the diagnosis.Diagnosis information is a common element among all instances of the CIMDR.
Patient History: co-morbidity diseases, height, weight, BMI, previous procedure history (if any), and initial symptoms. The standardized ICD 10 AM was used to capturethe co-morbidities, previous procedures, and symptoms. Patient history is a common element among all instances of the CIMDR.
Surgery/Procedure Information: common elements (for all the devices) but also information that is device specific; the recorded parameters are mostly related to the site of implant, e.g., cardiology (stents, Implantable Cardioverter Defibrillator [ICD], and pacemakers) or joints (hip and knee joints).
Follow-up Information: patient-related outcome information relating to the patient.

3.3. Development of Specific Device Data Sets in the CIMDR through Dynamic Forms

The CIMDR electronic system usesMicrosoft.Net as the application Framework, using MVC Architecture, built on arelational database (MS Sql Server 2017), with a complex database structure including 50 odd facts and classification tables, in order to comply with the unique dynamic scaling of the system, to include new registries instantly on the go. Adding a new registry neither requires any alteration within the database structure,nor does it require any additional tables to be created. Hence, the dynamic approach mentioned below, is followed.

The CIMDR is a parent registry for holding multiple device registries under the same umbrella. Therefore, specific device datasets need to be created dynamically and attached to the respective device registry under the surgery/procedure information, so that whenever the electronic registry is worked upon, the surgery and followup forms are automatically generated as per the variable definitions provided by the registry administrator. The term dynamic, refers to the registry administrator's ability to create a new device registry using the common variables(from the common minimum dataset)

and further add other device specific variables related to this implantable medical device. Once these variable definitions are created for a particular registry, it will be ready to accept the user input electronically as per the variable set, defined by the administrator for this registry. These dynamically generated electronic data input forms include all the required variables, along with thevalue option, inform of generic field types and user defined controls, which is used to capture the data, in the necessary format as per the data dictionary.

4. Discussion and Conclusion

The biomedical device/implants registry project involves multiple devices or implants with different natures, and hence the data related to each device/implant (clinical data and device data) varies in nature as well as composition [3-5]. It is indeed a challenge to include this data into one comprehensive registry. The minimum common data set was developed to emulate the patient journey and capture common elements throughout that journey irrespective of the clinical domain area. It includes patient information such as patient demographics, socio-economic data, and healthcare provider data.

To create a central database to include all implantable medical devices, the CIMDR was developed using an architecture with a common minimum dataset, where a separate instance of the CIMDR can be created virtually and automatically by the database administrator under the same CIMDR umbrella. This creation follows a dynamic approach that creates and stores the dataset while maintaining total data integrity and access privileges. In the future, we anticipate that the CIMDR will provide a large number of extensive search tools to query the data, as well as pre-defined and dynamic analytic tools to help support data downloads and analysis. All epidemiological outputs derived from the CIMDR project cover three main aspects: 1) *patients*, where it can help plan and evaluate strategies for the management of patients, 2) *medical devices,* where surveillance and evaluation can be performed with respect to the efficiency, efficacy, quality, and recalls of these devices, and 3) *healthcare providers*, where it can carry out various population-based analyses with regard to the implantable device.

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The Effect of Electronic Medication Administration Records on the Culture of Patient Safety: A Literature Review

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Abstract. Medication errorsare a leading cause of deathacross many parts of the world. Several factors increase medication errors. These can be individual-related factors, such as the burden ofa heavy workload, often experiencedby nurses, or organizational-related factors, such as inadequate space for documenting and poor labeling of medication. This paper shares the results of a preliminary literaturereview on the impacts of electronic medication administration records(eMAR) on patient safety. UsingPubMed and Google Scholar, we searchedthe following terms: “eMAR”, “medication errors”, and “workflow”. Our preliminary findings revealthat eMAR can have impacton nursing workflow, and reducemedication errors, thus improving patient safety. Although the results are preliminary, they provide some insight into the impacts of eMAR on nursing workflow and patient safety. Our plans for future researchare to conduct a systematic review study to further examine the impacts of eMAR on patient safety.

Keywords.eMAR, Medication Errors, Patient Safety

1. Introduction

Patient safety is a sought-after goal in every single healthcare organization. According to the Agency of Healthcare Research and Quality, an organizational and individual understanding of patient safety norms, values and beliefs is required to build a culture of patient safety.[1]According to the National Coordinating Council for Medication Error Reporting and Prevention, medication error is defined as: “any preventable event that may cause or lead to inappropriate medication use or patient harm while the medication is in the control of the health care professional, patient, or consumer.Such events may be related to professional practice, health care products, procedures, and systems, including prescribing; order communication; product labeling, packaging, and nomenclature; compounding; dispensing; distribution; administration; education; monitoring; and use.”[2] It is reported that medication errorscan cause adverse events; in fact, it is estimated that 328,000 patients die in the USA and Europe each year as the result of an adverse reaction to medicinal drugs.[4–6].

The safety of medication administration is an important topic that has garnered attention in recent years.[3]The use of medication administration software, has been proposed as one way that hospitals and medical personnel can minimize medication

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errors, and improve the efficiency and accuracy of medication management and documentation.[4] The eMAR is a medication administration software solution that is used by medical personnel to improve the efficiency and accuracy of medication management [4] . By implementing the eMAR, hospitals can improve patient safety and reduce the amount of time spent on documentation [4].The aim of this paper is to provide a preliminary review of the impacts of eMAR on medication administration and patient safety.

2. Methods

Papers relating to the impact of electronic medication administration records (eMAR) on healthcare settings were identified from Google Scholar, PubMed (up to 2018), and World Wide Web (blogs, news, and magazine articles). The following key terms were searched as headings or text words in the titles and abstracts: “eMAR”, “medication errors”, and “workflow”. In order to reveal additional papers, references in the literature were also searched and relevant papers were further analyzed. Every article was searched with a primary focus on the positive impactrelating to eMAR; the relevant information was extracted, analyzed, and included in the review.

3. Results

Bar code medication administration records (BC-MAR) are designed to support the five ‘rights’: right medication, right dose, right time, right route, and right patient. Since errors can be made at each stage of the closed-loop medication management process, information system applications have been designed to reduce errors and improve patient safety [5]. Farrell [6] found that, of all medication errors, 39% were associated withmedication ordering, 12% with medication transcription, 11% with pharmacy evaluation/dispensing, and 38% with errors of medication administration. Furthermore, it was observed that while “only” 50% of ordering, transcription and pharmacy/dispensing errors actually reached the patient—the restbeing caught in subsequent processes—98% of medication administration errors reached the patient.

3.1. eMARWorkflow Support

When using an eMAR system,nurses spend about 25% of their time on medication administration, which representsan improvement in workflow because ofbetter notification about adverse events.[7]Given that eMAR automatically notifies nursesaboutpossible adverse events arising from the prescription of certain medications, they become more efficient and accurate in dispensing these medicines.Research reveals that this has improved patient safety and quality of care.[8]

3.2. Reduction of Medication Errors with the Implementation of eMAR

The use of eMAR can reduce medication errors. Seibert et al. [9] found that using Bar code medication administration records (BC-MAR) with eMARsignificantly increased the accuracy rate of medication administration, and simultaneously decreased the

frequency of many preventable errors. Another study by Poon [8] also found that the rate of medication administration errors decreased significantly when using BC-MAR–eMAR. These authors also found that, when not using BC-MAR–eMAR, the non-timing error rate was 11.6% compared to 6.8% when using BC-MAR–eMAR. Accordingly, the authors concluded that there was a noteworthy reduction in error rates when BC-MAR–eMAR was implemented.

Prusch and Watts[10]foundthat intravenously (IV) delivered medications have the highest risk oferrors. To tackle this problem, IV interoperability was developed, which. takes BCMA and eMAR technologies and combines them with intelligent IV infusion devices. The authors found that, when using the interoperability pump programming process, 24.8% less nursing time was required compared to the manual process. This study concluded that implementation of the IV interoperability process reduced the frequency of many medication errors, and nursing workflow was simplified.

4.Discussion and Conclusion

In healthcare, the occurrence of everyday medication errors can be minimized ifthe right tools are used and the correct procedures put in place. There are many factors, both individual and organizational, that cause medication errors [11]. Our preliminary work shows that eMARcan be an effective technology fordecreasing the rates of medication errors and improving patient safety. Furthermore,eMARcan assist in supporting patient safety, reducing the amount of time spent on documentation,and increasing theaccuracy of medication administration. Although eMAR is used for the administration of medications, other solutions must be developedto improve patient safety and medication administration accuracy. Computerized physician order entry systems and ePrescribingalso have the potential to improvepatient safety and patient adherence to medication.We conclude that using eMARcan enhance patient safety and improve efficiency in the healthcare setting.

The review has a few limitations. Firstly, the literature search was biased towards finding positive results related to using eMAR. Furthermore, the results of this study cannot be generalized. Also, many information sources could have been missed or not included in the study. Future meta analysis and/or systematic review studies should be based on research validations of the impact of using eMARmedication errors and patient safety.

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Section IV

Evaluation Studies and Education

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Accessibility and Readability of Dementia-Related Information on Websites

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Abstract. The study aimed to identify websites with dementia-related content and evaluate their readability and accessibility. A purposeful sample of 300 websites, which provided information on dementia, were identified from searches using the Google, Yahoo and Bing search engines. Two generic evaluation tools based on WCAG2.0 were used to assess the accessibility of information on dementia and two readability tests (Flesh-Kincaid Grade level and SMOG) were used to evaluate the websites. Only 94 websites have a HON certificate (31.3%), while 38 of the finally selected websites have an average of 56.89 and 32 problems in relation to the Axe and Achecker tools respectively. The most common problems (for images on 19 and 17 of the websites respectively) were related to text resize and the lack of text explanation, and an insufficient color contrast was found on 35 websites. The readability score was 8.2 (FKG) and 7.4 (SMOG) on average, which meant that the sites in question were not recommendable for the general population.

Keywords. web accessibility, dementia, readability level

1. Introduction

In 2017, the world's population was almost 7.6 billion and the number of people aged 60 and above was 962 million, or 13% of the world population [1]. At the same time, with a rate penetration of 54.4%, the number of internet users in the world reached 4,156,932,140 [2]. At the same time, there is still no effective treatment for dementia, which is a common problem among the elderly. An estimated 50 million people around the world have dementia and it is forecast that 10 million new cases will arise each year [3]. Meanwhile, online health information from various sources is growing rapidly, as the Internet develops apace [4]. Despite the global risk posed by dementia[3, 4] and the rapid growth of the world's elderly population [1], the elderly have low Internet utilization rates due to a number of factors, such as low internet literacy, less trust in information sources, physical limitations etc [5]. However, little evidence has been gathered, based on valuation studies, on website accessibility for the purposes of elderly healthcare focusing on dementia. The aim of this study was to evaluate the accessibility and readability of dementia information on the Internet, using accredited tools to provide recommendations for related stakeholders. Two research questions must be resolved: (1) What is the average accessibility level of online dementia-related information? (2) What is the average readability level of online dementia-related information?

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2. Materials and Methods

Three popular search engines (Google, Yahoo and Bing) were used to identify the websites in question. A search of all sites was conducted on 7 May 2018. The search keywords "dementia" and "Alzheimer's" were used as based on the glossary term, dementia [6]. Only the top 50 websites listed by each search engine were selected based on how people tend to search online [7]. Inclusion and exclusion criteria were used to select each website for evaluation analysis. The selection process and analysis method are shown on Figure 1 below.

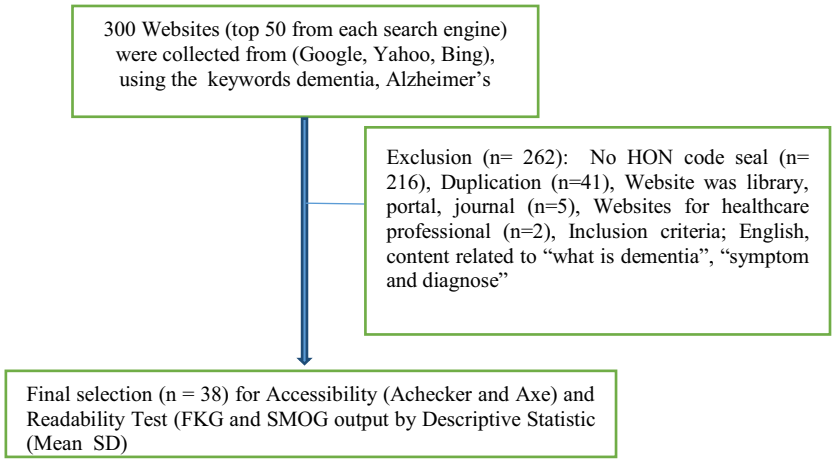

Figure 1. Material and method analysis

Axe and Achecker were the WCAG recommended tools for web accessibility evaluations based on WCAG 2.0 level A, AA [8]. The readability test tool, Flesch-Kincaid Grade level, was developed by Rudolf Flesch and J.Peter Kincaid, based on reading comprehension ranging from that of 5th grade children (very easy to read for the average 11-year-old student) to college graduates (very difficult to read, best understood by university graduates) [9]. Another readability tool, SMOG, was developed by G.Harry McLaughlin in 1969, based on a grade scale from 5 to 18 [10]. The online calculation tool source for measuring FKG and SMOG was based on WebpageFX [10].

Validation of the Automatic Evaluation tool was based on the Diaper and Worman approach of comparing results, generated by two different tools, from the same websites[11]. For this study, two WCAG tools and two readability tests are compared.

3. Results

Among the 38 selected websites, 25 and 32 failed to fulfill the WCAG 2.0 criterion, as evaluated using the Achecker tool and Axe tool respectively. On average, for every website, 56.89 (SD: 26.75) and 32 (SD: 32) violations were identified by Axe and Achecker, respectively. Of 38 websites, only two websites passed the Achecker test, but none were found to be without violations by the Axe tool. The most common problem identified by the Achecker tool related to Success Criteria 1.4. Distinguishable.

In particular, '1.4.4. Resize text (AA Level) require italic element is not available' was detected on 19 websites. This was followed by the Success Criterion 1.1.1 violation, 'No text alternatives for all non-text content' and the violation of Success Criterion 4.1.1. 'Attribute must be unique', which were not available on 17 websites.

Using the Axe tool, the most common problem found was insufficient color contrast on 35 websites (n=38) under Criterion 1.4.3. This was followed by 'Problem of lack of content in a landmark region' (33 websites). Similarly to the Achecker tool, violations related to not having discernible text were observed in respect of 27 websites with links (Success Criteria for 1.1.1 Non Text Content, 4.1.2 Name, Role and Value, 2.4.4. Link Purpose) and 15 websites with buttons (4.1.2. Success Criteria). In addition, of 300 websites searched using two keywords via three search engines, only 94 websites have HON seal certificates (31.3%).

The average FKG (Flesch Kinclaid Grade) readability score was 8.2, which means that the text can be easily understood by 13 to 15-year-old students and the SMOG average score is 7.4 for a reading age between that of sixth graders (11–12 years old) and seventh graders (12–13 years old). This fails to meet the recommendations of the American Medical Association and National Institute of Health, which specify that text should not exceed the reading ability of sixth graders in terms of their difficulty [12].

4. Discussion

Physical limitations among the elderly are an unavoidable problem due to the ageing process [13]. Complete and easily understood information is therefore required for people with cognitive problems or memory loss, in particular. Based on these findings, improvements in website design, in order to make web pages attractive to elderly people with physical limitations, should fulfill the criteria of WCAG 2.0. Websites with critical information such as healthcare content should be regulated at national level, based on international law enforcement standards [14]. Information content should be simpler, in order to avoid confusing people whose cognitive abilities have deteriorated.

Two common website problems which have been found in terms of accessibility level were the color contrast and incomplete information to navigate the text as a result collaboration is required among information content providers (authors), web developers and users of information. Such collaboration should focus on the user on the basis of knowledge sharing, with a priority on accessibility for lay people [14]. When designing websites, developers should be guided by user experiences and should adopt WCAG standard more comprehensively in order to reduce the accessibility problem [15]. In addition, the authors of information content should provide plainer information in order to engage poorly educated readers, or elderly people with lower brain function. Regarding finding on readability level which was still difficult to understand for elderly, creating more comprehensible information, authors, who are mainly health experts, should consult language editors. In addition, because of previous studies have shown that elderly readers were concerned about the complexity and reliability of online information [16], websites should be certified to have more legal trust.

In further studies, the measurement of information content should be customized by experts on the topic of the content. A customized tool would improve the content and accuracy of evaluation, enhance the research results and contribute to the development of guidance on the topic.

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User Evaluation of a Multiple Sclerosis Self-Management Mobile Application

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Abstract. This paper presents user evaluation of a high-fidelity prototype of a mobile application for patient self-management within the field of Multiple Sclerosis (MS). The application named *msHelse* consists of four modules: *Diary module*, *Summary module*, *Stress management module*, and a *Todo-list*. Four study subjects were interviewed in semi-structured interviews with questions regarding the functionalities and the user experience after using the application, as well as using System Usability Scale (SUS). User feedback resulted in functionality adjustments of the high-fidelity prototype, especially in data representation of the *Summary module* and the way the *Diary module* would assess user entered data. Thus, the *msHelse* application has been refined to tune into the needs of Norwegian users.

Keywords. Evaluation, Application, Multiple Sclerosis, Self-management

1. Introduction

Multiple Sclerosis (MS) is a chronic inflammatory disease of the central nervous system [1], and affects the body differently varying from person to person. The use of Information technology (IT) and mobile applications for self-management could support the users to economize their energy by planning and organize tasks in their everyday life [2]. However, there are reservations to use such tools in Norway. We found out that the medical experts at the Norwegian Competence Centre for MS at Haukeland University Hospital did not recommend MS applications to their patients due to the lack of the compatibility with the Norwegian healthcare system with national treatment plans [3]. Furthermore, a method for certification of mHealth applications in health care is needed [4]. To meet specific needs of Norwegian users, we have developed an application prototype entitled *msHelse* that consists of four modules: a*Mobile diary*, *Summary statistics module, Stress management module* and a *Todo-list*. Data gathered through the *Mobile diary* is represented in bar and line graphs in the *Summary statistics module*.

This paper focuses on user evaluation of a high-fidelity prototype presented in The Figure 1. The development was based on assessment of information needs [5] and took several design iterations that resulted in the prototype of a personal MS application to support the user's self-management.

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Figure 1. A selection of four wireframes from the high-fidelity prototype.

2. Methods

Four study subjects participated in the evaluation of the high-fidelity prototype (Figure 1). The study group was recruited through a Facebook group called *MS-venner* comprised of persons with MS or those who are dependents. The study subjects were interviewed individually at the University of Bergen and at a coffee shop in Bergen, Norway. There were three females and one male subject with age range of 27 to 50. The first part consisted of a presentation of the prototype where the users could navigate on their own (Figure 1) after which followed a SUS evaluation to capture the overall usability of the prototype. SUS was chosen as a standardized usability scale, which is simple, uses a ten-item scale to capture a subjective assessment of usability [6]. The second part consisted of a semi-structured interview with questions regarding the improvements of the prototype. Further, the study subjects were asked how they would use such application to self-manage the disease in their everyday lives. The responses were recorded using low-fidelity prototypes, see The Figure 2 for details, and by making field-notes during the interviews. The content analysis was applied on the interview material using open-coding.

3. Results

The study subjects commented on functionalities as they were shown to them. Two study subjects suggested that the diary should support occasional registration if a user forget to fill out the diary, or if the user prefers to register data when the disease is active. The study group reported that the diary should provide notifications by reminding the user to fill out the diary within a reasonable timeframe (i.e. every night or every third day).

In the symptom registration in the *Diary module 3* (Figure 1), two study subjects said that they would expect specific time registration of when a symptom occurred, as the two available options were too narrow. Furthermore, one study subject suggested that each symptom could have a grading of severity or at what stage a symptom affected the user that day on a scale from 0 to 10 (where 0 is normal and 10 is severe).

In the dialogue module in the *Mobile diary*, one study subject said that the diary should ask if the user has experienced an MS attack to keep track of the disease activity

and have it presented in the *Summary module 4* (Figure 1). Additionally, one other study subject said that the dialogue module should provide buttons representing activities that the user can easily click on rather than requiring from the user to type in activities. An example of such buttons could be: *Worked*, *Visited a friend*, *Relaxed* or *Made a good dinner*. Furthermore, the study subject suggested personalizing the activities.

The study group recommended that the *Summary module 4* (Figure 1) should be simplified, support filtering of data and expand the time period of data. One study subject suggested that the bar representing total count of a symptom occurrences could be removed, as it was too much information at one time. One study subject believed that it should be possible to flag an interesting time period using data points. Two study subjects thought that it would be interesting to combine graphs with data from the dialogue module in the *Mobile diary* containing MS attacks, data from the *Stress management module* and information whether a user is using prescriptive medicine. Both the subjects assumed that by combining graphs with different data the user could derive interesting information from such combined graphs. Moreover, one study subject suggested that the data could be represented in a calendar where one day would represent graphs that would appear automatically to the user. Furthermore, the study subject found that the time period of one week could be too narrow and the graphs would benefit by expanding the time period from one week to at least one month in order to see the bigger picture of the disease development.

The *Stress management module* was perceived positively by the study group. One study subject said that it should be possible to register a hike with, for instance, the distance walked or time used in a hiking session. One study subject would like to receive data via the phone's built in sensors (i.e. steps, stairs, and distance). One study subject would expect to adjust the time used to breathe in and out in the breathing exercise. In general, the study group would like the prototype to be more proactive by providing reminders and notifications to the user. One study subject said that the application should remind the user to fill out the diary within a reasonable time-frame according to the user preference. One study subject said that the *To-do list* should support reminders of tasks. The two other study subjects said that they would like to receive notifications with information about a symptom, and how to treat it, or information about the disease. For example, if a user has one or more prominent symptoms, then the prototype should provide more information about those prominent symptoms and link the user to information sources about MS provided by health officials. Finally, the study group claimed that they enjoyed the overall visual elements and design of the prototype. The SUS scores were as follows: subject one: 90, subject two: 95, subject three: 82,5 and subject four 97,5.

4. Discussion

Feedback from the study group was positive. The *Mobile diary* and the *Summary module* received most detailed feedback and were perceived as the two most useful components in the application. Consequently, the high-fidelity prototype was updated to a new version. Automation, personalization and registration was in general highlighted through the study groups' feedback (Figure 2). For example, when a user should register activities, the application should then know what activities the user is likely to register. The automation could be implemented by adding a one-time

registration of information about activity, types of typical symptoms, and types of exercises the user favors. This registration could benefit the user by providing such personalized information and buttons to support the minimal effort the user has to put in through each registration in the *Mobile diary*. The application requires from the user to register data in order to generate content and supports registration of data based on the user preference. However, the quality of collected data could affect the quality of the graphs in the *Summary module*. The high SUS scores showed that the application was appealing to the group. However, the limitations of this study might be a small subject sample size, even though this study is a part of a larger research project [3,5].

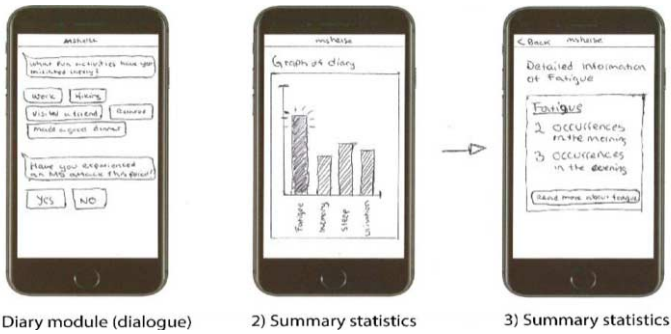

Figure 2. Three low-fidelity wireframes with improvement suggestions resulting from the user evaluation.

5. Conclusions

Results from the user evaluation suggested improvements to the Diary and Summary module and consequently the *msHelse* functionalities were refined. The future development will include usability evaluation with IT experts to be carried within one more design iteration. The clinical value of the *msHelse* has to be assessed in a clinical trial.

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The authors are thankful to the study group for sharing their user experience in this study.

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Patients' Perception of Privacy of Personal Data, Shared in Online Communities: Are We in the Presence of a Paradox?

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Abstract. Virtual online communities help people in coping with complex health issues, such as those present in patients suffering chronic diseases. Further research is required in order to clarify the impact of sharing of personal experiences on the perception of privacy and confidentiality by patients. We studied the case of Carenity an online social network created in France in 2011 bringing together 300,000 patients across Europe, and selected patients suffering Multiple Sclerosis. We conducted an exploratory-descriptive survey, and 253 patients completed an online questionnaire. Most participants did not consider that their privacy was threatened when sharing their personal experiences and data associated with their health condition. As common sense prevents one to share information to strangers to ensure privacy, such paradox may be explained by new strategies to face challenges imposed by chronic conditions disease, where sharing personal experiences may be considered as a complementary source of social support by patients.

Keywords. Privacy, Personal data, Online Patient's community.

1. Introduction

The flourishing of social media has allowed the creation of numerous health interactive platforms where "patients and caregivers can share their experiences with others, benefits from the support and knowledge of other users and contribute to large aggregated data archives as part of developing better medical treatments and services and conducting medical research" [1]. More than a decade ago, it was pointed out the need for identifying how these virtual communities helped people in coping with

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complex health issues, such as those present in patients suffering chronic diseases [2], a subject that is still in need of further research for its clarification [3]. Further research is required, also, in order to clarify the impact of these free sharing of personal experiences on the sense of privacy and confidentiality of patients, concerning their health-related sensitive data. It has been mentioned that "if this is the age of information, then privacy is the issue of our time" [4], and this is particularly relevant in the case of healthcare online communities.

In this context we chose to study the case of Carenity [5] an online free social network created in France in 2011 bringing together 300,000 patients across Europe and the US, aimed at connecting people affected by chronic diseases, and we selected patients suffering Multiple Sclerosis (MS) due to the particularities of this chronic, uncommon, and potentially disabling disease. In this study we describe and analyze the perceptions about their participation in the Carenity platform, focusing on their concerns about privacy and trust when they communicate with other participants.

2. Methods

We conducted an exploratory-descriptive online survey, which was applied to Carenity members [5].Those selected were patients suffering Multiple Sclerosis at different states of progression of the disease. The informed consent was obtained when they registered on the website, at the beginning of this study. The survey was designed in order to explore key issues, identified in our previous research [6-8].

We first rigorously and accurately defined the object of the study within our multidisciplinary team composed by ethicians, sociologists, philosophes, physician, pharmacist and medical informatics specialist. A first expert designed the first version of the online questionnaire to the other experts asking them to send their observations and suggestions to highlight convergences and consensus. The first questionnaire, which served as the basis, was enriched at each turn by results and comments generated previously. Several conferences were organized online, by phone or physical meeting.

The resulting questionnaire comprised 17 close-ended and open-ended questions, addressing broad topics. For this survey we selected six close-ended and one open-ended question, in order to explore the added value of the platform in improving the quality of life of the participants and their perception of data protection and privacy. The survey was displayed on the Carenity website during four weeks, for voluntary answer. A total of 253 patients completed the questionnaire online. We performed a descriptive analysis on quantitative data, using simple frequencies and contingency tables for specific variables. The software used was the Statistical Package for Social Sciences Version 22 (IBM Corp: Armonk, NY).

3. Results and Discussion

More than half of respondents (51.4%) declared that platform exchanges of daily experiences provided them psychological support; 43, 9% of the respondents declared, as well, a positive impact on their quality of life as a result of participating on the Carenity. The creation of new relationships within the platform, or outside it, was one of the reasons reported for this favorable outcome (see Table 1).

Only 12.3% declared that the relationship with their treating physicians changed as a result of their participation on the platform. With regard to the confidentiality of the data, 75.5% considered that sensitive data they shared at the site were well protected. This result, added to the high percentage of patients sharing information with other members of Carenity that they would not share with others, is consistent with that finding, reflecting collective trust in the platform, allowing a sense of ownership over the data they post (see Table 1).

Table 1. Added value of the platform to the quality of life of participants and their assessment of confidentiality and privacy.

	Yes (%)	No (%)
Do you consider that the exchanges made within the platform provided psychological support?	130 (51.4%)	123 (48.6%)
Based on your experience, have the exchanges made on this platform had a positive impact on your quality of life?	111 (43.9%)	142 (56.1%)
The use of this platform has been changing your relationship with your doctor/physician?	31 (12.2%)	222 (87.8%)
Would you agree, in the context of this platform, to participate in clinical trials?	152 (60.1%)	101 (39.9%)
Do you consider you are fully or quite well protected with respect to the confidentiality of the data processed on the platform	191 (75.5%)	62 (24.5%)
Do you think that since you are exchanging your personal information about your illness with other people you do not know on the site, your perception of privacy has changed?	45 (17.8%)	208 (82.2%)

Likewise, 82.2% of respondents indicated that their perception of privacy has not changed since they joined the platform. Although some of the respondents manifested restrictions on the personal information they share about their illness with other people they do not know personally, most consider that the exchanges are beneficial in providing emotional support, reinforcing the good sense of trust 75.5% and reciprocity within the platform. Privacy limits blur when patients provide their personal data, voluntarily sharing them with other patients, in order to get useful information for the diagnosis and treatment of their condition. One respondent expressed: **"*I am ready to exchange private information with other patients to better live my illness" (Woman, 33 years old), "Currently I realized that it was not important to keep secret the details of all my affections related to the MS, and the sharing of the info can benefit others having the same symptoms" (Man, 61 years old*).**

Thus, 82.2% of Carenity participants do not consider that by sharing their personal experiences and data associated with their health condition, their privacy is threatened. There is a paradox, however, that should be explained: on the one hand, most respondents declared ***that there was no problem with their privacy and that sharing information would not alter the nature of it,*** on the other, according to common sense, you cannot ensure the privacy of the information you interchange with strangers. It may be argued that the existence of a community of patients, affected by the same anxiety and anguish, occasioned by the same evil, i.e. an unpredictable and potentially disabling condition, created a special sense of trust, amongst a group of otherwise unrelated people [9]. Likewise, the exchange of personal experiences through a virtual community would allow sharing strategies to face challenges imposed by disease, and which can be considered as a complementary source of social support for patients with

MS or other chronic conditions [10]. Until now, to our knowledge no studies were performed to evaluate perception of privacy and data protection by means of online survey in online communities. Considering Multiple Sclerosis the closer work to ours was applied to discussion forums by analyzing thematic issues in posts [10]. Furthermore, they didn't study privacy and data protection issues. As regards online survey a recent study performed by PatientsLikeMe reported benefits of online communities [11] but again didn't consider privacy issues.

The participation in Online health communities like PatientsLikeMe in the USA, and Carenity across Europe and in the US has shown a new active role for patients, involving innovation and value creation in varied areas of healthcare industry, giving a sense of empowerment that differs from the traditional paternalistic conception, granted by healthcare professionals. These horizontal interactions enable patients to share personal information in order to construct a common knowledge, without fear of losing privacy or confidentiality, and allowing the growth of expertise in these communities, giving place to a new era of bottom-up data generation, previously unknown in biomedical sciences [8].

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Applying Deep Learning to Understand Predictors of Tooth Mobility Among Urban Latinos

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Abstract. We applied deep learning algorithms to build correlate models that predict tooth mobility in a convenience sample of urban Latinos. Our application of deep learning identified age, general health, soda consumption, flossing, financial stress, and years living in the US as the strongest correlates of self-reported tooth mobility among 78 variables entered. The application of deep learning was useful for gaining insights into the most important modifiable and non-modifiable factors predicting tooth mobility, and maybe useful for guiding targeted interventions in urban Latinos.

Keywords. Tooth mobility, aging, Latinos, deep learning, symptom science

1. Introduction

Inflammation of the gums (also called 'gingivitis') causes oral health problems, with consequences of the supporting bone structure loss and edentulism. Partial and complete edentulism is also linked to increased risk of heart disease, brain health, and whole body infection [1]. Among ethnic minority groups in the US, Latinos have been reported to have the poorest oral health status [2]. Besides non-modifiable factors (e.g., aging), there are multiple potentially innovative modifiable behavioral factors that may increase risk for tooth mobility such as stress or soda intake. Yet, the most important risk factors for gum inflammation and tooth loss among Latinos living in U.S. urban areas are poorly understood. As historical evidence reports "Modern human skeletons (e.g. teeth) have shifted towards lighter –more fragile when we adopted agriculture (behaviors) 12,000 years ago", it hints to us that looking into aging and behavioral determinants together may have the potential to better understand the determinants of teeth loss. In this study, we applied data mining techniques to explore the extent to which aging, behavioral, and psychological risk factors influence urban Latinos' self-reported gum health as groundwork for future targeted intervention aimed at preventing

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tooth mobility. Deep learning [3] has recently demonstrated the usefulness of big data predictive modeling in the area of image process or speech recognition. Yet deep learning methods have infrequently been applied in medicine compared to their use in industry perhaps in part due to their lack of transparency, leading to challenges in interpreting results [4]. Yet, we propose that health researchers and professionals can benefit from using data mining to more efficiently identify important variables predicting adverse health outcomes, such as tooth mobility, compared with traditional statistical approaches [4].

2. Methods

We applied a data mining process to a community-based dataset to build a model for predicting self-reported gum health after obtaining institutional review board approval. We used Weka 3.8 and Deep Neural Network-BigML software to conduct data mining analyses. We extracted 925 demographic and physio-psycho social variables from survey of 4,623 Latinos in the local REDCap database. First, 78 of total 925 variables were selected by dental and healthy behavior domain experts as potentially relevant to gum health based on the literature [5]. During feature selection, we applied deep learning in BigML and feature subset selection algorithm in Weka, which evaluates the worth of a subset of attributes by considering the individual predictive ability of each feature along with the degree of redundancy between them. The outcome variable was the dichotomized self-reported of non-traumatic tooth mobility ('experience of any teeth becoming loose on their own, without an injury' versus 'no experience of any teeth becoming loose on their own, without an injury'). BigML and Weka with default configuration were chosen to avoid algorithm dependency because selected features can vary by different tools. We applied 1) correlation based, 2) information gain based (entropy), 3) learner based techniques to create different views of the dataset and selected nine final variables based on the criteria of clinical meaningfulness based on an understanding of the literature on reasons for tooth mobility [5]. Next, we organized the variables into three conceptual categories: demographic, psychological, and behavioral factors. Next, we iteratively applied nine data mining algorithms including deep learning algorithms such as Multilayer Perceptron (Weka) and Deep Neural Networks (BigML) to build the prediction models for self-reported tooth mobility among urban Hispanic adults. For cross-validation (10-fold), the dataset was randomly divided into training and evaluating datasets for the model validation before applying the algorithm. We chose the final models based on the model predicative accuracy, interpretability, applicability and clinical meaningfulness, and the area under the receiver operating characteristic curve (AUC). Lastly, dental and behavioral science experts interpreted the models according to clinical meaningfulness.

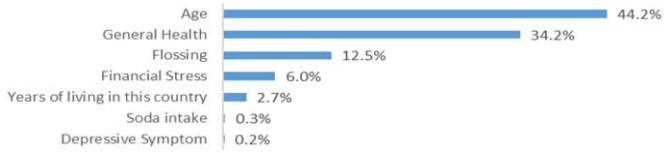

Figure 1. Deep Neural Network Ranking of Factor Importance for Tooth Mobility

3. Results

Study participants (n=4,623), age 18-100 (mean 49.3±16.8) years, were predominantly female (n=3,416, 74.0%), were immigrants (n=3,894, 84.2%), spoke Spanish (n=3,470, n=75.1%), were with limited health literacy (n=3437, 75.3%), and were Medicare/Medicaid beneficiaries (n=3,521, 77.5%). One out of ten participants (n=508, 11.0%) reported that they had experienced tooth mobility. Descriptive statistics for the study variables are summarized in Table 1. Among the factors selected by multiple algorithms, age, acculturation, general health status, soda intake, financial stress, depressive symptom, and flossing behavior were finally selected by dental and healthy behavior domain experts based on systematic review and meta-analysis literature (Figure 1). While physiological factors such as diastolic blood pressure (importance 6.3%) and Body Mass Index (importance 3.9%) also selected by deep learning algorithms, they were excluded in the final prediction model due to their relative lack of interpretability and applicability.

Table 1. Descriptive Statistics for Study Variables (n=4,623).

Variables*	Mean (SD), N (%)
Psychological factor	
Having Financial Stress[a] [Yes]	802 (17.4%)
Depressive symptoms[b] [0-27, 27:worst]	1.8 (SD 4.1)
Behavioral factor	
Flossing [0-51 times last week]	3.5 (SD 3.3)
Soda intake [0-84 times/week]	2.8 (SD 5.1)
General health status	
Excellent	1,069 (23.1%)
Very good	1,126 (24.4%)
Good	1,228 (26.6%)
Fair	1,007 (21.8%)
Poor	106 (2.3%)

[a]Perceived Stress Scale (PSS) (Cohen, Kamarck, &Mermelstein, 1983)
[b]Modified Patient Heath Questionnaire-9 (modified PHQ-9 depression)
*missing data ≤5% except for flossing behavior "don't know" 27.6%, "refused" 2.3%

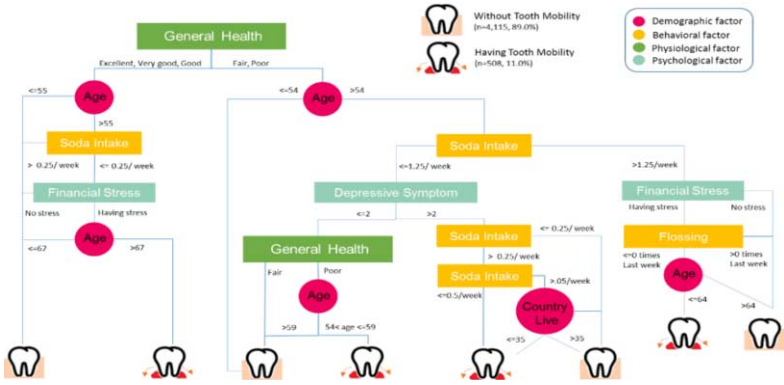

Figure 2. A Prediction Model (J48) for Self-Reported Tooth mobility (model accuracy: 88.4%, Precision: 0.83, Recall: 0.88, F-measure: 0.84, ROC area: 0.72)

4. Discussion

Among the many risk factors for tooth loss, deep learning found that aging was a key determinant (variable importance: 44.2%, Figure 1) among Latinos living in the US. Consistent with a long history of archeological and epidemiological findings, aging is a consistent determinant of tooth mobility. This study found that Latinos under 55-year-old (figure 2) were likely to have no tooth mobility regardless of their general health conditions, whether reporting that they are sick or are healthy (n=2,724). This study found soda intake behavior among age over 55 is a determinant of tooth mobility (figure 2). This finding is consistent with the literature, including the historical findings. Archeological evidence reports association between carbohydrate-heavy diet resulting from agriculture (behavior) and tooth decay [6]. The novel finding reported here concerned financial stress. For those who were considerably younger, and who had relatively increased soda intake, the presence of financial stress increased the probably of tooth mobility (figure 2). Consider the paths among these predictors will be an important next step. Is it the patients who cope with financial stress by increasing soda intake who have the most tooth decay? If so, such a pattern would suggest coping enhancement and behavior substitution as treatments when financial stress occurs, rather than straight dietary advice. Targeting patients who are 45-50 may be more appropriate for such an intervention. Deep learning has several practical and methodological limitations. Deep learning requires substantial computing time and years of training for engineering. Although optimizing multiple parameters can be challenging, this study used the Deep Neural Network function in BigML which offered a user-friendly automatic optimization options (e.g., setting up the appropriate number of hidden layers) to help us discover the best parameterization during our network search. Most of all, the biggest limitation is the lack of transparency and interpretability of the prediction model. The combined use of traditional machine learning algorithms such as C4.5 and Deep Neural Network in BigML is suggested for similar studies as Deep Neural Network in BigML offers the automated parameters customized to a user's dataset without engineering expertise. Our deep learning algorithm revealed aging, general health, soda intake, flossing behavior and financial stress as the strongest risk predictors of self-reported tooth mobility among Latinos living in a US inner city. This new knowledge adds insights about dental symptom science and aging for future intervention development.

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Designing Interaction and Guidance Technologies for Remote Consultations in Healthcare

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Abstract. We present our work in designing mobile interaction and guidance technologies for the application of remote consultation between healthcare professionals. We describe design case studies which address the needs and scenarios in this application: a hybrid and rich media tool which supports mobile one-on-one consultations; a remote guidance tool which allows an expert to remotely guide a nurse or junior clinician to perform clinical procedures; an integrated collaboration platform which supports remote consultations in a group meeting environment by enabling shared interaction with patient records and mobile interaction with large displays. These tools have been evaluated in usability studies in which the usefulness and potential value have been demonstrated. By presenting these case studies, we highlight the trend of incorporating emerging collaboration technologies and the need of integrated and multi-model interaction systems in a broader telehealth context.

Keywords. Remote consultation, interaction, remote guidance, healthcare

1. Introduction

Healthcare professionals, such as general practitioners and nurses, in rural and under-resourced regions often face the challenges of infrequent access to senior colleagues and inadequate availability of medical specialists in the regions. There are also particular challenges of improving the skills of these healthcare professionals, especially community health workers who are trained to assist the delivery of healthcare services at patients' homes. Telehealth supported by collaboration technologies has been used to address the challenges and provide remote expert consultation, support and guidance [1].

There are two types of remote consultation scenarios. One is one-on-one consultation which involves a single clinician at each site. The second is consultation meeting which involves a group of participantsat one site or two sites and normally has an education component. There are two broad interaction needs to be addressedin both scenarios. One is to share information and discuss patient cases with remote experts. The second is to allow remote experts to guide clinical procedures, such as wound dressing, physical examination of patients and the operation of medical instruments.

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With the availability of improved network, advanced systems and technical innovations have been developedto support telehealth [2]. Traditional video conferencing type of telehealth is increasingly enhanced by new technologies, such as mobile technology and augmented reality [2,3]. Research has also drawn attention to incorporating advanced interaction techniques and multi-modal interactions [2,4].

In this paper, we look at design case studiesin which mobile interaction and guidance technologies have been designed and have potential to address the particular remote consultation needs. By presenting these case studies of our work, we discuss the trends in designing interaction technologies for telehealth applications.

2. Case studies

We describe the design of three case studies. The first two case studies, a mobile collaboration tool and a remote guidance tool, are related to the one-on-one consultation context. The third case study, an integrated collaboration platform, is related to the context of group meeting consultation. Each design addresses different interaction requirements and scenarios and represents the following themes of technology design.

2.1. Mobile communication and hybrid approach

Mobile communication devices enabled by Internet, social media and sensors has brought opportunities of going beyond traditional clinic and hospital-based episodic care to a broader community care [1]. The "Hybrid" approach of combining real-time and asynchronous modes of telehealth in one system has been considered as an efficient way to fit with clinicians' workflow [5]. The usefulness of rich media contents as proxies for asynchronous interactions have been demonstrated in various environments.

We have designed a mobile collaboration tool to be used by a mobile health worker to discuss patient details with a remote expert when providing care to patients [6]. This tool uses hand-held tablet devices as a hardware interface on both the health worker and the expert sides since tablet devices are convenient to carry around. The tool supports real-time interactions between the two sites: video conferencing communication; live videos of patient details captured by the camera of the tablet device; share documents and patient information collected from various data resources; real-time pointing and annotation on the shared documents. Further, this tool also supports asynchronous interactions in which rich multimedia information can be captured and recorded for later review as remote experts are not always available when a consultation is needed. For example, a local clinician can use the tool to display patient images and draw annotations on them. This process can be video-recorded with the audio of the clinician and sent to an expert who can then review it and respond whenever it is convenient by sending back a new rich media reply.

2.2. Remote guidance and rich hand gesture over distance

The need of guidance in remote consultations is related to a body of research in designing technology to enable remote guidance on physical task between a helper and

a worker [7]. To support remote guidance, a shared visual space needs to be created to build a common ground, which is often done by overlaying a pointer, sketches, or the helper's hands over the video of the worker's workspace.

The remote guidance tool we have developed for health consultation is an adapted version of the ReMoTe technology [3] in the context of learning of clinical procedures [8]. This tool allows a remote expert to use his/her hands to perform guiding gestures. The hand gestures are combined with the video of the patients or other physical objects to form a view of gesturing over patients or objects for both of the remote expert and the health worker to see. This tool is a wearable solution that addresses the needs of hands-free and ease-of-access to visual information when a health worker performs clinical procedures on a patient. More specifically, a health worker wears a headset unit and the physical task is captured by the camera mounted on the unit and sent to the expert. The unit has a near-eye display from which the health worker can see the visual guidance with gesturing information sent from the expert side. The microphone and headphone enable verbal communications between them. The expert can see the physical task video displayed on a large titled display and can use his/her hand gestures over this video which is in turn captured and displayed to the health worker.

2.3. Shared interaction, secure access and mobile interaction

Recent research has investigated the integration of shared digital workspace in telepresence large display environment [9]. Systems of this type allow shared interaction and simultaneously display of various information, such as videos, images and documents. The design practices have also paid particular attention to the physical geometries of these environments. Incorporating handheld tablet device for individual meeting participants to interact with the displays has been demonstrated in multi disciplinary medical team meetings [10]. The collaboration platform we have designed integrates telepresence audio-video communications with a shared interactive workspace [11]. By installation of the workstation at each site, the platform allows real-time shared interaction with patient records, medical images and educational materials from different repositories and resources. The shared workspaces run as VNC servers and a central unit controls login and distributes configuration information. The physical setting of the workspace, such as the position of the cameras and how the remote participants' video is displayed, has been carefully configured to support telepresence communication and digital interaction for the distributed participants. The platform also integratesaccess control technology [12]. The authentication and authorization technology allowsparticipants at each siteeasily access the platform using individual RFID cards without typing in user name and password. Meeting participants are also authorised to interact with specific patient resources. This minimises the risk of manipulating sensitive medical information during the remote shared interactions in meetings involving clinicians with different roles and skills. We have explored the use of tablet device to interact with the displays of the platform [13]. Tablet device can beused by participants as a personal navigation tool and as a gesturing tool to allow synchronization of annotations on the tablet device and large displays. Our design supports efficient control of the views on the tablet devices which show the contents of the shared workspace. It allows an intuitive way of navigating between different areas of the shared workspace, zooming in areas for a closer look, and switching to the same view which their remote clinicians focus on.

3. Discussions and Concluding Remarks

Telehealth is an open and constantly evolving science. There are coupled evolution of telehealth through the space spanned by clinical applications and technology [4]. Developing suitable technologies to support collaboration and consultation in healthcare is a complex task. It requires thorough understanding of use cases, careful design considerations, effective implementation with proper hardware devices, and usability testing throughout the development process. The complexity also includes supporting the interactions entailed in the applications, such as communication, guidance, gesture, pointing, annotation, mobility and flexibility. We have explored design solutions to address the interaction requirements in remote consultations between healthcare professionals. The solutions are built using either emerging technologies, such as mobile and wearable devices, or innovative combination of traditional technologies with software techniques we developed. These tools have been evaluated in usability studies in which the usefulness and potential value have been demonstrated (e.g.,[3,6,11,13]). As future work, we will continue the exploration of the design in this space, conductuser studies to verify the usage and usability of these technologies, and to extend the investigation toa broader telehealth context and various applications.

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Evaluating the Impact of Incorrect Diabetes Coding on the Performance of Multivariable Prediction Models

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Abstract. The use of electronic health records for risk prediction models requires a sufficient quality of input data to ensure patient safety. The aim of our study was to evaluate the influence of incorrect administrative diabetes coding on the performance of a risk prediction model for delirium, as diabetes is known to be one of the most relevant variables for delirium prediction. We used four data sets varying in their correctness and completeness of diabetes coding as input for different machine learning algorithms. Although there was a higher prevalence of diabetes in delirium patients, the model performance parameters did not vary between the data sets. Hence, there was no significant impact of incorrect diabetes coding on the performance for our model predicting delirium.

Keywords. delirium, ICD coding, predictive modelling, electronic health records

1. Introduction

Nowadays, statistical methods are able to support clinicians in real time decision making, for example with risk prediction models. Risk prediction models help stratifying patients in different groups according to their risk for the occurrence of an event. The advantage of using electronic health records (EHRs)for such models is the big amount of collected data at several time points [1]. The use of EHRs has grown in the past years, but no consensus has been found whether the reuse of clinical data satisfies research standards. Incorrect or missing data may lead to biases [2] and one known source of such biases is the assignment of disease codes by physicians [3].

Although the impact of noise in an outcome variable of a prediction model on its performance is well understood, there is less research on the impact of noise in features of such models [4]. Zhu and Wu [4] state that noise correction can enhance the accuracy of a model and the higher the correlation between a feature and the outcome, the more important it is to handle noise in features. Previous studies showed that data pre-processing such as outlier extraction or imputation of missing values improves the performance of prediction models [5].

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Recently, we developed a model predicting the occurrence of delirium, a life-threatening condition in geriatric patients [6]. For delirium prediction, ICD-10 coded diabetes mellitus was one of the features with the highest variable importance. This result is concordant with previous literature revealing diabetes as a risk factor for delirium, e.g. for delirium after cardiac surgery [7].

However, ICD-10 codes may be sources of incorrect data in EHRs. Several studies have addressed incorrect or incomplete coding of diabetes, in particular distinguishing between different types of diabetes [8]. Especially coding of patients with type 2 diabetes as having type 1 diabetes occurred as a problem in ICD-coded diabetes data sets [9]. Our own evaluation of the EHR data used for previous modelling confirmed the phenomenon of incorrect coding: For 16.9 % of more than 86,000 diabetes patients, diagnosis codes for both type 1 and type 2 were found across their clinical history.

While misclassification may result in inappropriate clinical management [8], incorrect coding may influence the outcome of risk prediction. To our knowledge, the impact of diabetes miscoding on predictive modelling has never been studied on real-world data. Therefore, we aimed to investigate such an impact using data sets with different noise levels of diabetes coding as an input for delirium prediction. Furthermore, we examined the relationship between diabetes and delirium in our data.

2. Method

2.1. Original Data Set

The analysed data belongs to *Steiermärkische Krankenanstaltengesellschaft m.b.H* (KAGes), the regional health care provider in Styria (Austria). It was taken from the KAGes HIS *openMEDOCS*, based on IS-H/i.s.h.med information systems, implemented on SAP platforms. The study cohort included in-patients diagnosed with the ICD-10 Code F05 ("Delirium due to known physiological condition"; alcohol-induced delirium excluded), staying at one of the KAGes hospitals within 2012 and 2016. A control group of randomly selected patients was added to the data set. Inclusion and exclusion criteria as well as feature selection for modelling were based on prior research [6]. We used the variable importance of a previous model to select features within ICD-10 diagnoses, demographic data and computed variables, e.g. length of stay, as we assumed these variables to be lower in noise. The data set resulted in 18 features for prediction and anonymised data of 29,568 patients including 4,596 patients with diagnosis of delirium. To assess the relationship between delirium and diabetes mellitus, we compared the prevalence of diabetes in patients with and without delirium, standardised by age.

2.2. Data Manipulation

For modelling, we used four different data sets varying in correctness and completeness of diabetes diagnoses, resulting in one to four additional features. (1) Data set 1 included original EHRs; features with contradicting ICD codes were possible. (2) In data set 2, one feature represented any existence of diabetes. (3) In data set 3 only diabetes type 1 or type 2 was allowed for each patient. This required manual data cleansing based on lab parameters, antibodies, c-peptide, as well as free-text entries. (4) Data set 4 was equal to data set 1 but without any feature representing diabetes.

2.3. Predictive Modelling

For each of the four data sets we ran three machine learning (ML) methods for classification which showed good results in our previous research on delirium prediction [6]: random forest (RF), neural network (NN), and generalized linear model with elastic net penalty (GLM). Model performance for each method was evaluated using accuracy, sensitivity, specificity and area under the curve (AUC).Confidence intervals for these parameters were calculated using boosting methods.

Modelling and analyses were computed in R using the caret package [10] and associated packages. All methods were trained with a 10-fold cross validation [11]. We used 75 % of the data for training and tested the results on the remaining 25 %.

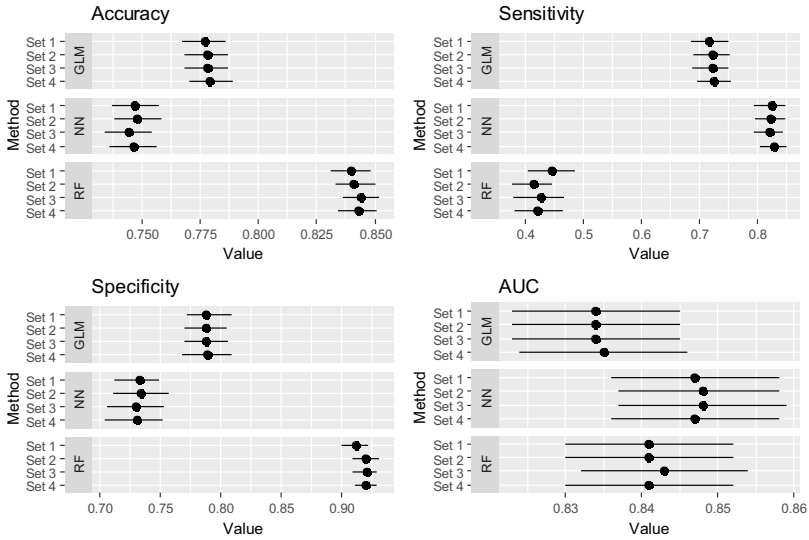

Figure 1. Model performance parameters using different data sets and methods for delirium prediction.

3. Results

The age standardised prevalence of diabetes in the delirium group was 16.3 % [14.6, 20.8], and 9.9 % [9.4, 10.4] in the group without delirium.

A comparison of the model performances of the four data sets and three methods is shown in Figure 1. First, we compared the different data sets within the ML methods. The data sets did not differ significantly in any model performance parameter, as indicated by the overlapping confidence intervals.

Second, we analysed differences between the three ML methods. RF achieved the best model accuracy and highest specificity; however, this was at the expense of low sensitivity. Accuracy and specificity were a bit higher for GLM than for NN, but NN achieved a higher sensitivity. All models achieved an AUC over 0.83.

4. Discussion and Conclusion

Our objective was to evaluate the impact of diabetes coding quality on the performance of prediction models for delirium. We found a significant relationship between the occurrence of delirium and diabetes, nevertheless all methods proved robust against changes in diabetes coding. Although the models consisted of few features, different noise levels in diabetes coding had no impact on the performance. This enables us to use prediction models even in case of missing values, e.g. missing diabetes diagnoses. Nevertheless, one should always aim for a complete medical history of a patient.

Some limitations of our work need to be considered. First, even though diabetes is a risk factor for developing delirium, diabetes prevalence in general is quite low. This may reduce the effect of incorrect coding on modelling. Second, changes in numerical features may be more relevant than changes in categorical features, as for numerical features more different values are possible.

Our results contribute to understand the influence of incorrect coding on risk prediction models. We believe that the use of such models will get more frequent in clinical routine and therefore a high understanding of the underlying data is essential to ensure patient safety.

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Machine Learning to Identify Behavioral Determinants of Oral Health in Inner City Older Hispanic Adults

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Abstract. We applied machine learning techniques to a community-based behavioral dataset to build prediction models to gain insights about minority dental health and population aging as the foundation for future interventions for urban Hispanics. Our application of machine learning techniques identified emotional and systemic factors such as chronic stress and health literacy as the strongest predictors of self-reported dental health among hundreds of possible variables. Application of machine learning algorithms was useful to build prediction models to gain insights about dental health and minority population aging.

Keywords. Dental health, population aging, Hispanics, deep learning

1. Introduction

Dental conditions disrupt quality of life among older adults. Aging is associated with recession of gum, loss of tooth, root caries, dry mouth, periodontitis and gingivitis leading to pain and inadequate nutrition [1]. Hispanics comprise a fast-growing ethnic group yet have one of the poorest dental health conditions among any racial or ethnic groups in the U.S. [2]. While Healthy People 2020 aspires to the elimination of dental health disparities, limited access to dental care persists within the U.S, resulting in profound, continuing dental health disparities [1,2]. In this study, we applied machine learning techniques to explore variables that are associated with urban Hispanics' dental health among older adults as a foundation for future targeted intervention development. The Washington Heights/ Inwood Informatics Infrastructure for Comparative Effectiveness Research (WICER) [3] project built an informatics infrastructure to understand health behaviors to improve the health of an urban underserved population dwelling in northern Manhattan in New York City. The WICER dataset is available to investigators within the institution, and those outside of the institution with data use agreement and institutional review board approval. One component of the infrastructure is a survey which was collected by bilingual

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community health workers. The WICER survey dataset contains 925 variables from 5429 Hispanics including physiological, environmental, behavioral, patient-reported outcomes, and sociodemographic factors [3].

2. Methods

Machine learning techniques offer power to search numerous possible relationships and efficiently remove redundant variables among hundreds of variables. The socio-ecological framework and the data mining process model [3] guided our analytic process. The data mining process includes: 1) understanding the problem, 2) understanding data, 3) preprocessing data, 4) reducing dimensionality, 5) applying mining algorithms, and 6) interpreting results. We applied machine learning techniques to the WICER dataset to search and evaluate attributes among 925 variables and to build a risk behavioral model. We used Weka 3.7.12, a collection of machine learning algorithms and BigML for our analytic process. We extracted 925 variables for 5429 Hispanics from the local REDCap database and queried 2007 records of Hispanics older adults (age ≥55). During the prime filtering, 80 of total 925 variables including demographics, predisposing and enabling factors (e.g., The Newest Vital Sign score for health literacy) were selected as relevant based on the literature [4]. During feature selection, we applied six machine learning algorithms to remove redundant variables and select variables that are strongly correlated to the dichotomous dependent variable ('good self-rated teeth and gum health' versus 'poor self-rated teeth and gum health'). Six machine learning algorithms with default configuration in Weka and a deep learning algorithm (deep neural network) in BigML were chosen to avoid algorithm dependency because selected features can vary by machine learning algorithm [5]. We iteratively selected nine final variables based on the criteria of clinical meaningfulness and identification in multiple of the six algorithms. We then organized the variables into four conceptual categories: emotional, behavioral, systemic (issues inherent in the overall socio-structural system rather than due to individual factor), and environmental factors. Next, we iteratively applied ten data mining algorithms in Weka (J48, ADTree, DecisionStump, RandomForest, BayesNet, SMO, AdaBoost M1, Bagging, PART, Random Tree) [5] using the top features to build the prediction models for self-reported dental health among Hispanic older adults. As with feature selection, we used multiple algorithms to avoid algorithm dependency. For 10-fold cross-validation, the WICER dataset was randomly divided into training and evaluating datasets for the model validation before applying the algorithm. We chose the final models based on predictive accuracy (i.e., correctly classified survey participants), the area under the receiver operating characteristic curve (AUC), and the model interpretability. Last, we interpreted the models according to clinical meaningfulness and applicability.

3. Results

Study participants (n=2,007), age 55-100 (mean 65.3 ± 7.8) were predominantly female (n=1,484, 73.9%) and Spanish speaking (n=1,222, 60.9%), an education level of eighth grade of less (n=1,045, 52.1%), and with a poor health literacy score. One third (n=683, 34.0%) of the participants reported that they perceived themselves as having

'poor teeth and gum health.' Table 1 summarizes descriptive statistics for study variables. Health literacy score, depressive and anxiety symptoms, the availability of large selection of fruits and vegetables in neighborhood (environmental factor) were the variables selected by at least five machine learning algorithms (Figure 1).

Table 1. Descriptive Statistics for Study Variables (n=2,007)

Variables*	Mean (SD), N (%)
Emotional factor	
Perceived Stress[a] [0-5, 5: worst]	0.6 (SD 1.0)
Anxiety symptoms[b]- days of having anxiety symptoms last month [0-30 days, 30: worst]	3.5 (SD 7.4)
Depressive symptoms[c][0-27, 27:worst]	2.2 (SD 4.6)
Behavioral factor	
Smoking (100 cigarettes) in life	N=263 (13.1%)
Sugary beverage consumption [0-70 times/week]	2.9 (SD 4.3)
Societal factor	
Health literacy[d][0-6, 0:limited health literacy]	1.7 (SD 1.8)
Environmental factor	
Fruits and vegetable available in the neighborhood Strongly agree 746, (37.5%), Agree 960 (48.3%), Disagree 239 (12.0%), Strongly disagree 44 (2.2%)	

[a]Perceived Stress Scale (PSS) (Cohen, Kamarck, &Mermelstein, 1983)
[b]Centers for Disease Control and Prevention Health-related quality of life (CDC HRQOL-14)
[c]Modified Patient Heath Questionnaire-9 (modified PHQ-9 depression)
[d]Newest Vital Sign-Health literacy (Weiss et al., 2005)
*missing data ≤1% except for chronic stress (3%), depressive symptom (4%) and anxiety symptom (5%)

While self-reported general health was depicted as a strong factor by four algorithms, it was excluded in the final prediction model because the concept of self-reported general health likely overlaps with self-reported oral health.

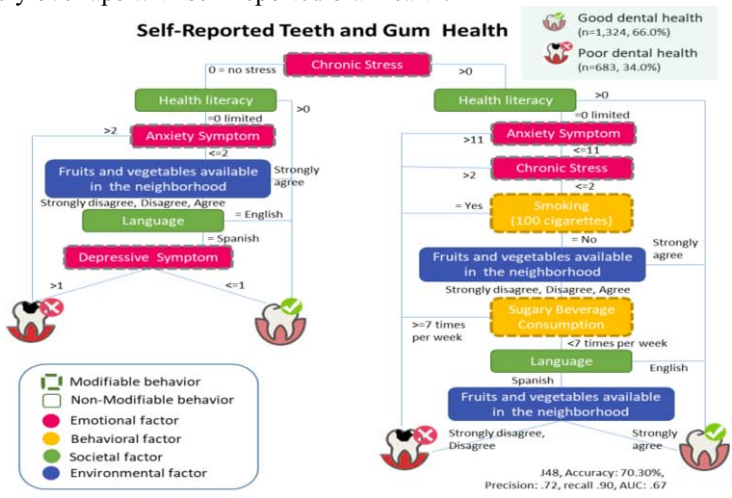

Figure 1. Prediction models for self-reported Teeth and Gum Health

This study mainly found that among the participants with low perceived stress and limited health literacy (n=523, 26%), the prediction model in Figure 1 shows that individuals experiencing anxiety symptoms more than 2 days in last month were more

likely to report 'poor dental health', while individuals experiencing less frequent anxiety symptoms (<=2 days last month) were more likely to report 'good dental health' if large selection of fruits and vegetables are available in their neighborhood.

4. Discussion and Conclusion

Among many risk factors, we found that emotional factors such as anxiety and depressive symptoms (red) and health literacy (green) were more strongly associated with self-reported dental health compared to other demographic or physiological factors among Hispanic older adults living in New York City. This is consistent with previous epidemiological findings among other ethnic/racial minorities in New York City [1], showing that low health literacy can adversely influence dental health outcomes. A large body of literature reports on the association between compromised dental health literacy and poor dental health outcomes. This study adds to that body of literature by revealing that health literacy using a common Newest Vital Sign tool was a main predictor of poor dental health among Hispanic older adults, when evaluating hundreds of competing variables in our machine learning models. In this study (Figure 1), individuals who had the worst score in the health literacy, were less likely to report 'good dental health' regardless of the level of chronic stress. Yet, one of the greatest challenges facing dental medicine continues to be the lack of diversity in the providers; providers from diverse ethnic backgrounds with cultural competency may be best suited to bridge the health literacy gap for these patients as future work [1]. Machine learning [5] was useful for efficiently removing redundant variables and for building prediction models for self-reported dental health from a large and complicated dataset with over 900 variables. Data visualizations (e.g., tree infographics) of the prediction model results were helpful to detect patterns and gain insights about risk factors for minority population dental health. Addressing health literacy through improved communication skills at the dental system level as well as through addressing inequities in education at the systems level may reduce disparities in dental health. This study was conducted in a single city where predominantly represents limited ethnicities. The machine learning including deep learning techniques revealed health literacy and emotional factors as the strong risk predictors of self-reported dental health among urban Hispanic older adults. This new knowledge adds insights about dental health and minority aging population for future intervention.

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Understanding the Roles of EMR Systems in Japanese Antenatal Care Settings

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Abstract. Electronic Medical Records (EMR)s are intrinsic to modern-day clinics. Understanding the *roles*, i.e., the unintended functions of EMR systems in their context of use can guide the design of EMR systems and clinics to better integrate them. To understand the *roles* of EMR systems in antenatal care check-ups, we conducted a field-based observational study at an antenatal care clinic in a Japanese university hospital. We observed 37 antenatal care check-ups where we looked at how the EMR system affects the communication between the involved parties and supports or hinders the clinical process. Our data analysis resulted in 10 EMR *roles*, namely: *the wingman, the third wheel, the accomplice, the bouncer, the messenger, the summarizer, the bureaucrat, the assistant, the gossip,* and *the alien*. Through the *roles,* this study reveals multiple EMR design considerations and opportunities for improving both the human-EMR and human interactions in antenatal care settings.

Keywords. Electronic Medical Records, Antenatal Care, Roles, Japan

1. Introduction

The main intended function of Electronic Medical Record (EMR) systems is to support the care process by allowing access to the patients' medical records [1]. However, clinicians had voiced concerns over the use of EMR systems affecting their communication with the patients [2] and hindering their existing clinical processes [3]. Thus, it is safe to assume that like any other artifact, an EMR system has its *uses* i.e., intended functions and its *roles* i.e., unintended functions [4]. The *uses* of an EMR system are usually decided by the implementers and are known prior to the implementation of the system in its context of use. However, the *roles* are mostly unknown to the implementers since they start to emerge and develop with time after the EMR system is implemented and used. Multiple unintended ways of using an EMR system could exist, for example, using it as an explanation support tool to visually communicate information to the patient. Understanding the different possible *roles* of EMR systems in their context of use would allow us to improve the design of EMR systems by reducing the unfavorable *roles* and magnifying the favorable *roles* [5].

In this study, we conduct a field-based observational study to understand the *roles* of EMR systems in antenatal care settings. The research question central to this work

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is: *What roles does the EMR system play in regard to the communication and the clinical process during the antenatal care check-ups?*

Most work aiming at improving EMR systems did not focus on specific clinical contexts and results in general EMR system requirements [6]. The importance of studying EMR systems in antenatal care settings derives from the uniqueness of the antenatal care context in terms of process and aims. Antenatal care is a routine, periodic, and systematic process making it longer and more structured than other care processes. Thus, the difficulty of designing EMR systems for unstructured and highly variable care processes can be alleviated. Moreover, unlike medical processes where the main goal is curing a patient, the purpose of antenatal care is the prevention and early detection of diseases that might affect two entities: the pregnant women and their fetus. Also, the pregnant women are encouraged to be highly involved and actively exchange information with their providers. As for their partners and family members, it is common for them to be involved and to accompany the pregnant women to the routine visits. In this sense, antenatal care settings are unique where the care providers and receivers do not fall into the usual `clinician-patient' scheme.

2. Methods

To gain an initial understanding of the antenatal care process, we conducted a review targeting the existing literature on the antenatal care process in Japan [7]. We then observed a team of obstetricians, midwives, and nurses providing antenatal care services at a Japanese university hospital. After obtaining the approval of 3 obstetricians to observe check-ups during their shifts, one researcher visited the antenatal care outpatient clinic two times a week over a period of three weeks.

In the observed clinic, there are two desks with computer terminals. One desk is used by the obstetrician and the other by the midwife. The room layout is 'semi-inclusive patient controlled' where the pregnant women can move their direction of gaze to see the EMR screen [5]. At the beginning of the check-ups, the obstetricians asked the pregnant women and their companions for their approval over having the researcher observe and take notes. In total, the researcher observed a team of 3 obstetricians, 6 midwives, and several nurses performing 37 antenatal care routine check-ups for 35 different pregnant women between their 8th and their 33rd week of pregnancy. After each observation, one researcher transcribed the field notes and imported them into QDA Miner, a qualitative data analysis tool. To identify the *roles,* we followed the 6 phases of inductive thematic analysis: familiarization with data; generation of initial codes; searching for themes among codes; reviewing themes; defining and naming themes; and producing the final report [8].

To familiarize ourselves with the data, while making the observations, a team of two researchers met regularly to discuss the observation findings. Once the observations were completed, one researcher coded the data over two iterations using QDA Miner. The initial codes were: (i) facilitates communication, (ii) hinders communication, (iii) facilitates process, and (iv) hinders process. In the second iteration, they used more detailed codes describing the ways the EMR system affected the communication and the clinical process. After the coding process was finished, we searched for the themes. Some codes were merged to form a theme, while other codes individually formed a theme. The themes were reviewed and discussed until an

agreement was reached between the researchers. Once agreed upon, the themes were clearly defined and named to reflect the EMR system's roles.

3. Results

We found that the EMR system plays four different *roles* in regard to the communication between the providers, the pregnant women, and their companions: (i) *the wingman*, (ii) *the accomplice*, (iii) *the third wheel*, and (iv) *the bouncer*. The *roles*, their purpose, and their overall effects are shown in Table 1. `+' indicates that the *role* has an overall positive effect and can be regarded as favorable. `-' indicates that the *role* has an overall negative effect and can be regarded as unfavorable. Regarding the clinical process, we found that the EMR system plays six different *roles*: (i) *the messenger*, (ii) *the summarizer*, (iii) *the assistant*, (iv)*the gossip*, (v)*the alien*, and (vi) *the bureaucrat*. Table 2 shows the *roles*, their purpose, and their effect.

Table 1. EMR system's *roles* in regard to communication

Role	Purpose	Effect
The wingman	Supports the obstetricians in the explanation process.	+
The accomplice	Helps pausing the communication with the pregnant women.	+/-
The third wheel	Distracts the obstetricians from communicating with the women.	-
The bouncer	Physically excludes the pregnant women and their companions.	-

The wingman was clear in situations where obstetricians pointed towards EMR notes or used automatically generated charts while communicating information to the pregnant women. The ambivalent *role*, *the accomplice*, was created by the obstetricians when they resorted to the EMR to pause the interaction or to avoid certain heavily emotional interactions. We regard it as ambivalent since it can be viewed as favorable from the obstetricians' point of view, but unfavorable from the pregnant women's point of view. *The bouncer* was detected when the pregnant women and their companions showed interest but were unable to look at the EMR screen due to their assigned seat. *The third wheel* was a result of obstetricians spending major time facing the EMR.

Table 2. EMR system's *roles* in regard to the clinical process

Role	Purpose	Effect
The messenger	Enables the communication of information between the involved parties.	+
The summarizer	Provides a quick summary of the pregnancy's state and care course.	+
The assistant	Facilitates the check-ups' management and preparation.	+
The gossip	Is not completely trusted by the staff with sensitive information.	-
The alien	Has low learnability, requires recall, and does not support routine tasks.	-
The bureaucrat	Requires the providers to halt the clinical process to report data.	-

The messenger was identified when intra-department communication of the pregnant women's health data took place via the EMR notes. *The summarizer* was identified when one obstetrician noted that: '*We would like to see the course of care in one glance'*. And *the assistant* was identified when the list of scheduled check-ups was used to estimate the day's workload and adapt the length and speed of the check-ups.

The gossip was identified when the staff either did not add psychosocial information into the EMR or tried to document them indirectly using internally agreed upon codes when the information was judged as sensitive or controversial. *The alien* was identified when usability issues were observed and the difficulty of learning how to use the EMR system was noted by an obstetrician during discussions. *The bureaucrat* was identified when the providers halted the clinical process multiple times in order to input data.

4. Discussion

The favorable *roles* are created by the obstetricians and assigned to the EMR system to achieve a certain purpose. On the other hand, the unfavorable *roles* are mainly a result of the design of the EMR system and the design of the clinic. They can be considered as imposed *roles*. For example, *the alien* is imposed by the EMR system's interface design. *The third wheel, the bouncer,* and *the bureaucrat* are imposed by the EMR system's design, the clinic's design to integrate it, and the non-integration of the used medical devices with the EMR system. *The gossip* could be imposed by the EMR system's design as it might be creating a feeling of distrust for the medical staff. However, it can be argued that *the gossip* is rather a result of the medical staff's uncertainty regarding the laws governing healthcare data. Through *the gossip,* this study highlights the inability of the current system to support the documentation of sensitive psychosocial information. The importance of exchanging psychosocial information is especially clear in cases of concern over Domestic Violence (DV). In Japan, 1 in every 20 pregnant women may experience DV [9], and addressing it is particularly difficult because Japanese people value endurance and keeping family secrets [10]. The ambivalent *role, the accomplice*, presents a possible conflict between the needs of healthcare providers and patients, and highlights the need to consider both sides during the EMR system's design phase.

A limitation of this study is the sample size and the observations' length. Additionally, in their current state, the *roles* are solely the result of observational data. In our future work, we will survey pregnant women and antenatal care staff to further understand and validate the extracted EMR system's *roles*. Our future work will also investigate the interactions between the *roles.* The analysis of the *roles'* interactions would allow us to find the *roles* with bigger cascade effects on the system, and therefore could be considered as higher priority design targets. Finally, even though these *roles* were identified in Japanese antenatal care settings, this study may provide valuable insights for designing EMR systems in various clinical settings.

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Identifying Biomedical and Health Informatics Competencies in Higher Education Curricula

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Abstract. This study describes the knowledge, skills and competencies found in bachelor's degree curricula for health and social care, engineering and business. The International Medical Informatics Association (IMIA) biomedicine and health information (BMHI) management recommendations was used as a framework to analyse bachelor´s degree curricula (n=14). The results showed that the curricula contained a variety of subjects related to competencies in the IMIA´s BMHI. The information technology (IT) engineering curriculum included the highest number of competencies and the business curricula the fewest. The nursing curricula included more competencies than any other health care curricula. When educating students in various professions, their diverse backgrounds and expertise must be considered. As future eHealth developers, students will learn to work as multi-disciplinary teams.

Keywords. Competence, multidisciplinary, higher education curricula, informatics

1. Introduction

According to the European Commission (EC), information and communication technology (ICT) can be the most powerful tool in maintaining cost-effective, high-quality care. The cross-border challenges among health care personnel are insufficient skills and a lack of motivation to take part in the digital world [1,2]. The European Qualifications Framework (EQF) is a general framework of vocational qualifications for competencies, at eight levels. The EQF defines competencies, skills and knowledge related to all degrees [3]. The European Computer Driving License (ECDL) [4] model is the standard for proficient ICT use and delivering certification worldwide. Several actions have focused on developing competencies for eHealth adoption in health care. The Technology Informatics Guiding Education Reform (TIGER) defines nursing informatics competencies [5]. The International Medical Informatics Association (IMIA) has issued recommendations for teaching biomedicine and health information

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management (BMHI) to health care and IT professionals. The purpose was to facilitate and standardize multidisciplinary curricula in BMHI [6]. The aim of this study is to describe the knowledge, skills and competencies in bachelor´s degree curricula in health and social care, engineering and business.

2. Methods

Data was collected in the fall of 2015 by using an e-questionnaire that included the following items: background information (n=9), the ECDL [4] (n=31) and the IMIA´s BMHI [6] recommendations (n=48). The total number of items was 88. The respondents represented four institutions of higher education: two from Finland and one each from Latvia and Estonia. The 14 curricula were divided into four groups: nursing, which included midwifery (n=6); other health and social care (n=5); IT (n=1); and business (n=2). The IMIA part has been recorded in Table 1 below, using descriptive quantitative analysis. The ethical guidelines encompassing all parts of the research, from design to truthful results, were incorporated as principles of the research conducted and documented. Additionally, each school granted a research permit for the study, and teachers responded to the study based on the curriculum of their program. The first author analysed the data, and data analysis focused on the IMIA's recommendations for BMHI education IT user level [6].

3. Results

Table 1 presents the quantitative results from 1) BMHI core knowledge and skills; 2) medicine, health, biosciences and health-system organization; and 3) informatics, computer science, mathematics and biometry of data analysis on IT user level. The options for answering questions were 'yes' or 'no'. The numbers for each curriculum refer to the number of 'yes' answers.

4. Discussion

The content of IMIA's BMHI curriculum [6] is known worldwide and often facilitates discussions of developing better eHealth and eWelfare services. The EC eHealth Action Plan states that professionals must be competent in research, development and innovation in addition to content knowledge of eHealth [1].

The eHealth aspects of the IMIA's BMHI [6] are covered in the curricula for IT engineers, nurses and other social and health care professionals, but they are less present in the Bachelor of Business Administration (BBa) curricula. All curricula cover the use of personal application software for documentation; ethical and security issues; personal communication (including Internet access for publication); basic statistics and informatics methods; and tools to support education. However, few include knowledge management and information processing, even though these areas are identified as important by the ECDL [4].

Most curricula covered the IMIA's [6] medicine, health and biosciences and health-system organization aspects the most comprehensively. This was expected, since these

aspects are closely related to all health and social care. Interestingly, all of these aspects were included in the IT curriculum, but none of them were found in the business curricula. It is important for BBa students to have basic knowledge of anatomy, physiology, and how health professionals make decisions, because students will provide services to them.

Table 1. IMIA´s BMHI recommendations in curricula

Items (n=40) Curricula (C)	Nursing C n=6	Other C n=5	Bussines C	IT C n=1	Total C N=14
BMHI core knowledge and skills Items (n=19)					
Use of information processing tools	6	2	0	1	9
Use of personal application software	6	3	1	1	11
Information systems in health care	6	3	0	1	10
Information systems to support patients and the public	6	2	0	1	9
Ethical and security issues	6	4	0	1	11
To support education	6	2	1	1	10
Information literacy	5	4	0	1	10
Evaluation and assessment	5	3	1	1	10
Health data management principles	4	2	0	1	7
The health record	4	1	0	0	5
Data representation and data analysis	4	3	1	1	9
Nomenclatures, vocabularies	4	1	0	1	6
Evolution of informatic	3	3	0	1	7
Architectures of information systems	3	0	0	1	4
Need for systematic information processing	2	1	0	1	4
Management of information systems	2	0	0	1	3
Regional networking and shared care	2	2	0	1	5
Modelling and simulation	1	2	0	1	4
Socio-organizational and socio-technical issues	0	2	1	1	4
Medicine, health and biosciences and health-system organisation knowledge and skills Items (n=7)					
Human functioning and biosciences	6	4	0	1	11
What constitutes health	6	4	0	1	11
Clinical decision making	6	4	0	1	11
Organisation of health institutions	6	3	0	1	10
Evidence-based practice	6	4	0	1	11
Health administration, health economics	6	5	0	1	12
Policy and reculatory frameworks	5	3	0	1	9
Informatics, computer science, mathematics and biometry knowledge and skills Items (n=14)					
Basic informatics terminology	6	4	1	1	12
Ability to use personal computers	6	3	1	1	11
Ability to communicate electronically	6	4	0	1	11
Biometry, epidemiology	6	3	1	1	11
Theoretical informatics	4	0	0	1	5
Project and change managemen	4	4	1	1	10
Mathematics	3	1	0	1	5
Technical informatics	2	1	1	1	5
Iinformation system life cycle	2	2	1	1	6
Decision support	2	3	0	1	6
Interfacing and integration	1	0	0	0	1
Human-computer interaction	1	2	1	1	5
Ubiquitous computing	0	2	0	1	3
Practical informatics	0	1	1	0	2

In the IMIA's informatics, mathematics and biometry knowledge and skills [6], the item that occurred most often was basic informatics terminology. Every nursing and IT curricula included the ability to use personal computers and communicate electronically. However, this was not found in all curricula. Items related to basic computer-use skills were better represented in curricula than items related to technical issues. Interestingly, not all curricula included practical informatics, the ability to use personal computers or the ability to communicate electronically. The largest number of

items were found in the IT engineering curriculum; however, this curriculum did not cover all informatics and related subjects, including practical informatics. Project and change management are not included in all curricula, even though EQF [3] general competence levels five and six in the bachelor's degree demand that students have knowledge and skills in these subjects. The analysis identified the degree to which eHealth competencies exist in current curricula based on the IMIA's BMHI. The evaluation identified a wide range of subjects on various levels associated with competencies in digital health care and welfare. The main areas of the IMIA's BMHI are already part of the various curricula in health and social care and engineering, but BBa curricula do not contain much BMHI content. The reason is self-evident; health care is not a traditional subject in the BBa curricula. The present study has some limitations. The results are not generalizable because of the small sample size. However, they provide perspective on various bachelor's degree curricula at EQF levels five and six [3], and can be used as baseline information when creating new multidisciplinary curricula. Despite its limitations, this evaluation showed that when educating students from various professional fields to develop digital health and welfare services, it is important to consider their diverse background knowledge. Cooperation among various professionals lends new perspectives to developmental work. It is necessary and valuable to include these items in every curricula as complementary to the health and social care sector, as well as engineering and BBa curricula, more systematically. The future should focus on multidisciplinary developmental work in the eHealth sector already during bachelor's degree studies, which would benefit students in their future working lives. This study was part of the Developer of Digital Health and Welfare Services project (CB25), and was supported through funding from the Central Baltic Interreg Programme of the European Union, the European Regional Development Fund (ERDF).

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Classifying Provider-EHR Screen Interactions During ICU Pre-Rounds

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Abstract. Electronic health records (EHR) usability is paramount for high quality of care delivery, clinician productivity and effectiveness, and patient outcomes. This paper investigates clinicians EHR pathways during pre-rounds by characterizing the top EHR screens, duration per screen, and the path taken to complete a task. Structured observations were conducted of ICU providers interacting with the EHR in a real-time, real-world setting to better characterize the information retrieval process. Based on preliminary results of the observations, key areas of information needs have been identified and a preliminary model of EHR workflow has been established. The study highlights that there is a clear discrepancy in usage in EHR screens among ICU residents suggesting that there is a perceived clinician's pathology to finding patient information.

Keywords. Electronic Health Records. Information Overload. Critical Care

1. Introduction

Many attributes of Electronic Health Records (EHRs) contribute to information overload, including the number of fields containing clinical data and the various ways this data is presented. This problem is especially relevant in Intensive Care Units (ICUs), where over 5.7 million patients are admitted in the U.S. each year [1]. ICU providers sort through over 200 variables and an average of 1348 individual data points a day, taking two minutes on average to gather, synthesize, and act on this data during their clinical rounds [2-4]. Compared to other patient populations, ICU patients require constant monitoring and are more vulnerable to acute clinical changes, which may not always be clearly reflected within the EHR. Failure in information processing is directly attributed to cognitive errors, which lead to misdiagnosis [5].

EHRs have become a major source of patient information in the ICU. ICU clinicians are finding EHRs to be cumbersome, and their use disrupts workflow within the ICU [6,7]. This, coupled with poor EHR design, is contributing to increased rates of incidents, accidents, and mortality [7-9]. This paper provides preliminary results of an ICU observational study investigating Provider-EHR interactions.

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2. Methods

This study is part of a bigger exploratory project that utilizes mixed methods such as focus groups, structured observations, and simulation-based testing to qualitatively and quantitatively assess the interaction between the EHR and the clinical provider.

This study utilized ethnography (structured observation) of real physician interaction with the EHR to better understand provider workload. This enabled the research team to investigate the patterns of EHR use in real-time, and to compare these observations with the information reported by participants during the semi-structured interviews. A structured observation checklist was developed to reflect an ICU provider's cognitive workflow, and was used by the research team during observation. This checklist was designed from conversations with ICU clinicians and information gleaned in the semi-structured interviews.

This study took place in the medical ICU at a major U.S. medical center. Fellow and resident physicians were observed during morning pre-rounds, when providers individually and independently review patient data in the EHR in preparation for team rounds. Observation of each physician-EHR interaction lasted between fifteen to twenty minutes. The inclusion criteria include active ICU physician trainees (residents or fellows) who use the EHR to store or retrieve patient information. Observational studies of the EHR with similar sample sizes have been reported previously [5].

During the observations, two research assistants observed individual physician participants as they progress through morning pre-rounds. As physicians progress through their cognitive workflow, the research team utilized a checklist to characterize key EHR screens visited, patterns of usage, scrolling burden, external distractions, and individual variation. After the observation, a survey was administered to gauge participants' perception of the EHR directly after use. The survey instrument was a modified version of the User Experience Questionnaire (UEQ), which has been validated in usability assessments elsewhere [6]. This study will aid in validating the findings from semi-structured interviews and as a validation for the final part of the study: simulation-based testing.

3. Results

A total of 10 physician-EHR interactions were completed while observing 5 physicians in two different observation sessions. Preliminary data from several semi-structured interviews with resident physicians (Table1) and observation of 10 provider-patient EHR interactions (Fig. 1) is included. Key themes emerging from the semi-structured interviews include information excess and poor accessibility of key clinical data. ICU clinicians agreed that excess information in the EHR is burdensome and may introduce more harm than benefit. The design of the Notes page was criticized to include functionalities that providers do not need or use. Furthermore, an agreement that the current EHR interface design presents challenges in finding updated and accurate information relating to the care plan or for team coordination as stated by one of the participants that intake/outtake are useful however, they are hard to find.

Table 1. Sample Qualitative Data from resident focus groups.

Theme	Supporting Quotations
Excess Information is waste	"There's lots of miscellaneous stuff on the Overview Tab I don't need."
	"Most of those columns on the Notes screen I don't even use."
Key Information can be hidden from view	"Intake and Outtake are super useful but are sometimes hard to find."
	"It's hard to tell if the patient actually got the dose of the PRN medication."

Structured pre-rounds observation revealed variation in user patterns. In aggregate, users visited 15 discrete EHR screens to review clinical information, but four of these screens accounted for > 50% of total screens visited (results review, flowsheet, notes, and orders). Over average, it took providers 3.5 minutes to complete pre-rounding per ICU patient record with a maximum of 6 minutes and minimum of one minute. Approximately 7 screens were visited per patient encounter with a maximum of 11 EHR screens visited and a minimum of 4 screens. The flowsheet was the most visited screen (total=8 times); vital signs, radiology, and medication administration record were the least used at one visit per screen.

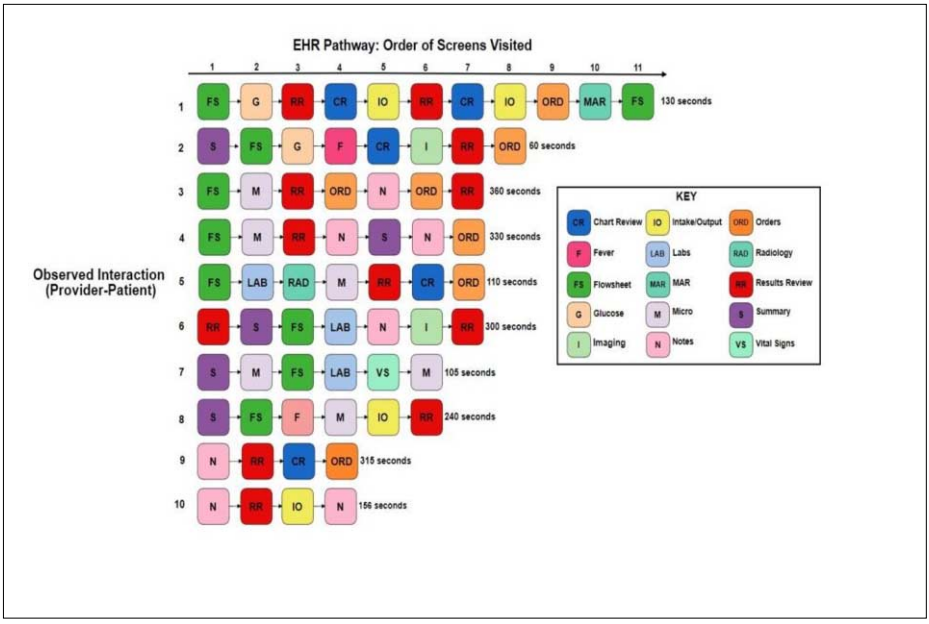

Figure 1. Preliminary data from structure observations of 10 EHR interactions (1 provider: 1 patient). Five physicians, each reviewing 2 patient charts, have work flows represented above with a mean duration of 3.5 minutes and 6.7 screens per encounter.

4. Discussion

This pilot study revealed provider dissatisfaction with the current representation of information in the EHR. The chief complained appeared to be in excess information

that introduces unnecessary noise to the EHR. Because of too much information, there is a risk of missing or overlooking important patient information in the EHR. There is a need to improve information representation within the EHR to avoid burdening providers with information that may be less relevant to the user. One way of doing so is by customizing the EHR further to accommodate user information preferences and needs. The EHR has useful functionalities however; the frustration appears to be when it is hard to find those functionalities. The inability to locate certain functions leads to a click-heavy interface, which is counter intuitive to a user-friendly interface.

Observing providers during their EHR interaction showed the behavioral variety in seeking information within the EHR. There are multiple ways to complete pre-rounding for resident physicians, in other words, residents visited different screens and spend varying times to complete their pre-round tasks. We have observed that residents favored visiting specific screens versus others, and the rationale behind their preferences is to be investigated. We believe that EHR training and education is pivotal in how providers use the system, which suggests standardizing training and education to ensure that providers are seeking information on the correct screens.

Future work will include investigating any correlation between number of screen visited and time spend pre-rounding and patient outcomes in particular, medical errors or sentinel events. Next steps will include developing a dashboard that aggregates most-needed ICU patient information and conducting a comparative effectiveness study comparing the current EHR interface with the new user-centered dashboard in a simulated environment. The limitations of this study include the small sample size, and utilizing only one EHR system, which may limit the generalizability of our findings.

To truly understand information overload as experienced by clinicians, both their perceptions as well as the reality of working within the EHR must be examined. This will allow for optimal EHR modification and improved design moving forward, which may translate to key improvements in provider performance and satisfaction as well as patient safety. A novel, mixed-methods approach is proposed to better understand the effects of EHR information overload on provider performance, satisfaction, and workload. This approach is more comprehensive than traditional methods, and will perform an important needs assessment wherein data is triangulated and validated from semi-structured interviews, structured observation, and simulation testing.

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Barriers for Implementation and Use of Health Information Systems from the Physicians' Perspectives

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Abstract. This study aimed to investigate barriers to the implementation and use of health information systems (HIS) in Iran by physician's view. This cross-sectional study was conducted in 2016 on 163 physicians employed in 10 teaching hospitals. Data collection was carried out through a questionnaire with questions about the technical, organizational, ethical and personal barrier categories. Data analysis demonstrated that technical (e.g. inadequate planning for implementation and use of HIS) (3.56±1.32), organizational (e.g. inadequate facilities for fast and easy access to the Internet) (3.67±1.91), personal (e.g. inadequate awareness of healthcare providers about the benefits of HIS) (3.33±1.28), as well as legal and ethical (e.g. concern about the security and confidentially of HIS) (3.15±1.31) were the most important barriers to the implementation and use of HIS. Reducing barriers, especially technical and personal ones will increase the implementation and use of HIS based on the physicians' perspectives.

Keywords. Health Information System, Implementation, Barriers, Physicians

1. Introduction

Healthcare organizations need timely and quality information to improve quality of services [1,2]. For this aim, the use of health information systems (HIS) is a must [2]. Despite the importance of these systems, implementation and use of these systems has many barriers. Based on a study, lack of national information standards, concerns about physicians' acceptance and use, lack of national information networks, and concerns about maintaining confidentiality of information were identified as the most important barriers [3]. In studies in other countries, human, technical, organizational, personal, attitude, legal, ethical, and financial barriers have been identified as the challenges of the implementation and use of HIS [4,5]. A physician, as one of the most important users, often resist the implementation and use of these systems, which results in problems in implementation of these systems and also affects the quality of information. In the studies from the physicians' viewpoint, personal and organizational

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barriers were identified as the most important obstacles [6]. Different countries need to identify such barriers first to address these challenges. Iran is one of the countries that are in the process of implementing these systems, but there are no many studies on these barriers. Therefore, this study aimed at to identify such barriers from the viewpoint of Iranian physicians.

2. Method

The study was conducted in 2016. The research population consisted of physicians (general, resident, specialist and sub-specialist) working in teaching hospitals affiliated to two main universities of Iran (Tehran and Iran Medical Sciences universities) including 10 hospitals. By using the Krejcie and Morgan table, 260 physicians were randomly selected. Finally, 163 participated in the study. To collect data, a questionnaire consisting of 29 questions was prepared based on literature review [1,6-10]. The questionnaire contained demographic questions (4), organizational barriers (9 questions), technical barriers (9 questions), personal barriers (4 questions) as well as legal and ethical barriers (3 questions). The questions were designed based on a 5-point Likert scale (very little to very much) from 1 to 5, respectively. Content validity of the questionnaire was verified by 10 experts in the field of health informatics and health information technology and its reliability was determined by calculating internal correlation (α=0.8). In order to collect data, the researchers referred to the hospitals in person and handed the paper-based questionnaire to physicians. They provided the necessary explanations to answer the questions and gave them enough time to complete it. For data analysis, SPSS16 was used for descriptive (mean and percent) and inferential statistics. ANOVA and T-test were used to compare the means.

3. Results

The mean age was 30.2±7.3 years. 52.1% of participants were female and most of them were general practitioner (73.1%) and had less than 5 years working experience (80.4%). Most of them have experiences in using hospital information systems and electronic medical records. The average work experience was 6.2±3.64. The overall mean score for barriers was as follows: technical (3.4±0.89), personal (3.1±0.98), organizational (3.06±0.88), and legal (3.04±1.2) (Table 1). Among the technical barriers, the most important ones were the lack of national networks and appropriate information systems and Internet access. Inappropriate planning and inadequate support services were the most important organizational barriers. Inadequate awareness of providers and their participation in system implementation as well as information security were the most important personal and legal barriers. Physicians' opinions about any of these barriers were not significant within age groups. Women (p=0.022) and less experienced physicians (p=0.022) considered their legal barriers more important. Less experienced physicians (p=0.022) considered technical barriers more important in comparison with experienced physicians (p=0.04). General physicians considered organizational barriers more important than residents and specialists (p=0.003).

Table 1. Physicians' perspectives on barriers of implementation and use of HIS

Barrier category	Barriers	Very much and much	Moderate	Very little and little	Mean±SD
Organizational	Changing clinical workflows following the use of HIS	(33.7)55	(32.5)53	(33.7)79	2.87±1.19
	Complexity of delivery of health care due to use of computers	(19.7)32	(25.2)41	(55.3)90	2.51±1.05
	Getting new skills and participation in new courses	(35.0)57	(32.5)53	(32.5)53	3.02±1.11
	Inadequate support of senior managers	(46.0)46	(24.5)40	(29.4)48	3.29±1.28
	Shortage of human resources specialized in health information technology	(44.2)72	(23.3)38	(36.5)53	3.19±1.27
	Lack of efficient planning for HIS	(57.7)94	(17.2)28	(25.2)41	3.56±1.32
	Inadequate maintenance, support and updating services systems	(52.1)85	(18.4)30	(29.4)48	3.33±1.28
	Reduction of performance when implementing HIS	38(23.4)	50(30.7)	(46.0)75	2.67±1.16
	The intangible benefits of HIS	71(43.6)	37(22.7)	(33.8)55	3.10±1.34
Technical	Lack of national health information networks	(56.4)92	(23.9)39	(19.6)32	3.61±1.20
	Inadequate effective information systems	(58.9)96	(19.6)32	(21.5)35	3.60±1.14
	Lack of fast and easy internet access	(58.3)95	(22.7)37	(19.0)31	3.67±1.91
	Lack of equipment and hardware for access to HIS	(53.3)87	(27.6)45	(19.0)31	3.52±1.17
	Lack of suitable software for users' needs	(40.5)66	(31.1)54	(26.4)43	3.20±1.18
	Inappropriate infrastructure to integrate information systems	(57.6)94	(22.1)36	(20.3)33	3.53±1.22
	Lack of national standards for medical vocabularies	(35.6)58	(31.9)52	(32.5)53	3.04±1.21
	Lack of national standards for data exchange	(42.3)69	(33.7)55	(23.9)39	3.27±1.07
	Incompatibility of existing HISs in terms of structure and content	(48.5)79	(20.2)33	(31.3)51	3.23±1.28
Personal	Inadequate awareness of healthcare providers about benefits of HIS	(48.5)79	(24.5)40	(27.0)44	3.33±1.28
	Unwillingness of providers to use computers	(39.3)64	(20.9)34	(39.9)65	3.05±1.29
	Increasing providers' workloadsfor documentation	(35.0)57	(32.5)53	(32.5)53	3.06±1.13
	Inadequate participation of providers in the process of designing and implementing HIS	(46.0)75	(27.6)45	(26.4)43	3.27±1.20
Legal and ethical	Concerns about the exchange of patient data and information without informing patients	(33.1)54	(30.7)50	(36.2)59	2.96±1.28
	Concerns about the access of unauthorized persons to information	(41.1)67	(17.2)28	(41.7)68	3.02±1.34
	Concerns about the security and confidentiality	(42.3)69	(23.9)39	(33.8)55	3.15±1.31

4. Discussion

The technical, personal, organizational, and legal barriers are the most important barriers for HIS, respectively. Other studies in Iran and other countries also indicated that technical barriers were the most important barrier for electronic health records [1,4]. The most important technical barriers were the lack of facilities for fast and easy access to the Internet. Other studies [7,11] also described technical barriers as one of the most important obstacles. The most important personal barrier was inadequate awareness of providers about the characteristics and benefits of HIS that matches with the Jabraeili study. According to him, if the benefits of HIS are shown for users, their resistance will decrease [8]. Lorenzi mentioned the lack of willingness to learn computer skills, imposed discipline, time wasting, and increased responsibility for providers' resistance to use of HIS [12]. Inadequate planning for HIS was recognized as one of the most important organizational barriers. Also, organizational barriers, after financial and technical ones, were identified as the most important challenges for HIS [9], which is consistent with our results. However, changing the workflows and the cost of support in their study was the most important. Organizational barriers were also, of great importance after technical and personal barriers [10]. In a study, organizational barriers had more priority than technical barriers [8]. The need for extensive changes in organizational structure, service delivery processes and managerial factors should be considered [8]. Concerns about the security of HIS were one of the main barriers identified in our study. This study showed that the most important barriers to the implementation and use of HIS are technical barriers. Therefore, it is suggested that, while developing appropriate hardware and software infrastructure, use of content and data exchange standards to integrate HISs should also be considered. In order to eliminate personal barriers, it is recommended to hold courses for physicians with the aim of familiarizing them with the benefits of such systems.

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Identifying Consumer Health Terms of Side Effects in Twitter Posts

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Abstract. Prevalence of social media has driven a growing number of health related applications with the information shared by online users. It is well known that a gap exists between healthcare professionals and laypeople in expressing the same health concepts. Filling this gap is particularly important for health related applications using social media data. A data-driven, attributional similarity-based method was developed to identify Twitter terms related to side effect concepts. For the 10 most common side effect (symptom) concepts, our method was able to identify a total of 333 Twitter terms, among which only 90 are mapped to those in the consumer health vocabulary (CHV). The identified Twitter terms are specific to Twitter data, indicating a need to expand the existing CHV, and many of them seem to have less ambiguity in word senses than those in CHV.

Keywords. Consumer health concepts, pharmacovigilance, social media, Twitter

1. Introduction

Prevalence of social media has yielded a growing number of health related applications using social media data. One of the active areas of this endeavor pertains to pharmacovigilance whose primary task is the continuous detection of suspected unknown side effects from the use of pharmaceutical products in order to promote the safe uses of the products. This has been evidenced by a 2015 research conducted by Golder et al. [1] who searched "pharmacovigilance" and "social media" in 16 databases and discovered more than 3,000 relevant published articles with an upward trending.

It is well known that there exists a gap in expressing health concepts between healthcare professionals and laypeople (consumers) [2], and this is particular true in the era of social media where consumers typically share their personal experiences related to their health issues and use different expressions to describe health concepts. Therefore, there is a need to understand how social media users express health concepts.

2. Method

A data-driven, attribution similarity-based method was developed to identify Twitter terms corresponding to concepts of side effects (symptoms). Our method leverages a significant amount of Twitter data and is based upon attributional (syntactic and

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semantic) similarity through which Mikolov et al. [3] demonstrated the state-of-art results in many related tasks from the vector space model(VSM) of words. In June of 2017, a total of 53 million tweets were collected from twitter.com using a set of 1,147 medication names as keywords, and it was done with the help of a homemade web crawler to overcome the limitations of Twitter APIs. The collected tweets were preprocessed to remove non-English and duplicate tweets. Phrases were learned from the preprocessed tweets using the gensim software[2], which implements the data-driven, co-occurrence-based phrase learning algorithm [4]. Afterward, the text of the preprocessed tweets was replaced with learned phrases. A vector space model (VSM) was created from the preprocessed tweets using Google's word2vec [3] (skip-gram, window_size=10, min_count=5 and dimension=300).This VSM was used to generate Twitter terms similar to each health concept with a similarity of 0.2 or higher. The similarity is the vector cosine similarity. The SIDER side effect list[4] was used as the standard side effect concepts in identifying Twitter terms similar to the concepts, by comparing the vector similarity of each pair of concept and Twitter term. To understand the differences of side effect concepts between the Twitter terms and the existing CHV[5], we compiled a list of CHV side effect terms (CHV+SE) by intersecting the CHV and the SIDER side effect list through the alignment of concept IDs (CUIs).

For each of the side effect concepts, a list of Twitter terms similar to the concept was generated by including all the terms with a similarity of 0.20 or higher. Terms matching any of CHV+SE terms were assigned the corresponding concept ID. The list was sorted first by the occurrence (the # of times it appears in our corpus) and then by the similarity. Stop words and irrelevant terms were removed from the list. Afterwards, the list was manually annotated by the first two authors, and each term was labeled with one of three choices: Yes, No, and Unsure. A Yes term is a term *highly likely* to be the side effect concept; a No term is a one *highlyunlikely* to be the concept; and an Unsure term is somehow in between. All the Yes terms became the candidate terms for the same concept, and all No terms were added to the irrelevant term list.

3. Results

Table 1 shows the statistics of discovered Twitter terms and CHV terms that are considered to have the same meaning and/or the same concept ID (CUI).

Table 1. Statistics of side effect terms discovered in tweets and found in CHV. The first column lists the 10 most common side effect terms. The column of "# of discovered" is the number of Twitter terms discovered in this study. The column of "# of match" represents the number of common terms in their Twitter terms and CHV, and the column of "% of match" shows the percentage of common terms with respect to the discovered Twitter terms.

Side Effect	# of discovered	# in CHV	# of match	% of match	Occurrence
pain	52	6	3	5.8%	376,627
headache	57	16	3	5.3%	135,953
anxiety	48	4	4	8.3%	95,998
depression	37	13	4	10.8%	63,001
migraine	28	13	2	7.1%	53,460

[2]https://radimrehurek.com/gensim/

[3]https://code.google.com/archive/p/word2vec/

[4]http://sideeffects.embl.de/download/

[5]http://consumerhealthvocab.chpc.utah.edu/CHVwiki/

Side Effect	# of discovered	# in CHV	# of match	% of match	Occurrence
insomnia	33	7	3	9.1%	38,571
stress	8	4	4	50.0%	34,120
nausea	35	13	6	17.1%	29,777
cough	12	6	3	25.0%	17,677
asthma	23	8	5	21.7%	15,091
total	333	90	37	11.1%	860,275

For the top 10 side effect concepts, there are a total of 90 CHV terms and 333 Twitter terms. Summarized in Table 2 are the numbers of tweets with CHV terms and Twitter terms for each of the top 10 side effect concepts. Table 3 lists example tweets with Twitter terms of highest similarities.

Table 2. Statistics of tweets containing CHV and Twitter side effect terms.

Side Effect	Total # of tweets	# of tweets w CHV terms	# of tweets w Twitter terms	% of tweets w Twitter terms in total
pain	376,627	366,780	9,847	2.6%
headache	135,953	124,633	8,804	6.5%
anxiety	95,998	90,778	5,220	5.4%
depression	63,001	60,198	2,803	4.4%
migraine	53,460	49,974	3,486	6.5%
insomnia	38,571	29,379	9,192	23.8%
stress	34,120	33,813	370	0.9%
nausea	29,777	28,789	988	3.3%
cough	17,677	16,676	1,001	5.7%
asthma	15,091	13,651	1,440	9.5%

Table 3. Examples of tweets containing the Twitter side effect terms. The tweets are related to the personal experiences of the side effects.

Twitter Term(similarity)	Example Tweet
massiveheadache(0.615)	*Day 3 of a massive headache. No amount of acetaminophen, ibuprofen or caffeine helps for long. Poop.*
excruciatingpain(0.777)	*Im in excruciating pain who got some Xanax*
anxietypanicattacks(0.716)	*Yeah :/ Albuterol gives me anxiety/panic attacks because its a stimulant. Pulmozyme usually is ok... but tobramycin tastes NASTY.*
cripplingdepression(0.595)	*My crippling depression and addiction to Adderall*
migrane(0.800)	*@USER I used to take clonazepam but it always gave me migrane. I just stick to zolpidem now but even that isnt reliable.*
stres(0.251)	*i need to stay up for at least 3 more hours but im so stressed but if i take a xanax im afraid ill fall asleep but my head hurts bc stres*
insomia(0.657)	*I just took a AMBIEN CR I think that this is going to help me actually sleep tonight, insomia sucks and so do pills! at least I am sleepy`-`*
extremenausea(0.680)	*Two days of extreme nausea and headaches...nothing works like my Ativan. Ugh I really need to find a new doctor. — feeling sick*
caugh(0.450)	*So the doc gave me prednisone for my caugh/asthma. Good news cough is getting better-bad news I cannot sleep ugh! #steriodsarebad*
asthmasymptoms(0.559)	*I use seretide my pneumoligist said its better and I take 2 different pills no asthma symptoms!Rinse mouth after puff*

4. Discussions

Table 1 shows that although there is a total of 90 CHV terms and 333 Twitter terms for the top 10 side effect concepts, only 37 terms were found in both Twitter and CHV, indicating that not all the CHV terms were found in our tweet corpus. In other words,

Twitter users appear to not use all the CHV terms in expressing health concepts, and they seem to have their own Twitter-specific expressions. This demonstrates the need to expand the existing CHV to include the Twitter specific terms.

Even though more Twitter side effect terms than CHV terms were identified for each health concept (Table 1), the actual number of tweets with the Twitter side effect terms is relatively smaller than those with CHV terms (Table 2). This may indicate that the discovered Twitter side effect terms are of less dominance in usage, but they may show more relevance to the corresponding health concepts than the CHV terms.

Illustration in Table 3 are the actual examples of tweets containing the Twitter side effect terms, and texts of the examples show that these Twitter terms are closely related to the corresponding health concepts. The discovered Twitter terms can be single words, phrases, and even misspellings (e.g., migrane, stres, insomia, and caugh). Also included in the table are the similarities of Twitter terms, and the terms listed are the ones most similar to (i.e., the highest similarities) the corresponding side effects. The term of *painful*, which was found in both Twitter terms and CHV, has a similarity of 0.346 to concept *pain*, whereas the Twitter term of *excruciating pain* has a 0.777 similarity, indicating that the latter is more closely related to *pain*. This observation may signify that some CHV terms were used in senses unrelated to the health concepts (e.g., it is *painful* to get a medication), and Twitter terms may have less ambiguity in word senses due to their higher (syntactical and/or semantic) similarities to the health concepts.

5. Conclusion

A data-driven, attributional similarity-based method was presented to identify Twitter terms that are most (syntactically and semantically) similar to the health concepts. For the 10 most common side effect concepts, it was able to discover 333 Twitter terms, among which only 90 terms match with the CHV terms. Analysis of our data shows that (1) there is a need to expand the existing CHV by including Twitter terms which are more specific to the Twitter data, and (2) many identified Twitter side effect terms seem to be less ambiguous in word senses than CHV terms because of their higher similarities to the health concepts than that of CHV terms.

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Towards Understanding the Impact of EHR-Related Information Overload on Provider Cognition

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Abstract. Information overload is a significant problem in the digital age of healthcare and plays key a role in diagnostic errors, near misses, and patient safety, especially in critical care settings. Because of this, we propose a new mixed-methods approach for evaluating EHR-related information overload on clinicians in the ICU. We describe a three-part approach to better understand ICU clinicians' information needs and workflow as they relate to the EHR, and to explore the effects of the EHR on provider workload, performance, and satisfaction. Based on discussions with ICU providers, key areas of information needs have been identified and a preliminary model of EHR workflow has been established.

Keywords. Mixed-Methods, EHR, ICU

1. Introduction

As technological advances generate increasing amounts of electronic patient data, clinicians struggle more and more with information overload. This problem is especially relevant in Intensive Care Units (ICUs), where over 5.7 million patients are admitted in the U.S. each year [1]. Data is generated for approximately 55,000 patients a day in this high risk and critically ill population [2]. ICU providers sort through over 200 variables and an average of 1348 individual data points a day to perform their clinical care rounds [3,4]. However, these providers only have an average of two minutes per patient to gather, synthesize, and act on this data [5]. Diagnostic errors, linked to misinterpretation of this data, are occurring with increasing frequency and can lead to medical errors. Information overload is a key factor in this cycle [6].

This study aims to assess the ways in which EHRs impact provider workload, performance, and satisfaction in the ICU, as well as to better understand EHR usability and information overload. We propose a three-part approach to generate quantitative and qualitative data for a comprehensive picture of the EHR's effects on providers. The study will seek to explore the extent to which poor EHR interface design—with critical patient data scattered on different screens and presented in different ways— is related to the metrics of interest.

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2. Methods

Our approach utilizes mixed methods such as interviews, structured observations, and simulation-based testing to qualitatively and quantitatively assess the interaction between the EHR and provider workflow.

2.1. Study 1: Semi Structured Interviews

Semi-structured, individual interviews are conducted to understand ICU providers' information needs and their perception of the EHR as it relates to clinical workflow. Participants are given a survey instrument to quantify their current level of satisfaction with the EHR. Then Interviewer will then seek to identify key data elements necessary for clinical decision-making. Three groups of ICU providers have been identified for inclusion: (1) attending, (2) fellow, and (3) resident physicians. By including participants across three clinical roles, we aim to investigate the similarities and differences of user-requirements for end-users with different levels of experience. Fifteen participants will be recruited for the interviews.

2.1.1. Procedure

Trained researcher will take careful notes during the interviews, concentrating on key descriptive language used by participants, and will record the interviews on smart phones. Each interview will begin with the administration of a survey instrument, the Questionnaire for User Interaction Satisfaction (QUIS). This survey has been modified from the original QUIS, produced and validated by the University of Maryland [7] to best address the elements relevant to ICU clinicians interacting with the EHR. The areas to be evaluated are the overall impressions, screen factors, terminology and system feedback, and learning factors. There are twenty questions in total, each assessing participants' satisfaction with EHR factors on a nine-point scale.

2.2. Study 2: Real-Time Observations

The second portion of the study utilizes ethnography (structured observation) of real physician interaction with the EHR to better understand provider workload and satisfaction. This will allow the research team to investigate the patterns of EHR use in real-time, and to compare these observations with the information reported by participants during the interviews. A structured observation checklist will be developed to reflect an ICU provider's cognitive workflow, and will be used by the research team during morning pre-rounds observation. The inclusion criteria include active ICU physician trainees (residents or fellows) who use the EHR to store or retrieve patient information. Observational studies of the EHR with similar sample sizes have been reported previously [8].

2.2.1. Procedure

During the observations, research assistants will observe the physician participants as they progress through morning pre-rounds. As physicians progress through their cognitive workflow, the research team will utilize a checklist to characterize key EHR screens visited, patterns of usage, scrolling burden, and individual variation. After the

observation, a survey will be administered to gauge participants' perception of the EHR directly after use. This study will aid in validating the findings from the interviews as a validation for the final part of the study: simulation-based testing.

2.3. Study 3: Simulation Study

This part of the study will utilize Tobii Pro Glasses 2 [9] to track eye movement as well as standardized usability software (TURF) [10] to provide key quantitative information related to the physician-EHR interaction (mouse clicks, time to complete the task, etc.). The simulation session will last one hour while physician participants are observed working through various patient scenarios in the EHR training environment. The research team has designed six EHR scenarios to mimic standard patient cases seen in the ICU. Participants will be licensed physicians but vary in clinical experience, experience using the EHR system, and hours worked per week on the system.

2.3.1. Procedure

A board-certified Pulmonary and Critical Care physician was consulted as a domain expert to develop four EHR test cases. These test cases require participants to perform clinical activities (e.g., place orders) after reviewing the medical record (e.g., demographics, vital signs, flow sheet, ventilator settings, etc.). Each participant will be set up with the Tobii Pro Glasses 2, which will allow for a variety of data to be captured. The path of eye movement can be recreated to show the path that participants use when searching for data in the EHR. Glance and fixation times are calculated to quantify time spent on a given EHR screen. Number of mouse clicks, time spent per screen, and mouse clicks will also be recorded through TURF.

3. Results

In preparation for the current study, a usability pilot study was conducted in the medical ICU at a large academic health system. An observational study was conducted during patient rounds; 30 patient visits were observed in four hours of observation. The ICU team consisted of approximately 17 clinicians and utilized various technological tools during team rounds including four computers on wheels (COWs), three laptops, and one tablet. All devices were connected to the EHR and were used to retrieve and store patient information. In a post-observation survey, the leading complaints from clinicians highlighted the problem of information overload: "the EHR system is heavy on data", "data is scattered", "important data at the bottom of the page", "redundant data in one screen", and "it would be nice to have easier flow sheets and labs". In consultation with a board-certified Pulmonary and Critical Care physician with domain expertise, we developed a list of data elements most commonly used by ICU providers (Table 1). This will serve as foundation for discussion during the interviews.

Table 1. Characterizing essential ICU patient data elements

Neuro	Heart	Lungs	Renal	ID
Sedation	CVP, MAP, CO	Vent Settings	UOP	Fever
Delirium	ECMO data	ABG	I/O	Micobiology
EEG	Echo	Daily Awakening	C/r	Abx
Imaging	Cath	SBT	CVV Data	

4. Discussion

This study explores information overload in the EHR, investigating the impact of data representation (in its current state) on the clinician's workload, performance, and satisfaction. The information gained from the interviews will be useful in determining the extent to which one's pattern of EHR use is associated with level of experience and clinical role. The observations will be useful in seeing how environmental distractions effect the way in which the EHR is used in gathering clinical data and the time that is taken on interactions. Simulations will be key in provide quantitative data for determining the burden of use of the EHR and if there are certain screens contributing more to information overload that can be redesigned to better display information. Future work includes developing a visualization dashboard that aggregates most-needed ICU patient information (as reported by clinicians) and conducting a comparative effectiveness study comparing the current EHR interface with the new user-centered dashboard in a simulated environment. The visualization dashboard will serve as a summary page of daily checklist items: diet, lines/drains, DVT, GI, PT/OT orders etc. This will improve the current click-heavy EHR design and will save clinicians time seeking information. The limitations of this study include investigation of only the medical ICU in a single institution utilizing only one EHR system, which may limit the generalizability of our findings.

We propose a novel, mixed-methods approach to better understand the effects of EHR information overload on provider performance, satisfaction, and workload. Our approach is more comprehensive than traditional methods, and will perform an important needs assessment wherein data is triangulated and validated from interviews, structured observation, and simulation testing. To truly understand information overload as experienced by clinicians, both their perceptions as well as the reality of working within the EHR must be examined.

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Usability of Telerehabilitation System Supporting Multipronged Exercise in Patients with Multiple Sclerosis

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Abstract. Multipronged exercise interventions comprising aerobic, resistance and corrective therapeutic components were shown to result in endurance and strength improvement and reduction of fatigue and spasticity in patients with multiple sclerosis (PwMS). Telerehabilitation systems may have significant potential in improving patient access to multipronged exercise, however it is not clear whether PwMS can successfully use a multipronged exercise system at home without assistance. The goal of this project was to assess usability and acceptance of a multipronged exercise system in PwMS. Usability assessment was based on evaluation of patient ability to successfully carry out a standardized list of common tasks necessary to operate the system. For each task, time to completion, perceived difficulty and satisfaction were documented. Our results indicated high level of acceptance of the system by these patients. On average, it took about 1-2 minutes for the patients to complete the study tasks essential for the system operation. They were able to successfully use the system and follow their individualized exercise prescription. The resulting system is warranted for a definitive systematic evaluation in a randomized controlled trial to demonstrate its clinical impact in PwMS.

Keywords. telemedicine, physical exercise, multiple sclerosis

1. Introduction

Multiple sclerosis (MS) is chronic neurodegenerative condition of the central nervous system leading to accumulation of disability in mobility and cognition. Approximately 50% of people with MS (PwMS) require the use of a walking aid within 15-25 years of diagnosis [1]. Recent studies demonstrated that multipronged exercise interventions comprising aerobic, resistance and corrective therapeutic components resulted in endurance and strength improvement and reduction of fatigue and spasticity in PwMS [2]. However continuous engagement in regular multipronged exercise activities is limited in these patients due to multiple barriers including mobility limitation, access to an exercise facility, and cost. New care models supporting comprehensive exercise programs for PwMS in home settings are urgently needed [3]. Telerehabilitation applications have been shown to successfully support patient exercise at their homes for a spectrum of chronic conditions [4-6]. Previous studies demonstrated high acceptance of telerehabilitation by PwMS [7,8]. In a recent study, we demonstrated positive impact of home-based physical therapy program in PwMS delivered via a

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telerehabilitation system [9]. However, telerehabilitation support of multipronged exercise programs in PwMS has received limited attention. It is not clear whether PwMS can successfully use a multipronged exercise system at home without assistance. The goal of this project was to assess usability and acceptance of a multipronged exercise system in PwMS.

2. Methods

2.1. System Design

To facilitate home-based multipronged exercise in PwMS, an interactive telerehabilitation system has been designed that supports prescription of individualized exercise plans by a rehabilitation team and assists patients at home in following their individualized exercise program in safe and effective manner [10]. The system consists of a patient website, clinician website, and arm bike with biking speed being monitored using a magnetic ANT+ sensor [11].

2.2. Study Design

Ten consecutive PwMS were recruited into the study. The clinical diagnosis of MS was confirmed using patient self-report and chart review by their neurologist. Patients were recruited regardless of their previous computer experience, but patients were required to comprehend simple instructions in English. Following the initial training session comprising demonstration and practice phases, the patients were asked to complete an abbreviated telerehabilitation session consisting of a predefined set of tasks using the system without supervision (task analysis phase). Patient comments, time to complete each task, ability to complete the tasks independently without research assistant prompts were documented. After completion of each task, the patients were asked grade each task on a scale from 1 to 5 using a 3-item survey which included the following questions: (1) How difficult or easy was it to complete this task? (2) How satisfied are you with using this application/system to complete this task? (3) How would you rate the amount of time it took to complete this task?

3. Results

3.1. System Overview

The telerehabilitation portal allows patients to log in and complete an individualized multipronged exercise program. Patients are given step by step written instructions and precautions about each exercise. They also have the option to watch a video explaining how to do the exercise. When a patient is ready to start the exercise, they click “Start Exercise” and are shown an exercise repetition video which counts the number of repetitions shown. When the prescribed number of repetitions is completed, the patient clicks “Finish Exercise” and answers post-exercise questions. All results are immediately sent to a server where they are available for review. The system includes

decision support to provide patients with tailored feedback based on their performance and to alert a rehabilitation team if patient performance requires in person counseling.

3.2. Usability Assessment

Ten PwMS with moderate to severe disability participated in initial prototype assessment. The average age of the study subjects was 55±10 years old, 70% were White, 10% were Black, 80% used computer at home on a daily basis, MS duration was 24±12 years.

Table 1. Task Self-Assessment

Sessions	Mean (SD)
Task 1: program start and user login	
Difficulty	4.7 (SD 0.6)
Satisfaction	4.6 (SD 0.9)
Amount of time	4.8 (SD 0.6)
Task 2: completion of pre-exercise symptom diary	
Difficulty	4.9 (SD 0.3)
Satisfaction	4.6 (SD 0.9)
Amount of time	5.0 (SD 0.0)
Task 3: execution of one prescribed exercise	
Difficulty	4.7 (SD 0.6)
Satisfaction	4.7 (SD 0.9)
Amount of time	4.9 (SD 0.3)
Task 4: completion of post-exercise survey	
Difficulty	4.9 (SD 0.3)
Satisfaction	4.7 (SD 0.9)
Amount of time	4.9 (SD 0.3)

Table 2. Task Performance

Sessions	Task Accomplished (%)	Help Needed (%)	Accomplished time (sec) Mean ± SD
Task 1	100	20	171±93
Task 2	100	10	63±17
Task 3	100	10	56±36
Task 4	100	10	42±18

A list of major tasks performed by the study subjects as well as their assessment of the tasks is presented in Table 1. The task difficulty was perceived as very low and they expressed high satisfaction with task presentation, cues and feedback provided by the system. Majority of patients were able to successfully complete all tasks in a short period of time (Table 2).

4. Discussion

A telerehabilitation system supporting individualized multipronged exercise program was well accepted by PwMS. The system was perceived as easy to use. All essential tasks necessary to operate the system were completed successfully. On average, it took about 1-2 minutes for the patients to carry outreach of the study tasks. Our results corroborate previous reports that demonstrated high acceptance of home telemanagement by PwMS [12] including interactive resistance exercise [13], televisits using a web cam [14], and internet-controlled cycling exercise [15]. Home telerehabilitation is a promising consumer health modality however further research is needed to elucidate its full potential [16]. The resulting system will have to undergo a definitive systematic evaluation in a randomized controlled trial to demonstrate its clinical impact.

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Methods to Measure the Impact of mHealth Applications: Preliminary Results of a Scoping Review

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Abstract. Important requirements for mHealth, the availability of devices and network connectivity have dramatically improved in the past years globally. mHealth applications are being developed at a rapid pace. But a thorough impact assessment is not routinely performed. We performed a scoping review to compile an overview of evaluation methods used to assess mHealth applications. Preliminary results are reported here, and a full scoping review is in preparation. Qualitative measurement of user experience is common. A number of studies measured the impact of the mHealth intervention on clinical outcomes. Few measured usability and end-user experience. Assessment of the impact on treatment process was rare and evaluations of cost and cost-effectiveness analyses are rarely ever done. An evaluation framework for mHealth interventions that includes disease-appropriate clinical outcome measures, use experience measure but also an economic component in form of cost comparison of the intervention with the standard of care should be developed.

Keywords. mHealth, evaluation methods, impact assessment

1. Introduction

If mobile devices are involved in the delivery of healthcare services, it is referred to as mobile health or short mHealth [1]. Two important drivers for mHealth are the availability and affordability of mobile devices as well as connectivity. The number of mobile cellular subscriptions has dramatically increased from under 500 million in 1999 to 7.5 billion in 2016 [2]. The availability of devices is dramatically increasing with decreasing prices and increases in performance of mobile devices (mobile phones and tablet computers).

The fulfillment of those two prerequisites has led to an influx of application for a wide range of health domains [3]. Especially the area of consumer mHealth applications has seen a dramatic increase in the past years. A main driver for this trend is the emergence of wearable devices. With hardware prices for body sensors and smart watches that were attractive for the broad consumer market, the corresponding applications were just the logical next step [4].

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The main issue with consumer applications is that their commercial success is not determined by their objective medical benefit, but subjectively assess by end users and can therefore be influenced by marketing[5]. Jake-Schoffman et al. list the factors that should be assessed in consumer mHealth applications: content analysis, usability testing, observational studies and efficiency testing [6].

Applications that are intended to be part of the healthcare delivery process and should in the long run be financed by healthcare systems, their medical benefit needs to be objectively proven. With the rising cost of healthcare, the healthcare systems of many countries are under increasing pressure to contain costs [7]. Many countries for example have implemented mandatory health benefit assessment of new pharmaceuticals in order for them to be reimbursable by the public healthcare system [8].

If healthcare systems should pay for mobile health applications, their medical impact has to be objectively proven. The purpose of this scoping review is to provide an overview of evaluation and impact assessment approaches used by mHealth projects to set the foundation for an evaluation framework and in the long run policy recommendations on how to assess the impact of mHealth applications.

2. Methods

A scoping review of published literature was conducted to provide an overview of different methodologies applied to determine the impact of mHealth intervention. We searched for published literature on Medline and EMBASE published from 2000 until 2018. The last search conducted on May 14st 2018. The following keywords were used: “mHealth”, “m-Health” and “mobile health” as well as “evaluation”, “assessment” and “impact”. We also looked at references in the papers the searched turn up and recommendations on journal websites.

Papers that were turned up by the search were first reviewed based on their title and abstract. All papers that were determined to fit the purpose of the review, were reviewed in full. For this paper, examples of different evaluation approaches were chosen and presented as preliminary results of the scoping review. A full scoping review is in preparation.

3. Results

A systematic review of mHealth applications for chronic diseases showed that the most common evaluation was regarding usability, feasibility, and acceptability of the tools. Only a small subset of studies applied a randomized comparison approach to compare the intervention (mHealth application) with the standard of care. Within this subgroup, treatment adherence was commonly used as an impact indicator. Few studies also looked at clinical outcomes for the respective disease through an RCT to assess impact [9].

Another systematic review of mHealth application for chronic diseases specifically looked at studies conducted in developing countries. Clinical outcomes were studies in 6 studies. The authors defined another indicator as “Process of care”, which included influence on treatment compliance and loss to follow-up. Seven of the studies also

looked at cost, but only the comparison of electronic reminder vs. reminders via telephone [10].

An mHealth intervention for peer health workers for AIDS care in Uganda looked a number of indicator. Cumulative risk of virologic failure (an important indicator for AIDS treatment compliance) was used as the primary indicator. A secondary indicator was loss to follow-up [11].

A review of mHealth interventions for maternal, newborn and child health in low- and middle-income countries found that most of the studies looked at clinical treatment outcomes. A number of studies also looked at utilization of care. Two studies looked at quality of care (rates of attendance and in terms of content and timing of antenatal care). But two studies also looked at the quality of data collection [12].

A systematic review of apps to support self-management of heart-failure identified small samples sizes and as a result limited power of the RCTs to be a main issue of evaluating mHealth interventions performed. Nine studies performed a usability assessment of the newly developed solutions [13].

A commonly used measure to evaluate mHealth applications is through feedback from end-users by conducting surveys [14,15].

Cost-utility and cost-effectiveness studies are not routinely done for mHealth interventions [16].

4. Discussion

The preliminary findings from the scoping review showed that a number of factors and outcomes are assessed when mHealth interventions are evaluated. The most common aspect is a qualitative assessment of end-user experience. Often treatment outcomes and compliance are evaluated through quantitative measures. Less common are usability studies. Evidence on cost and cost-effectiveness is rarely every collected.

For mHealth applications that are intended to be part of the healthcare delivery process and should eventually be financed by a healthcare system, cost data and a measure of cost-effectiveness or cost-benefit is curtail. We therefore see the need for the development of an evaluation framework for mHealth interventions that includes disease-appropriate clinical outcome measures, use experience measure but also an economic component in form of cost comparison of the intervention with the standard of care. This information could be used for a cost benefit assessment.

The results reported here are only preliminary because a full scoping review is still in progress, limiting the generalizability of the findings. However, trends can already be observed.

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Benefits of Using Mobile Technologies in Education from the Viewpoints of Medical and Nursing Students

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Abstract. Increasing the use of mobile phones in education depends on the understanding of its benefits. The purpose of this study was to assess the vision of medical and nursing students about the benefits of using mobile technology in education. This study was conducted on medical and nursing students in 8 hospitals affiliated to Tehran University of Medical Sciences in 2016. 372 students participated in the study. Data were collected by a questionnaire consisting of 11 questions in Likert scale. Students' efficiency, improvement in quality of care, faster access to information and the positive effect on education were emphasized. Nursing students have more positive attitude regarding the use of this technology to save time at the time of providing services, faster access to patient information and influence on education. In summary, students considered mobile technology to be useful for educational purposes, so by eliminating the barriers in this field, it is possible to promote mobile learning for medical and nursing students.

Keywords. Mobile technologies, Educational affairs, Medical students, nursing students, Benefits, Opportunities

1. Introduction

Handheld computers, such as personal digital assistants and mobile phones, are new technological advances [1] that have many applications today [2]. These tools play a major role in health care [3]. These programs and their capabilities are widely used by physicians and nurses and studies have shown that the use of these technologies by physicians and nurses is increasing [4]. In addition to clinical applications, the educational use of this technology has increased. One of the advantages of this technology in education is the improvement of learning, reducing medical errors, increasing the accuracy of medical and nursing students in the clinical settings [5]. Various studies have also shown that the students' use of these technologies is increasing [6,7]. For successful application of technologies, the appropriate interaction between the technology, software and user is important. In the event of disruption of any of these components, these technologies cannot be applied in practice [8].

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The results of various studies have shown that user satisfaction and understanding of the benefits of technology are the most important factor in the continued use of smart phones [9]. Iran is one of the countries that are moving towards using this technology in the health system, but there are not many studies on the use of medical and nursing students in this type of technology. Previous studies have shown that the rate of use of Iranian students is not high. In order to increase the students' use, they should be aware of the benefits of these technologies and, if necessary, make appropriate corrective actions. Therefore, this study aimed at to investigate the perspectives of medical and nursing students about the benefits and opportunities of using mobile technology in education.

2. Method

This study was conducted on medical students (intern and resident) and nursing staff in 8 teaching hospitals of Tehran University of Medical Sciences including in 2016. Using Krejcie and Morgan table, 200 medical students and 200 nursing students attending internship and apprenticeship were randomly invited to study. Finally, 372 questionnaires were collected. To collect data, a questionnaire consisting of 15 questions was used. It included 4 demographic questions and 11 questions regarding the view of medical and nursing students about the benefits of educational use of mobile technologies. The questions were designed with a Likert scale of 5 options (completely disagree to completely agree) from 1 to 5, respectively. Content validity of the questionnaire was evaluated by 3 experts from the field of health informatics and health information technology, 3 medical students and 3 nursing students, and its reliability was confirmed by a test-retest method ($r = 0.8$) and Cronbach's alpha ($\alpha = 0.9$). In order to collect data, the researchers referred to the hospitals in person and handed the questionnaire to students. They provided the necessary explanations to answer the questions and gave them enough time to complete the questionnaire. For data analysis, responses were scored and SPSS16 was used for descriptive (mean and percent) and inferential statistics. T-test was used to compare the means.

3. Results

372 students including 186 medical students (52.2%; 84 interns and 102 residents) and 170 nursing students (47.8%) participated. 51.9% of students were female and most of them (83.3%) were under 30 years of age. The mean age was 26.1 ± 4.4 years.

The average score of medical and nursing students' views on the benefits of mobile technologies shows that the students confirmed all of these benefits (score of over 75% in all questions). From their viewpoint, students' efficiency, quality of care, faster access to information and the positive effect on education were emphasized more than the other benefits. Nursing students more than medical students believe that these technologies save time during the services, have faster access to patient information and a beneficial effect on education. Nursing students also recognized these technologies as compatible with university environment ($p < 0.05$) (Table 1).

Table 1. Viewpoints of medical and nursing students on the benefits of educational use of mobile technologies

Questions		Fully agree and agree	To some extent	Fully disagree	Points	p-value
More effectiveness of students in delivering clinical services	Medical	167(89.8)	15(8.1)	2(1.1)	4.2 ± 0.69	0.299
	Nursing	144 (84.7)	24(14.1)	2(1.2)	4.3 ± 0.75	
Improving the quality of care	Medical	159(85.5)	23(12.4)	4(2.1)	4.1 ± 0.73	0.710
	Nursing	140(82.4)	28(16.5)	2(1.2)	4.17 ± 0.74	
Enhancing student self-esteem in providing clinical services	Medical	149(80.1)	32(17.2)	5(2.7)	4.06 ± 0.79	0.154
	Nursing	128(75.3)	33(19.4)	27(4.1)	4.14 ± 0.92	
Saving time for providing clinical services	Medical	(79.1)147	(19.9)37	(0.5)1	4.04 ± 0.69	0.032
	Nursing	(78.8)134	(18.2)31	(2.4)4	4.18 ±0.81	
Get faster access to patient information	Medical	156(83.9)	28(15.1)	2(1.1)	4.11 ± 0.68	0.017
	Nursing	143(84.1)	23(13.5)	2(1.2)	4.27 ± 0.87	
Enhancement of evidence-based nursing and medicine	Medical	143(76.9)	39(21)	2(2.2)	4.02 ± 0.75	0.76
	Nursing	123(72.3)	38(22.4)	8(4.4)	4.02 ± 0.75	
Help to reduce medical errors	Medical	133(71.5)	46(24.7)	7(3.8)	3.98 ± 0.84	0.784
	Nursing	118(69.5)	37(21.8)	15(88.8)	3.93 ± 0.94	
Desirable effect on learning	Medical	146(78.4)	38(20.4)	-	4.1 ± 0.71	0.036
	Nursing	147(86.5)	21(12.4)	2(1.2)	4.25 ± 0.71	
Adaptation to the university environment	Medical	124(66.73)	48(25.8)	14(7.6)	3.77 ± 0.87	0.005
	Nursing	124(72.9)	39(22.9)	7(4.1)	4.04 ± 0.87	
Increasing the quality of student learning	Medical	136(73.1)	45(24.2)	5(2.7)	3.98 ± 0.79	0.204
	Nursing	129(75.8)	37(21.8)	1(1.2)	4.09 ± 0.77	
An appropriate alternative in the absence of print resources	Medical	129(69.3)	42(22.6)	13(8.1)	3.88 ± 0.97	0.236
	Nursing	120(70.6)	41(24.1)	9(5.3)	4.02 ± 0.91	

4. Discussion

Based on findings, students approved all the educational benefits of mobile technology. Both groups believed that improved student quality, improved quality of care, and faster access to information were the main advantages of mobile apps. Nursing students had a more positive view on the impact of these technologies on saving time at the time of services, the faster access to patient information, the favorable effect on learning and adaptation of these technologies to the university environment. Other studies on the students' views showed various benefits such as increased efficiency, ease of use [6], quick access to information, quality of care [10,11], improvement of knowledge and performance [12], increasing the accountability and compensation for the lack of students' experience [6,10-14]. In a US study, nursing students perceived increased efficiency (71%), and educational effectiveness (100%) as the most important

advantage of mobile technology [15]. In another study, nursing students offered the following benefits: quick access to information, usefulness, the possibility of quick consultation with a partner, better documentation, access to patient records, rapid access to information to guide patients and increased student self-esteem [1]. According to Swedish nursing students, access to medical information, access to patient information and patient records were among the benefits of these technologies [2]. There are also several studies regarding medical students. For example, these programs significantly improve the knowledge and function of residents [16]. In Wales, most students said that having such a program was helpful in mobile devices, and they found these technologies increased students' accountability [10]. Other studies reported benefits such as having access to resources [3], repetition of learning, complementary training (not substitution), and better use of leisure time [17]. These studies have almost similar results and show that medical and nursing students have a positive view of using these technologies. In short, the study showed that medical and nursing students have a positive outlook on the use of mobile technology, and they perceived many benefits. Due to the fact that the use of these technologies in educational affairs in Iran is not high, it seems that the reasons for not using these technologies are not in students' attitude, and conditions such as improving the infrastructure of using these technologies in universities should be improved.

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The Technology Use and Information Flow at a Municipal Telemedicine Service

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Abstract. Health care services facechallenges with providing individualised treatment to an ageing population prone to chronic conditions and multi-morbidities. The research project *Patients and Professionals in Productive Teams* aims to study patient-centred teamworkservice models. This paper presents an evaluation of a telemedicine service for chronic obstructive pulmonary disease patients integrated with municipal health care services. Qualitative methods were used to study the technology use and information flow. The results showed that the telemedicine technology was a standalone system, not integrated with the electronic health record of the municipality. A benefit of the system was a function to provide the patient with written instructions on agreements and advices. As a constraint for the patient-centred team approach, the information in the telemedicine system was available only for the telemedicine nurses and not to other health care professionals.

Keywords. Health technology assessment, telemedicine, patient-centred care

1. Introduction

Demographic changes with a growing ageing population are threatening the sustainability of the health and care services [1] as the prevalence of chronic diseases is increasing [2]. Patients with long-term chronic conditions and multi-morbidities dominate the specialised health care budget, through complex care processes over longer periods [3]. The World Health Organization (WHO) has emphasised the need to focus on patient-centred health care service models [4] and different approaches have been developed such as the Chronic Care Model [5][6] with the aim of operationalising patient-centred care and focusing on quality of care and patient outcomes. Information and communication technology (ICT) has an important role for supporting efficient team collaboration. In this context, the research project *Patients and Professionals in Productive Teams* (3P) has the aim to study health care services models run with a patient-centred teamwork approach [7]. 3P is a 4-year long project (2015-2019) funded through Helseforsk, a cross-regional health research fund owned by the four Norwegian Regional Hospital Trusts.The 3P project involves four innovation arenas utilizing patient-centred teamwork service models, located in different health regions of Norway

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and Denmark. This paper presents a study on the technology support and information flow made in one of the innovation arenas, Risør municipality in Norway, where a telemedicine service for chronic obstructive pulmonary disease (COPD) patients was integrated with the municipal health and care services [8]. The research questions (RQs) stated for the study were:

RQ1: *How does the technology support the communication and information flow at a municipal telemedicine service?*

RQ2: *What are the benefits and constraints of telemedicine technology in municipal patient-centred care?*

2. Methods

Qualitative research methods were applied to study the technology use and information flow at the telemedicine service [9],[10]. A total of 7 informants contributed to the study, including health care professionals, technicians and administrators. 5 semi-structured interviews were made with key informants, having an average duration of 63 minutes. A 2-hour long focus group interview was made with 7 participants addressing the topic telemedicine technology, telemedicine follow-up, and the information flow in a future perspective- what is needed to support patient-centred team collaboration? In addition, a demonstration of the telemedicine technology was made to show the practical use in the preparation and performance of a consultation. The data were collected at the end of year 2017 and beginning of 2018, consisting of audio-video recordings and annotations from the interviews and demonstration, that were categorised into thematic groups. The Norwegian Centre for Research Data (NSD) approved the studywith project number 53771. The participation in the study was voluntary and the informants signed aconsent form.

3. Results

The telemedicine service was organised as a unit integrated with the municipal health care service. Two nurses were responsible for running the daily operations during weekdays. The service was open for all inhabitants of the municipality needing medical follow up of COPD and that could benefit from remote monitoring. Patients could be referred from home nursing services, General Practitioner (GP) or hospital. As the telemedicine service was integrated with the other municipal services, there was a close collaboration with physiotherapist and occupational therapist. In addition, the telemedicine nurses had regular meetings with the GPs in the area. The patient's GP was responsible for medical treatment and advises during the telemedicine follow-up. In addition, there was collaboration with pulmonary specialists at the hospital. When enrolling a new patient into telemedicine, the patient received a home visit from a telemedicine nurse for connecting the equipment and to provide user training. In addition, there was a research protocol to follow with registrations and a patient questionnaire on eHealth literacy and patient safety [8][11]. An electronic notification was sent to the patient's GP to inform about the inclusion to telemedicine monitoring. During the period when a patient was enrolled in the telemedicine service, the telemedicine nurses could assist with contacting or sending referrals to other health care providers and related services when needed due to medical circumstances. Two

technical systems were used at the telemedicine service: 1) the municipal electronic health record (EHR) named Gerica from Tieto [12] and 2) a solution for the telemedicine services developed by Open TeleHealth [13] and delivered by Siemens Healthineers [14]. Both systems had to be used separately to carry out the telemedicine services. All statutory medical documentation was made in the municipal EHR system for permanent storage. For telemedicine follow-up, the patient at home logged on a tablet application with a username and password. The patient used a pulse oximetry device with Bluetooth transmission to the tablet and filled in a symptom self-evaluation questionnaire. The data communication from the patient's tablet to the server was encrypted by standard Hypertext Transfer Protocol Secure (HTTPS). To access the information from the patients, the nurse used a laptop to log into the telemedicine management system, connected with a network cable and secured by end-to-end VPN. The measurements sent in by the patients, were automatically colour coded as there was a triage function implemented in the system based on an algorithm. The nurse could call the patient's tablet from the telemedicine management system to perform a video consultation, but telephone was also used for the consultations. The telemedicine management system had a function to send messages and written instructions to the patient's tablet, for instance on temporary changes in medication. The information sent from the patients was stored in the telemedicine management system, and available only for the telemedicine nurses. For permanent documentation, the nurse had to create a journal note in the patient's EHR, with manual transfer of the telemedical measurements. For registering a new patient in the telemedicine management system, all administrative information from the patient's EHR had to be manually inserted.

4. Discussion

This paper has presented a study of the technology use and information flow at a municipal telemedicine service driven with a patient-centred service model. The research questions (RQs) are answered based on the results. RQ1 asked about how the technology supported the communication and information flow at the telemedicine service. The study showed that the telemedicine system was a standalone technology and not integrated to the municipal EHR, which created double work with manual transfers between the two separate systems, also seen in other studies [15]. The technical solution used for the telemedicine service did not efficiently support patient-centred teamwork, as incorporated personnel at the municipality, GP or hospital could not log on to the stand-alone system for accessing information. The information was only available for telemedicine nurses. The municipal system was used for electronic communication within the municipal health care services, and for instance if a patient was categorized with a red alert based on the telemedicine measurements, the telemedicine nurse would contact the patient and send a notification on the digital working list of the home nurse that the patient is needing a prioritised home visit. The communication with the patient's GP was based on electronic messages. Regarding the videoconference function, there were technical issues with the quality that made the nurses preferring use of telephone for consultations and follow-up. RQ2 asked about benefits and constraints of using telemedicine for carrying out patient-centred care. The aim of running the telemedicine service was to increase the quality of care, safety and outcomes for COPD patients in the municipality. When it comes to the patient-centred care approach, it was beneficial to have the telemedicine service integrated with the

municipal health services, for operating as a team for instance when the telemedicine consultations revealed a need for advices on physiotherapy or occupational therapy, but also for collaborating efficiently and closely when a telemedicine consultation had shortcomings and an urgent home visit was needed. The telemedicine service had two nurses that followed up the patients, which was beneficial for the continuity of care and communication procedures. The function of sending messages to patient's tablet was a quality feature for better adherence to oral information given by the nurses and expedient for patient safety, but a constraint was that the patient needed to be logged in to hear that a message was received. Another constraint was that to hear an incoming call on the tablet device, the patient needed to be logged in to hear the signal. Due to battery capacity and privacy reasons, the patients were instructed to log out after each use of the tablet. This was solved with an initial phone call to ask the patient to log in for an upcoming video-consultation. For privacy and security reasons, the patients were not registered with their name in the telemedicine system, instead de-identification of personal information was made with a number, as the access to medical information in Norway is restricted by the authorities [16]. This study has some limitations, such as a limited number of informants. However, the study participants had different professions and backgrounds, meaningfully representing the user group. Future research agenda targets an extension of the study, by including patients and health care professionals in a new evaluation made one year later to evaluate changes in the use of technology, and summarising the results in a recommendation to the stakeholders.

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Evaluation of a Telemedicine Service Run with a Patient-Centred Care Model

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Abstract. The number of patients with chronic conditions and multi-morbidities is increasing, addressing a need for patient-centred care. The research project *Patients and Professionals in Productive Teams* aims to study patient-centred teamwork for this patient group. This paper presents an evaluation of a telemedicine service for chronic obstructive pulmonary disease patientsrun with a patient-centred care model. Observations and interviews were made to study the technology use and information flow. The results showed that the technology worked well in a patient-centred care perspective, even though the system was a standalone system for telemedicine services. The information in the system was only available for professionals providing the telemedicine services and was not shared with other health care providers.

Keywords. Telemedicine, health technology assessment, patient-centred care

1. Introduction

Health services are facing challenges of providing individualised treatment to a growing ageing population prone to long-term conditions and multi-morbidities [1]. There is aneed to understand how to operationalise patient-centred, integrated and pro-active care, supported by technology. In this context, the research project *Patients and Professionals in Productive Teams* (3P) has the aim to study health care services models that are run with a multidisciplinary patient-centred teamwork approach [2]. 3P is a 4-year long project (2015-2019) funded through Helseforsk, a cross-regional health research fund owned by the four Norwegian Regional Hospital Trusts [3]. Ten research groups are focusing on different aspects of patient-centered teamwork service models, such as technology support and medical outcomes. The 3P project involves four innovation arenas that utilize patient-centred team models, located in different health regions of Denmark and Norway. This paper presents a study on the technology support and information flow made in one of the innovation arenas, Lyngby-Taarbæk municipality in Denmark, where a telemedicine service for chronic obstructive pulmonary disease (COPD) patients was run in collaboration with an eDoctor service based on the Epital Care Model [4]. The model has the aim to support the independent life and self-management of the citizens by providing telemedicine services, in line with the Chronic Care Model [5][6]. COPD has been predicted as the fourth fatal

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disease globally in 2030 [7] and the patient group is prone to exacerbations requiring frequent hospital admissions [8]. In this context, the Epital Care Model aims to provide individualised care by treating COPD patients at home or at a municipal local health clinic to avoid hospitalisation. The research questions (RQs) stated for the study were:

RQ1: *How does technology support the communication and information flow at the telemedicine service?*

RQ2: *What are the benefits and constraints of the telemedicine technology in a patient-centred care perspective?*

2. Methods

Qualitative research methods [9],[10] were applied in the study of the telemedicine service, performed in September 2017. A total of 8 informants contributed to the study, including health care professionals, patients and a family member. A group interview was made with 4 informants, (three COPD patients and one family member), followed by individual interviews. Three physicians were interviewed addressing organisational and technical issues of carrying out telemedicine. A workshop on benefits and constraints of the information flow and reflections on how to optimise it in the future, was made together with one patient and two physicians. A field visit was made to the telemedicine service hosted by a nurse, with a practical demonstration of the technology involved. Later, a detailed demonstration was made on a large screen of the telemedicine technology to show the user interface and implemented functionalities. The collected data consisted of audio-video recordings and annotations, that were analysed and categorised into three main groups inspired by [11]. The Norwegian Centre for Research Data approved the study, with project number 53771. All informants participated voluntary and signed a consent form.

3. Results

The telemedicine service was organised as a municipal health service, with nurses responsible for running the daily operations and an eDoctor service available for consultations. The service was established to support the active and independent living of the COPD patients of the municipality, and available for the citizens that could benefit from the procedure. The patient could self contact the telemedicine service for inclusion in the remote monitoring procedure. As a part of the inclusion procedure, a physician from the eDoctor service visited the patient at home for medical examination and registrations. A tablet was connected, and user training provided. The equipment was owned by the municipality and was permanently borrowed out to the patient. The eDoctor service was responsible for medical treatment and advises during the telemedicine intervention, in close collaboration with the nurses. Each patient had a personalised treatment plan and a set of medication available at home in a kit. The patients used the telemedicine service mainly during deteriorations, and not for daily measurements and follow-up. As the telemedicine service was municipal, there was a team of nurses that could attend the patient at home, and in addition, there was a municipal local health clinic for short stays. The telemedicine service worked as one-point-of contact for the enrolled patients. The nurses contacted the eDoctor service and other related health service providers such as the pharmacy when needed due to

medical circumstances. The telemedicine service was available at day-time during weekdays.

Two technical system were developed for this particular telemedicine service: 1) Appinux for overview of enrolled patients and 2) EpiProcess, a Windows-based open source web-service that was process-oriented. Appinux was evaluated as a system that was easy to use, user-friendly and providing a good overview, but one weakness was that it was not a clinical system, so EpiProcess had to be used in parallel. EpiProcess was developed to support the clinical workflow in telemedicine monitoring.It was through a broadband access connected to a centralised data server for storage. It had some limitations, such as lack of integration with Appinux and not having classification or separation of notes which made the overview overloaded. The system had a lack of standards and was not technically integrated with other health care providers, meaning that electronic messages could not be sent. An exception was citizens receiving municipal health care services, for those messages could be sent to the municipal care system.

The patient at home used a tablet, with a pulse oximetry and spirometer connected through Bluetooth. The tablet had a clear user interface providing a good overview, it was evaluated as easy to send measurements and the video-conference function was explained as important. The patients expressed that it was practical to bring the equipment during journeys, only needing network connectivity for using the service. As a future improvement, it was suggested that patients should be able to use their own smartphone device instead of borrowing a tablet. The nurse used a desktop for logging into the management system. The measurements sent in by the patients had early warnings to detect deterioration and the system provided decision support. The information in the telemedicine system was available only for the telemedicine nurses and the eDoctor service. When enrolling a patient into telemedicine monitoring, no notification was sent to the patient's GP or pulmonologist. The telemedicine system did not have a function to send messages or written instructions to the patient's tablet, to be used for confirming oral information.

4. Discussion

This paper has presented a study of the technology use and information flow at a telemedicine service driven with a patient-centred care model. The research questions (RQs) are answered based on the results.

For RQ1, asking about how the technology supported the communication and information flow at the telemedicine service. The telemedicine service was run with a person-centred care approach, putting the citizen and his/her needs at the centre and it was established as a sustainable service, in line with the European Union Health Strategy [12]. The study showed that the telemedicine system was a tailored system designed and developed to carry out person-centred telemedicine follow-up of COPD patients. It was described as well functioning, but it was run beside the municipal EHR and administrative systems. There was limited electronic communication with other health care providers such a GP and hospital specialists.

RQ2 asked about benefits and constraints using telemedicine technology in a patient-centred care perspective. The study identified both strengths and weaknesses with the technology used. Addressing patient-centred care, it was beneficial that the service was run as a municipal supplement to the other health care services, for

instance municipal nurses could attend patients at home when needed in addition to video-conference with telemedicine nurse or the eDoctor. The individualized care was beneficial for the patients, and the telemedicine measurements and consultations were mainly carried out in worsening of the patient's clinical conditions, which might be good for the adherence to the intervention. In other studies, the patients have made daily measurements [13],[14], which might cause drop outs or lack of adherence to the service. In the tablet application, the patients had access to the history of measurements but could not access their own information in the management system. A constraint in the daily operation was the lacking function of sending a message to the patient's tablet, to confirm oral information for instance on temporary medication adjustments. The technical solution used for the telemedicine service was suited for patient-centred teamwork that incorporated personnel at the service, but there was lack of technical integration with other health providers. This study has some limitations, such as a limited number of informants. However, the study participants had different professions and backgrounds, meaningfully representing the target user group. The main contribution lies on the evaluation of benefits and constraints, applicable and transferable to other contexts. Future research agenda targets a continued evaluation of the innovation arena, including a comparison of the results with the other three arenas.

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The Stratified Framework for Enhancement of Study Programs in Public Health in Montenegro

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Abstract. Montenegro plans to enhance its educational system in the area of health information management, in accordance with well-known EU best practices. Within the Erasmus+ project PH-ELIM, a Stratified Framework was developed to provide education of public health professionals making them highly skilled to support the nation in creating a sustainable and flexible health system, in providing good quality health, in protecting citizens against health threats, all by a cost-effective and straightforward approach. The objective of this presentation is to present the intermediate results of the Framework and lessons learned until now.

Keywords. Public health education, study programs, EU best practices

1. Introduction

Medicine is currently undergoing a major revolution that is gradually transforming the nature of healthcare from reactive to preventive [1]. Developing, managing and exploring integrated models of health service delivery and cooperation across many sectors is challenging for all nations and countries all over the world. Montenegro (ME) is a small country facing rapid changes and development challenges in all areas that are relevant for societal progress and prosperity. The ME Government and Ministry of Health [2] defined health as a priority value and as the major developmental task to: prepare a set of measures to achieve optimal health of the population, reduce inequalities in health between regions and among citizen groups, promote healthy behavior and prevention of early morbidity, improve accessibility,

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safety and quality of health services, invest in human capacities and modernization of health facilities [3].

In order to support the nation moving towards achievement of defined aims, the University of Donja Gorica as a coordinator implements the Erasmus+ project 'Enhancement of study programs in Public Health Law, Health Management, Health Economics and Health Informatics in ME' (PH-ELIM) [4] (Ref.No: 573997-EPP-1-2016-1-ME-EPPKA2-CBHE-JP) which is aimed at enhancement of the educational system in ME in accordance with well-known EU best practices, thus providing education to students to become public health professionals who are highly skilled to support their own nation in creating a sustainable and flexile health system, providing good quality health, and protecting citizens against health threats.

2. Methods

PH-ELIM is an ambitious project aimed at enhancing and improving the educational system in public health fields, with the simultaneous development of new elements (such as: new study programs, an innovative national platform for education and research in public health, etc.). Noting the complexity of such a process, and having in mind current EU standards and best practices with clear initiatives and guidelines at national level, the following stratified approach is designed: '*learning from others'* (through peer review processes), '*adapting the best practices to own educational system and national diversity'* (through review and benchmarking), and finally *implementation, evaluation and development of sustainable options* for continuing education in public health fields. All these steps are planned to be implemented within a stratified frame work of the following dimensions: (I) development of educational programs and curricula; (II) quality assurance of the educational process, development of high teaching expertise; (III) raising awareness, public health promotion.

3. Results

Implementation of the stratified framework is logically organized within the following developing work packages, with clear aims contributing to overall achievements.

3.1. Analysis and road-mapping: Public health Education in Montenegro

This WP is aimed to create a good research ground for carrying out the other project WPs by reviewing and analysing current EU practices, principles and education of public health; on these bases the Roadmap will be created for improving ME's educational system and human capital development. Implementation of the following tasks will contribute to the achievement of defined goals:

Task 1.1: Analysis of EU practice for public health. Make a comprehensive overview of existing practices in the EU and globally concerning public health. Identify and analyse different aspects of public health practices, including: the role of public bodies, national regulations, ICT support services, human and capacity building, etc.

Task 1.2: Analysis of EU practices for public health education. Make a comprehensive overview and analysis of educational practices in the fields of public health.

Task 1.3: Cross-matching of practices in ME with EU standards. Cross-matching of public health practices and best practices in public health education of the EU and ME, aimed at the identification of similarities and possibilities for improvements in ME.
Task 1.4: Roadmap for a New Educational System in Public Health in ME. Creation of the Roadmap at a national level with identified key actors and assigned roles, and a stepwise approach for implementation of the proposed public health educational system.

3.2. Human Capacity Building in Public Health Education in Montenegro

The aim of this WP is to prepare and organize training events aimed at enhancing the expertise and competencies of staff members of Higher Educational Institutions in ME (ME HEIs) in public health fields, as well as enhancing their connections with and visibility to the international public health community. Implementation of the following tasks will contribute to the achievement of defined goals:
Task 2.1: Analysis of teaching approaches commonly used in ME. It shall serve as a basis for planning and preparing training events for staff members from ME HEIs.
Task 2.2: Teaching Competencies Development of academic staff from ME. Training content is prepared and given by the EU partners aimed at enhancing teaching and expert competencies in the fields of public health (Public Health Economy and Management, Law of Public Health, Medical Informatics, and Medicine).
Task 2.3: Strengthening cooperation with EU authorities in public health education. The results of this task shall strengthen the grounds for further development of educators in public health through entering into EU associations in public health fields.

3.3. Development of study programs in Public Health in ME

The major aims are the analysis of existing and creation of enhanced programs in public health in ME, as well as preparation of learning repository in Public Health. Implementation of the following tasks will contribute to achievement of defined goals:
Task 3.1: Analyses of educational programs in Public Health. This activity is aimed to facilitate understanding and transparency regarding current and future courses/programs on public health at the University of Montenegro (UoM), University of Donja Gorica (UDG) and University Mediterranean (UNIM) (thus covering 99% of all ME HEI) including information on subjects, technical background and staff.
Task 3.2: Creation of new and updated programs and courses curricula. In order to develop comprehensive approach for small country, each HEI identified specific field(s) for development/integration of courses/programs in specific faculties/departments, as follows: (i) UoM- Medical Faculty- field of **medicine**; (ii) UDG- fields of **economy, medical informatics** and **law** (new master program, new courses and modules); (iii) UNIM- fields of **management** and **law (**new courses).
Task 3.3: Accreditation of new study program(s). New master program "*Health Information Management*" will be accredited at UDG. In long-term perspective, the program is aimed to be inter-linked with European Master's programme EU-HEM[5].
Task 3.4: Integration of updated courses into the curricula of ME partner HEIs. HEIs will conduct formal procedure of integration of developed/adopted programs/ curricula.
Task 3.5: Preparation of study and learning materials and development of ICT support. Innovative learning and teaching approach will be developed and implemented in the form of integral platform with public health data and several software modules, such

as: Health Statistics and Data integration; Disease Control and Prevention; Financial Analyses: Health Care Costs and Utilization; National Surveys.

3.4. Piloting and Evaluation

This WP is aimed to: (i) provide first generation of professionals in public health fields; (ii) organise high quality education in study programs and courses of public health; (iii) conduct comprehensive evaluation assessments over organised education process. Implementation of the following tasks will contribute to achievement of defined goals:
Task 4.1: Enrolment of new generation of students. This first generation of students is planned to be enrolled for academic 2018/2019 year.
Task 4.2: Strengthening cooperation with EU partner HEIs through organisation of workshops for students. Organisation of workshops aimed on sharing experience and described processes in developing and validating qualitative and quantitative evaluation tools to assess courses and programs in public health.
Task 4.3: High standards and quality assurance of educational process and teaching. Partner EU HEIs will also share their experience in evaluation assessments.
Task 4.4: Evaluation of teaching process and students experience. Evaluation and assessment of organised educational process at ME HEIs in public health. As one example, innovative teaching strategies fostering self-regulation of students have been described, implemented and evaluated as part of the PH-ELIM trainings [6].

4. Discussion

Presented Stratified framework is planned to be implemented for duration of 3 years. During first 18 months of project implementation (results are available at project web site [4]), the following key elements are developed: (i) *continual sustainable educational curricula*, from BSc to PhD level, all adopted to ME specificities; (ii) *capacity building trainings* for ME staff members in multidisciplinary fields of public health, and (ii) carefully selected *raising awareness campaigns* about health prevention and public health promotion among citizens are initiated. However, the sustainability grounds for key project results shall be ensured, which could be achieved by increasing the awareness among various stakeholders, all in close cooperation with key players at national level in ME. Finally, the preliminary impacts are expected to be measured after implementation of the core element of the Stratified framework, i.e. organisation of the first year of new Master study program and its comprehensive evaluation.

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Diagnostic Games as a Teaching Tool

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Abstract. Diagnostic games were developed in the 70s of the last century for elicitation and formalization of the physician's clinical experience. This laborious technique was successfully used to elaborate decision rules for several complex clinical problems but had no further development. Modern information and communication technologies and achievements of medical informatics allow developing digital transformation of diagnostic games. One of the areas of application of this new technology may be simulating of clinical decision making for educational purposes.

Keywords. Digital transformation, diagnostic games, clinical decision making, simulation

1. Introduction

Diagnostic games (DG) were developed at the school of IM Gel'fand (1913 - 2009) in the 70s of the last century for elicitation and formalization of the physician's clinical experience (see [1-5]). IM Gel'fand, one of the leaders of world mathematics of the second half of the 20th century, was also known for his work in cell biology and physiology of motion. The experience of using the structural approach characteristic for mathematicians for the analysis of complex biological systems has proved useful in the field of medical informatics.

DG is an intensive method of expert's knowledge acquisition and formalization. It was developed during a long-term collaboration with physicians. This collaboration was devoted to formal methods in decision of clinical problems and was based on three principal requirements:

- the results have to help a doctor to make decision concerning concrete patient;
- the methods of analysis have to make good use of knowledge and experience of clinical experts;
- the results have to be as demonstrative as results in biology and psychology.

The general shape of DG technique resembles some of experimental psychological techniques proposed earlier in [6] in order to formalize human methods for interpreting the results of psychological tests.

DG is a very laborious procedure requiring the participation of highly qualified specialists. At the same time, they have a number of attractive features that indicate the expediency of using them in some new, digital format.

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In the following sections, the idea of digital transformation of DG will be offered and possible scenarios for their use for training will be described.

2. Diagnostic Games – Brief Description

The focus of the team of mathematicians, engineers and physicians who worked under the leadership of IM Gel'fand was not so much the use of methods of machine learning to solve the problems of diagnosis and prediction arising from the needs of clinical medicine, but rather the modeling of decision-making by the doctor.

At the basis of the developed approach, named as "method of adequate formalization" (see details in the literature, especially in [5]), were observations of the real work of the doctor. The main were such simple conclusions:

- when discussing very many situations, doctors are very concise and can transmit essential information to each other in very few words;
- the doctor almost always makes decisions, relying on information which is redundant and insufficient at the same time.

How does the doctor manage to make decisions in such conditions and overcome "curse of dimensionality" and the "magic number of Miller" 7 ± 2 ([7]), which determines the capacity of the human's operative memory?

One possible answer lies in the hypothesis of data organization. This hypothesis assumes that in the process of forming clinical experience the physician finds specific forms of organization of the clinical data and forms some integral features (called in [1] "structural units") based on typical characteristics for the considered clinical situation, observed symptoms and syndromes. The reliance on structural units, which usually turns out to be a bit, allows overcoming both the "curse of dimensionality" and the almost always present lack of data. Structural units have some important features:

- it is possible to formulate in terms natural to the doctor;
- they depend on the task facing the doctor - the same symptoms can be organized into structural units in different ways to solve various problems;
- they are outwardly simple, but they may have complex internal structure.

The investigation of methods of data organization by a doctor is one of the main purposes of the method of DG. Its main idea is to create conditions in which the doctor will answer questions similar to those to which he is responsible in his daily activities. In other words, DG are modeling the decision-making process of a doctor.

In a typical clinical situation, the doctor gets acquainted with the patient's medical records, talks with him, conducts an examination and decides on further actions. DG model this process as follows.

First, a fairly clear question is formulated, which will be put before the doctor during the diagnostic game - as a replacement for the whole range of problems that the doctor has to resolve during the meeting with the patient.

Secondly, for the game, the patient's role is played by his formalized description - a pre-designed and completed questionnaire.

Finally, the patient's examination and conversation with him are replaced by a game procedure, during which the physician receives the patient information he needs, asking questions about the patient's condition to the host of the game who finds the

answers to them in the questionnaire. The whole course of the game is recorded automatically or by the assistant of the host. After a sufficient number of games, informaticians conduct an analysis of the protocols. At this stage, with the help of various formal procedures, those structural units are identified, on the basis of which the doctor solves the task, and formal decision rules are created. The formulation of decision rules is not the final stage of the whole work. After their receipt, verification is necessary, which is largely similar to the testing of drugs in clinical trials. Only after carrying out such an inspection it is possible to use the obtained decision rules in clinical practice. Note also that simplified and reduced versions of DG can be used at various stages of work - for example, when composing questionnaires.

3. Diagnostic Games - Digital Transformation

There are two features of DG that are of special value.

- The doctor makes decision in the controlled informational environment.
- The doctor's mistakes are not dangerous for real patients, so the doctor is free in his mental constructions.

All this makes DG a good contender for the role of a tool for modeling clinical decision making, and with the help of modern information and communication technologies they can be widely disseminated. Modern information and communication technologies allow us to go further and create a platform for conducting DG making following substitutions.

- The content of the several questionnaires can be replaced by a very large database, which is based on electronic medical records of different clinics.
- In this case, the structure of the questionnaire can be replaced, for example, with a template in the sense of openEHR technology
- The host of the game and his assistants are no longer needed. The host will be replaced by an intelligent system that will monitor and manage the flow of questions.
- By placing the platform of DG in the cloud, it is possible to attract not one but many experts from different countries and different medical schools to solve the task.
- The expert doctor will be able to access the system many times; as a result, his new experience will be revealed and formalized.

The result of the digital transformation of DG - let's call it "digital diagnostic games" (D^2G) - can find different applications.

4. Digital diagnostic games –a training tool

DG in a new, digital format can be used not only to elicit and formalize the clinical experience of doctors, but also to disseminate it. We describe one of the possible scenarios for testing medical students. At the preparatory stage, "clinical tasks" and "Questionnaires" are prepared by experienced doctor in collaboration with informaticians: a description of certain clinical situations and decisions taken by

doctors in these situations. Suitable cases may be selected from the database of clinical cases in sufficient quantity. At the stage of testing the student receives the formulation of the clinical task and examination of the patient is simulated: the student asks those questions about the patient's condition and his treatment that seem to him necessary for the solution of the task. Having received all the necessary data, the student formulates his decision. After a similar analysis of several cases, the teacher conducts a detailed analysis of the student's decisions. In the course of such a "virtual examination" the program controlling the process can complicate the task in various ways. This scenario can be diversified. For example, it is possible to conduct testing on a knowingly inadequate data set, stimulating the student to develop alternative solutions and comparing them, it is possible to partially change patient data, forcing the student to seek new approaches to solving problems, etc.

5. Conclusion

The first step that has to be done on the way of digital transformation of DG is developing of information model of the whole process. After that the architecture of the new platform may be designed. The use of the proposed digital transformation of the diagnostic game technique can be especially useful nowadays, when more and more functions of the doctor will be transferred to various diagnostic devices, including artificial intelligence programs. In this situation, the traditional possibilities for acquiring clinical experience in the course of clinical practice can be reduced, and various ways of modeling clinical experience will be in demand. The proposed D^2G can, on the one hand, to some extent replace clinical practice. On the other hand, they can introduce a "clinical experiment" in the training of medical students, which is impossible when training in real clinical conditions.

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Co-Creation of an Innovative Vocational Training Platform to Improve Autonomy in the Context of Alzheimer's Disease

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Abstract. Support of autonomy, at the onset and while Alzheimer's Disease progresses, is of utmost importance for both older adults and their caregivers. AD-Autonomy project aims at co-creating an innovative training platform with and for elderly people and their caregivers. Main aim of the project is to increase the competencies of older adults and their caregivers to cope with the disease effects, by leveraging existing ICT tools and applications, while transferring their applicability in real life contexts and activities. Initial anecdotal feedback is collected through a co-creation session, where all above themes were discussed and analyzed between seniors, family caregivers and professionals.

Keywords. Alzheimer's Disease, autonomy, e-learning, assistive technologies, co-creation

1. Introduction

Alzheimer Europe estimates the number of people with dementia in Greece in 2012 as being 201,766. This number represents 1.77% of the total population of 11,418,878 people. It is estimated that in 2030 and 2050 it will reach 276,000 and 365,000 people respectively [1]. One of the key socio-economic burdens that Alzheimer's Disease (AD) poses to older adults and their family, is the loss of autonomy in daily life activities. In recent years, innovative approaches [2] have been developed that allow Persons with Alzheimer (PwA) to develop a life as full as possible outside the healthcare environment, improving their Quality of Life (QoL), as well as ICT Tools that enhance their autonomy [3,4] in a secure environment with the relevant supports. AD-Autonomy aims at developing a methodological guide to provide a structured training platform, which will focus in the support of experiential learning activities, simulating real life contexts and situations. This approach, combined with the participatory design principles that we aim to integrate throughout the project and present in this study, will hopefully maximize the uptake of existing ICT tools and apps, when used in the context of older adults autonomy support.

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2. Materials and Methods

In order to facilitate the process of eliciting daily life aspects of autonomy, a co-creation session was realized in the premises of the Thessaloniki Active & Healthy Ageing Living Lab [5]. Five (5) elderly participants (4 females, mean age 77.2 y.o.), either suffering from Mild Cognitive Impairment (MCI) or having subjective memory complaints participated. One of the elderly participants has a sister who is suffering from Alzheimer's Disease and provides daily care to her. In addition, three professional caregivers interacted and provided their perspectives on the caring of the PwA. The co-creation session lasted 120' and it was audio and video recorded, after all participants provided their consent. A short presentation about the project's scope and objectives was made by the facilitator of the group and then certain parts concerning autonomy of people with memory problems were discussed: i) definition of autonomy and its basic dimensions, ii) tools and procedures embedded into daily routines, so as to sustain autonomy in elderly people and finally, iii) assistive, ICT tools, apps and barriers or facilitators for adoption.

3. Results and Discussion

3.1. Definition of Autonomy and its dimensions

Elderly people participated in the group referred to autonomy as: "to be able to serve yourself", "visiting the toilet", "physically, mentally and emotionally healthy". Daily life activities and routines linked to the autonomy definition and perceived as important included: safety as the primary aspect for both the PwA and the carer as it was mentioned that "…sometimes PwA even become violent or aggressive"; money management; medication management; personal hygiene; meal preparation and sleep rituals; housework; transaction with public services; sexual relationships. Emotion management is a skill for both patients and caregivers that needs to be trained. According to professionals, emotional competences means to understand one's feelings, to express oneself properly, given the existing social context, baring with one's emotions, to control one's feelings in order to have more effective social relationships. In conclusion, emergent themes of this part of the focus group, included the autonomy dimensions that are linked to daily activities and are most important for older adults with memory problems to maintain. Surprisingly, two dimensions, that we did not expected came up, such as transportation or driving and sexual relationships. With respect to professionals and the caregiver, emotion management matters the most.

3.2. Tools and skills developed in daily life to sustain autonomy

Elderly people highlighted the fact that they develop habits or repurpose other daily life activities in order to stay active and participate in society. One participant mentioned that using public transportation is a means of keeping themselves as socially engaged: "when I enter the bus, I check who is sitting next to me so that I choose the one who is more likely to be open for a discussion during the bus ride!". Adjustment of daily routines and home environment were proposed by both professionals and the elderly, e.g. not using public transportation during busy times. Rituals to help PwA to remember include note keeping; they store notes to a place which they visit very

frequently or spend a lot of time during the day, e.g. kitchen, living room, bedroom so as to check to-do list immediately after waking up and schedule the day ahead. Note keeping is necessary for remembering appointments with their doctors, to make an important phone call and make the shopping list. Example strategies on sustaining autonomy dimensions were proposed by professional caregivers as well. For instance, trying to remember the shopping list by bringing into mind pictures of their fridge or prioritization of duties could improve daily problem-solving ("do easy tasks instead of spending a lot of time to something that you cannot figure how to do by oneself").Obstacles identified in achieving the skills required for autonomy, also include negative emotions such as fear, anxiety and discouragement by their relatives. Summarizing the results of this part of discussion, there were two main themes identified by all participants. Keeping habits in note keeping was one of the key factors that enabled older adults to maintain their independence in daily life activities. Prioritization of daily duties focusing on positive aspects (what they can do by themselves) of older adults was emphasized by professional caregivers.

3.3. Assistive ICT tools and apps for supporting autonomy

Most of the participants mentioned that they have used devices such as: smart phone, tablet and smart watch – it was specifically mentioned for health and safety reasons. One PwA mentioned the use of calling line identification to facilitate searching contacts and make phone calls. She also mentioned using the tablet as a strategy to exercise memory by learning new things or performing problem-solving tasks, such as crosswords in a fun and engaging way. Using apps for updating theoretical knowledge with respect to driving and road safety was highlighted by the older male participant. A PwA searches for recipes through the internet and watches instructions through YouTube videos. Other ways that elderly people exploited mobile technologies included: checking bus timetable, watching music videos, using Skype for chatting with loved ones, to read online health articles. Professionals mentioned the use of a GPS-enabled smart watch which is used to track the outdoor position of people with orientation problems and produce alerts in case of an emergency. Obstacles of using technology, included: functionality does not meet their expectations, e.g. pushing a button does not result to the desired action; unreliable programs and difficult to use apps are major factors that cause disappointment to elderly people; language problems were also mentioned -especially when technological terminology is used makes it hard to understand; if they do not use technology regularly, they tend to forget; relatives on the other hand, mention lack of time to teach them how to use devices such as tablets. There are also some ethical issues raised about technology use from PwA. They express their concerns about inappropriate content viewed while on Internet could be a cause of not using technology in daily life. Also, misleading information that is widely available on the web makes them feel unprotected and vulnerable - an example was provided with respect to fake medical articles presenting new therapies with unpredictable results. Caregivers suggested the strategy of cross checking information from multiple sources so as to verify the validity of online content. In order to use technology, PwA need someone by their side to educate and guide them. Some participants use notes to record all steps needed on how to use an app or a device. Learning process, according to professionals, should be long-lasting and technology use should become part of everyday life, such as cooking. Also it was mentioned that different people may have different needs and learning curves, as it may happen that

they do not learn so fast as others do. To sum up, a multitude of usage scenarios were mentioned by older participants and caregivers, including mostly devices such as smart phones and tablets. In addition, main barriers to technology adoption, include social stigma, ethical reasons, not senior-friendly design and technical terminology used instead of simple human language. Finally, participants highlighted that training should be provided on an individual learning pace and on a continuous base, so as to sustain in the long term the benefits obtained.

Figure 1. Co-creation session results in a nutshell

4. Conclusions

Including all relevant stakeholders in a co-creation session, let us collect valuable insights about their everyday life and how technology can be used to improve their autonomy. Information not previously documented by experts was provided by PwA and professionals. Main limitation of this study is that all participants had previous experience with technology artefacts, which subsequently could bias their attitudes towards the use of assistive technologies. A second co-creation session is planned, which will provide more details about how these technologies can be embedded in real life context and improve the competences of PwA and their careers.

Acknowledgements

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Education in Biomedical and Health Informatics: A Mapping Approach

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Abstract. The emergence of the information technologies has seriously changed the healthcare system. Thus, health professionals need to be well-educated in order to respond successfully to the challenges of their job. In higher education programs in, biomedical informatics and health informatics are continuously developing. At this study more than 500 universities and colleges in Europe were checked in order to find related educational programs at all academic levels. The outcome of the research includes316study programs at undergraduate and postgraduate level including a variety of specializations. The majority of these programs are taking place in Czech Republic, Ireland and Austria. In contrast, countries such as Croatia and Cyprus have very low number of study programs in these fields.

Keywords. Health professionals, educational programs, health informatics, EFMI.

1. Introduction

The emergence of the information technologies has seriously changed the healthcare system. Thus, health scientists and professionals in order to respond successfully to the challenges of their job, need to be well-educated with knowledge and skills [1].

The literature emphasizes in curriculums with specialization in Health Informatics, Biomedical Informatics, Medical Informatics, Medical Engineering and Biomedical Engineering of the European Universities which are offered at undergraduate and postgraduate level [2-4]. However, there is a remarkable absence of detailed recordings of the European educational programs in these specializations. Thus, the aim of this research is to fill in this gap.

2. Method

More than 500 universities and colleges in Europe were checked in order to find educational programs in the following topic areas: Health Informatics, Medical Informatics, Biomedical Informatics, Bioinformatics, Nursing and Dental Informatics, Health and Medical Technology, Health Engineering, Medical and Biomedical Engineering at all academic levels.

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Firstly, after a Google search a full list of the universities and colleges of each European country was compiled, and then their official website was verified to locate related educational programs. Similar search was conducted on Coursera database [5]. The research was restricted in countries which are members of European Federation for Medical Informatics (EFMI) [6]. It is worth mentioning that this research is still in progress.

3. Results

This study has covered 21 EFMI countries-members out of 32 so far [6].

Table 1. The list of Countries,-Members of EFMI.

Countries-Members of EFMI			
Armenia	Austria	Belgium	Bosnia-Herzegovina
Croatia	Cyprus	Czech Republic	Denmark
Finland	France	Germany	Greece
Hungary	Iceland	Ireland	Israel
Italy	Republic of Moldova	Netherland	Norway
Poland	Portugal	Romania	Russian Federation
Serbia	Slovenia	Spain	Sweden
Switzerland	Turkey	Ukraine	United Kingdom

Specific information was collected for each educational program [7]: University/Institution/College, Department/Faculty, Name of the Educational Program, Specialization(s),Academic Level (Undergraduate/Postgraduate/PhD studies), Programs' Websites (URL), Type of Education (Full Time, Part Time, Combined), Language (e.g. English, Local, Bilingual) and Mode (On Campus, E-learning / Distance Learning).It is worth to note that the authors' interest focuses only on academic degree programs.

This research has found 316 educational programs in these domains.

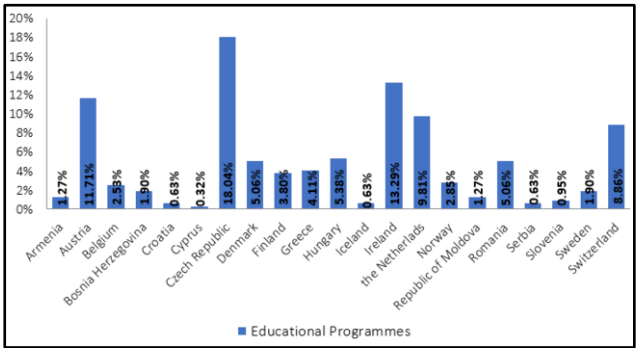

Figure 1. Educational Programs per Country in Europe

According to Figure 1, the educational programs are mostly taking place in Czech Republic, Ireland and Austria. Furthermore, the Netherlands and Switzerland are offering a notable number of similar programs. In contrast, Cyprus, Croatia, Iceland, Serbia and Slovenia are sharing the lowest numbers of educational programs.

Based on specializations, the majority of the study programs expertise in Biomedical Engineering and Bioinformatics. While, a significant number of these programs belong to Medical Informatics, Health and Medical Technology. In addition

to Health Informatics, Biomedical Informatics, Health and Medical Engineering specializations are tendered by several institutions.

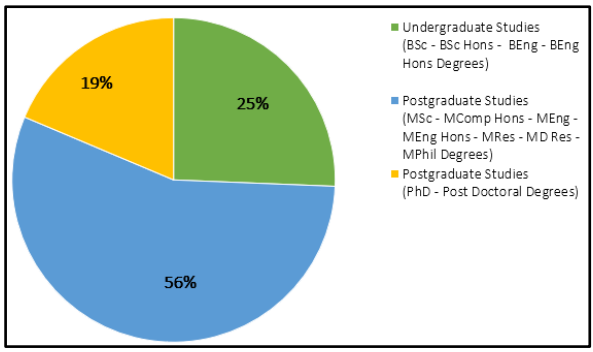

Figure 2. Academic Levels of Educational Programs in Europe

According to Figure 2, 25.63% of the programs are Undergraduate Studies whilstto74.37% of the programs are Postgraduate Studies. In more detail, Postgraduate Studies divided to MSc Degrees- MEng Degrees- MPhil Degrees (55.70%) and PhD Degree- Post Doctoral Degrees (18.67%). Depending on the type of education the majority of programs are fulltime (58.54%). About 42.10% of the educational programs are running in English language while about 55.06% of them are running in local language. Only the 2.84% belongs to the bilingual study programs. Therefore, the study programs are conducted mostly on campus.

As is referred before is still conducted in the countries France, Germany, Israel, Italy, Poland, Portugal, Russia, Spain, Turkey, Ukraine and United Kingdom.

4. Discussion

A variety of educational programs and specialties at different academic levels are offered in Austria, Denmark and the Netherlands. More specifically, Austria has concentrated heavily on Medical and Biomedical Informatics UMIT in Hall in Tirol. UMIT is the first academic institute in Europe which has offered educational programs in Medical Informatics at all academic levels [3].

Many countries such as Belgium, Iceland, Republic of Moldova and Serbia prefer to establish Biomedical Engineering programs more than other similar specializations. Studies have shown that Biomedical Engineering programs at postgraduate level (MSc / PhD) experienced rapid growth during 2005-2010 [2]. Moreover, in this research is clearly stated that Bioinformatic programs mostly exist in Armenia, Ireland, Switzerland and Slovenia. Also, it is important to mention that in Scandinavian and Central European countriesthe Health Informatics, Medical Informatics, E – Health and Medical Technology programs are very popular. Czech Republic, Finland, Greece, Hungary and Sweden are mainly conducting educational programs at postgraduate level.

This study tries to fulfill the gap that the Working Group 1 on health and medical informatics education of the International Medical Informatics Association (IMIA) left behind. The initiative of IMIA had aimed the creation of an online database would provide information about programs and courses in Health and Medical Informatics

worldwide [8]. In our case, the data of the research comes from European Countries and provide information about programs in Health and Medical Informatics, Biomedical Informatics, Bioinformatics, Medical and Biomedical Engineering etc. Due to the limitations of this research is an unclear viewpoint for specific countries such as Estonia, Latvia and Belarus.

5. Conclusion

In developed countries, evidence have shown that information technology can improve the quality and safety of health care with minimal cost. This is the reason for an increasing need of technological experts in healthcare sector [9]. In higher education of each country includes various related programs so the graduates have the opportunity to follow different kinds of specialties [10]. The present educational programs are offered at undergraduate and postgraduate level including a variety of specializations such as health informatics, bioinformatics, biomedical engineering etc. The expectations of education are higher and higher demanding new requirements so qualified educational programs are greatly needed. However, the growth of the educational programs is not the same in each country [7,11]. It would be useful to see if in each country a satisfying number of educational programs is provided with well-detailed curriculum at each level depending on their specialization.

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Evaluation of a Laboratory e-Learning Course in Health Informatics

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Abstract. The current paper presents the students' evaluation of a laboratory e-learning course in Health Informatics. After attending the e-learning course, students assessed the e-learning course through an anonymous questionnaire. The study results present the positive attitude of the students towards the e-learning course in Health Informatics. The current e-learning course is easy to use, and it is preferred on the same extent as the hybrid one (e-learning and in-class learning combination). The majority of the participants believed that the e-learning method is at least the same or more efficient compared to the traditional learning approach. Based on the study findings, it seems that this e-learning course could offer important advantages on the learning process as long as it helps students learn in a more effective manner than traditional learning.

Keywords. e-learning, laboratory courses, health informatics

1. Introduction

E-learning is used as a teaching approach on several university courses in Greece [1]. The evaluation of this approach has produced positive results [2,3] and seems to be accepted by students. Various studies have revealed that e-learning and traditional learning can be equally effective as teaching methods [4,5]. Nowadays, European universities offer a number of Health Informatics courses, using both traditional and e-learning methods at Bachelor, Master and Doctorate levels [6].

The aim of this paper is to evaluate an e-learning course in Health Informatics, by measuring and recording the students' perceptions who participated in the course. The laboratory e-learning course mainly included teaching modules related to the collection and processing of health data as well as the design and use of health databases. Positive results are expected to be produced according to the findings of a previous study [5].

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2. Methods

The current evaluation was conducted on 2015 among 79 first-year nursing undergraduate students who followed an e-learning laboratory course in Health Informatics at the Faculty of Nursing, School of Health Sciences in the University of Athens, Greece [5]. After the course completion, students were asked to evaluate the e-learning course, in which they participated, by completing an anonymous questionnaire. The questionnaire was self-developed and included 6 simple questions regarding the e-learning platform's ease of use, the students' preference for e-learning, and the students' perception about the effectiveness of the e-learning approach compared to the traditional learning. Information about the participants' gender and their previous experience on e-learning courses was recorded as well. All the above questions were closed-ended type with pre defined answers. An open-ended type question about the advantages of the e-learning was also included. A descriptive statistics data analysis performed using SPSS [7].

3. Results

The 85,7% of the sample were females. Only, 5,4% of the sample had prior experience on e-learning courses, having followed at least one course with similar approach. The majority of the students (94,6%) did not have any previous experience on e-learning.

Regarding the ease of use of the e-learning platform, 27,6% responded "Very easy", 60,5% "Easy", and 11,8% stated that its use is neither easy nor hard.

58,9% of the sample believed that the e-learning is more efficient learning method than the traditional one. 20,6% stated that e-learning is as effective as traditional, and 20,5% believed that the efficacy of the traditional learning is greater than e-learning. As far as the participants' preference for the learning approach is concerned, 48,6% of the sample preferred e-learning for Health Informatics Laboratory courses, 48,6% preferred an hybrid approach (a combination of e-learning and traditional learning), and only 2,7% expressed their preference for traditional learning.

According the opened-ended type question, the response rate was 64,6%. The majority of the students stated that e-learning can contribute to better manage the learning process time, and this is one of the most important advantages of e-learning. Based on students' answers, other advantages of the e-learning approach are the possibility of repeating theoretical sessions, exercises and tests, and the availability of the content of the course whenever need. Additionally, they stated that multimedia material and easy-to-use interface lead to a better understanding of the course's content.

4. Discussion

The aforementioned results present the positive attitude of the students towards the e-learning laboratory course in Health Informatics, who in their majority had limited previous experience on other e-learning courses. It seems that the current e-learning course is easy or very easy to use, as the overwhelming majority of the respondents expressed this opinion.

Meanwhile, the majority of the sample believed that e-learning is at least the same or more effective compared to the traditional one. On the other hand, students expressed the same preference for participation in both the hybrid method of learning and the e-learning.

Based on the study findings, it seems that this e-learning method could offer important advantages on the learning process, as long as it seems to help students learn in a more effective manner than traditional learning.

The learning outcomes have been investigated in previous study [5] which revealed positive results for e-learning. Considering both the positive evaluation of the e-learning course by the students, which is presented in this paper, and the positive learning outcomes of the previous study, it can be assumed that e-learning is an accepted teaching approach for a laboratory course on Health Informatics. Related studies present similar results [3-5].

A limitation of the current study is that the evaluation was conducted only on one semester and by students who chose to participate in an e-learning course. Thus, participants might be positive biased towards e-learning. Future work may include further investigation of the effectiveness and acceptance of the e-learning laboratory course on Health Informatics, and the factors that affect them.

Concluding, e-learning methods in laboratory courses in Health Informatics are an efficient choice in the educational process, offering useful advantages compared to traditional learning methods.

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Survival Models in Computer Virus

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Abstract. During the communication between various computer system parts under a basic unit various threats can appear causing different damages into the system. The spreading of the computer virus into the system must be investigated under modeling analysis and simulations must be applied. In this work survival analysis models have been introduced to overcome the problem with the computer virus. During that process of spreading two main considerations analyzed: (1) the epidemiological models of the spreading and (2) the survival of the computer virus inside the system under mathematical modeling.

Keywords. computer virus, survival analysis, computer security, malicious software

1. Introduction

Threats can approach computer systems and viruses can be spread on them at anytime, especially during connections on several networks or on individual standard processes. [1,2]. The modeling of the survival time of the virus inside a computer system have to be investigated leading us to the results of the damages [3-6]. Epidemiological models for human virus monitoring seem to have some similarities with computer virus monitoring algorithms. In this work survival analysis models have been introduced to overcome the problem with the computer virus.

2. Methods

Computer virus is malicious software that infects other programs by modifying them. A computer virus carries in its initial main code to other programs by making copies of itself or by copying parts of the infected program to the network. Each time an infected host is in contact with an uninfected piece of software, a new copy of the virus infects the new program [7,8].

Continuous study of possible models of a virus attack in a population with different properties led to further study of epidemics. During the computer epidemiological analysis, the mathematical models are explaining cases under pandemic conditions. This also applies and vice versa, studying viruses spread

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phenomena in homogeneous populations using modelling resulting from a statistical spread model.

For the modelling of the problem epidemiological SIR model will be used in order to build the frame which should be used for calculating the results of the outcome for the completion of two viruses in a population [9,10].

3. Susceptible-Infected-Removed (SIR) Model

The SIR model is an extension of the Susceptible-Infectious (SI) Model, where includes one more factor (Removed) in relation to the SI model. The stage is called removed and represents the hosts which have recovered from the infection and cannot be re-infected again, or which have been in quarantine and those who have died during the infection (Figure 1) [9,11-13].

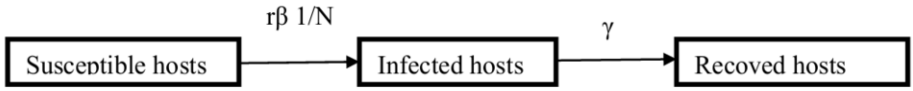

Figure 1. SIR Model [7]

In this model, S(t): the number of uninfected hosts at time t; I(t): the number of infected hosts at time t; N: the size of population (N=S+I) and β: the medium rate of population. The R(t) which represents the number of removed hosts at time t and the γ. The size of population is N=S+I+R. The system of the dynamic equations is given by [14].

$$\frac{dI(t)}{dt} = \beta I(t)S(t) - \gamma I(t)$$
$$\frac{dS(t)}{dt} = -\beta I(t)S(t)$$
$$\frac{dR(t)}{dt} = \gamma I(t)$$

Based on the basic equation for the population size

$$N = S(t) + I(t) + R(t) = \frac{\partial S}{\partial t} + \frac{\partial I}{\partial t} + \frac{\partial R}{\partial t} = 0$$

Solving for S(t), the final result for the survival equation is given by

$$S(t) = S(0)e^{\frac{\beta}{\gamma}(R(t)-R(0))}$$

meaning that at the end of an epidemic process, some patients have been recovering but not all of them. The ratio of the infected people has been increased but not completely [15].

4. Conclusion

In this work, an introduction of a survival model for SIR epidemic model is presented. According to this, SIR could be applied on computer virus or other threats management. Based on that modeling the survival curves could be computed and the results based on the rate of infected and recovered people in the population are explained.

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A Medical Decisions Support System in Diagnosis of the Jejunum and Ileum Neoplastic Diseases (Tumors) Based on Video Capsule Endoscopy

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Abstract. Search of tumors in video capsule endoscopy (VCE) record in some cases presents significant difficulties even for experienced specialist. We made an attempt to develop rules supporting clinical decision for processing of VCE images. An algorithm for assessment of neoplastic diseases of the jejunum and ileum on the basis of VCE to support tactical decision-making of doctors was conducted. The algorithm was implemented as a software module "The conclusion in a capsule" with integrated development environment Visual Studio and the programming language C#.

Keywords. Tumors small bowel, Video capsule endoscopy (VCE), Decision support system

1. Introduction

One of the important problems of the VCE is the laboriousness and large time costs for processing the data (Figure 1). Long time to view the long recording, conventionalism of process, the inability precisely to examine the affected areas of the intestine affects the quality and timeliness of treatment (Figure 2). After watching the video, the doctor often cannot make a conclusion about the nature of tumor lesions [1]. The aim of this work is the development of an algorithm for assessment of neoplastic diseases of the jejunum and ileum on the basis of VCE to support tactical decision-making of doctors.

Figure 1. Video capsule

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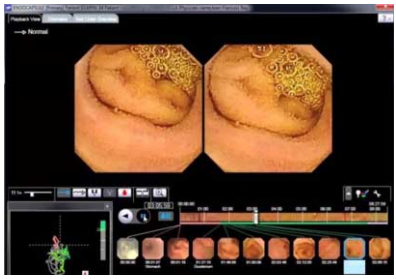

Figure 2. Systems for capsule endoscopy ENDOCAPSULE.

2. Methods

From October 2008 to April 2017 we examined 65 patients (m-35, f-30, mean age 46±28 years, range 18-80) with the use of VCE. The results of VCE were identified 181 the case of neoplastic diseases in the jejunum and ileum. Each tumors object in front of our study was histologically verified. Sifferent systems for capsule endoscopy were used, like Olympus (Japan), Miro Cam Intromedic (Korea), Pill Cam Given Imaging (Israel), OMOM Chongqing Jinshan Science &Technology (China).

3. Results

With the help of experts received a list of 30 features and their gradations, which are important for the assessment of neoplastic diseases of the jejunum and ileum on the video capsule endoscopy images. From the obtained characteristics to be statistically significant (affecting the division of objects into groups) were 8: gender of the patient, deformation of the wall/lumen of the intestine, the course of the folds of the small intestine, polyps changes changes of the mucous, vascular pattern, mucous regularity, lobed structure of neoplasia and color of the mucous (Figure 3). Using heterogeneous Bayesian diagnostic procedures and the calculation of the diagnostic ratios was developed three-level algorithm for differential diagnosis of neoplastic diseases of the jejunum and ileum (Figure 4). We've got a satisfactory distribution of research objects into 4 groups: non-neoplastic lesions of the small bowel (sensitivity= 86%, specificity= 92%); epithelial benign tumors of the small intestine (sensitivity= 89%, specificity= 93%); non-epithelial benign tumors of the small intestine (sensitivity= 86%, specificity= 97%); malignant tumors of the small intestine (sensitivity=89%, specificity=93%) [2]. The algorithm is implemented as a software module "The conclusion in a capsule" with integrated development environment Visual Studio and the programming language C#.

4. Conclusions

An algorithm used for decision support of a doctor at the stage of diagnosis for neoplastic diseases of the jejunum and ileum and produced promising results for further implementations.

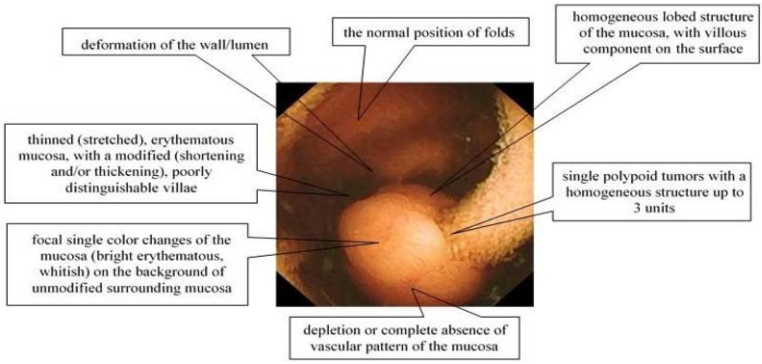

Figure 3. Benign epithelial neoplasm of jejunum (hamartoma). Description of the tumor by formalized criteria.

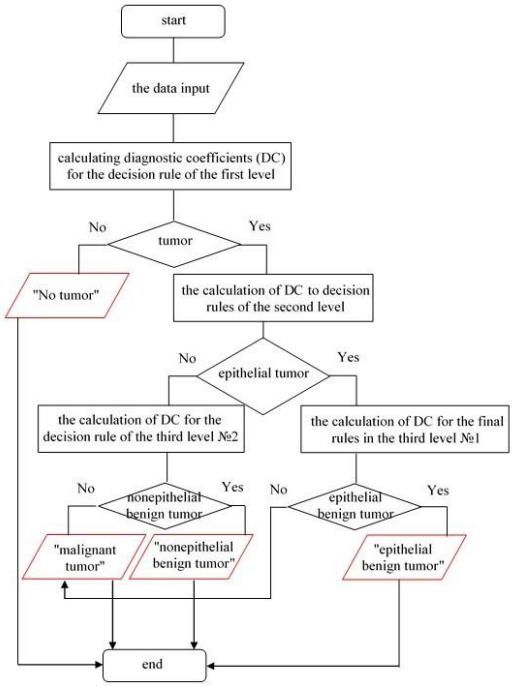

Figure 4. The block diagram of the algorithm for the differential diagnosis of neoplastic changes in the jejunum and ileum.

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Biomedical informatics is important for the entire domain of healthcare, from clinical informatics and health informatics to the wider field of public health informatics.

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