Diagnostic Musculoskeletal Ultrasound and Guided Injection: A Practical Guide

Peter Resteghini

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Preface

The popularity of ultrasound in the diagnosis and management of musculoskeletal pathology has witnessed a considerable increase in recent years. Given the ability for ultrasound to be utilized in an "office setting," the enhanced resolution with high-frequency probes, and the relative affordability of newer machines, this perhaps is not surprising. In addition, ultrasound has the advantage of allowing clinicians to incorporate the modality into their practice with relative ease, thus forming an essential adjunct to their routine clinical examination and allowing a direct and real-time comparison between clinical and anatomical findings.

There is no doubt that skilled clinicians have great benefit in utilizing ultrasound in their clinical practice, facilitating their ability to answer specific questions regarding a patient's pathology and anatomical relationships as well as being able to monitor disease and increase the accuracy of interventional procedures. Although several specific training programs exist for non-musculoskeletal ultrasound, very few programs exist particularly for musculoskeletal medicine. Taken with this is the fact that the correct use of ultrasound has a relatively long learning curve, which means that clinicians struggle to achieve competency. Indeed, it is reckoned that less than 5% of rheumatologists are able to correctly use ultrasound in their daily clinical practice (Grassi et al 2004).

It is the aim of this book to provide a pragmatic and accessible guide for the use of ultrasound in both the diagnosis and management of musculoskeletal and sports pathologies. The book is aimed at clinicians from a wide variety of backgrounds, including chiropractic, orthopaedics, osteopathy, physiotherapy, rheumatology, sonography, and sports medicine. The book is intended for both the novice clinician who has only recently started to incorporate ultrasound into her/his clinical practice and the experienced clinician as a handy reference guide.

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Introduction

The last decade has seen a considerable increase in interest in the use of ultrasound in the management of musculoskeletal pathologies, which is reflected in the volume of literature published regarding its applications in both the diagnosis and treatment of musculoskeletal conditions. Papers have highlighted its use particularly in shoulder pathology (Arslan et al 1999, Bouffard et al 2000, Ostlere 2003, Teefey et al 2004) and as a form of interventional radiology, guiding the placement of needles for aspiration or local injection (Ghozlan and Vacher 2000, Koski 2000, Weidner et al 2004). This increase in interest has come from a wide variety of clinical specialties, including chiropractic, orthopaedics, osteopathy, physiotherapy, rheumatology, sonography, and sports medicine (Balint and Sturrock 1997, Tan et al 2003).

The reasons for the increase in the popularity of musculoskeletal ultrasound are many. A lack of ionizing radiation makes the technique more acceptable, readily usable, and repeatable (Grassi et al 2004). It is capable of high spatial resolution, has multiplanar imaging capability, and is considered patient friendly due to its ease of tolerance and noninvasiveness (Backhaus et al 2001, Grassi et al 2004, Tan et al 2003, Wakefield et al 1999). With experience, scanning time is short, 5 to 15 minutes for an experienced clinician compared to approximately 40 minutes for a magnetic resonance imaging (MRI; Swen et al 2001). This has the advantage of enabling multiple joints to be examined in one sitting, if necessary, and in increasing throughput of patients (Wakefield et al 1999). For specific anatomical structures, ultrasound and MRI are comparable in both sensitivity and specificity (de Jesus 2009). In the assessment of the shoulder and rotator cuff pathology, ultrasound has been demonstrated to have 98.6% sensitivity and 99.3% specificity for full-thickness tears and 97.9% sensitivity and 94.4% specificity for partial-thickness tears (Al-Shawi et al 2008).

Unlike other imaging modalities, ultrasound may be performed as a bedside procedure (Grassi et al 2004). In particular, and in contrast to other imaging modalities, it not only provides anatomical information, but also informs on the physiological state of the joint, being particularly sensitive to inflammatory changes and subsequent response to treatment intervention (Grassi et al 2001).

Ultrasound is also unique in that scanning occurs in real time (Tan et al 2003), making it possible to discuss reproduction of symptoms with the patient and to view dynamic images of the structures under examination. This is particularly useful for evaluating tendons (Ellis et al 2002, Grassi et al 2000), and adds significantly to the diagnostic accuracy of many clinical tests (Shirtley 1999). Indeed, it is considered to represent the gold standard for evaluation of tendon pathology, in part due to this quality (Grassi et al 2000).

References

Al-Shawi A, Badge R, Bunker T. The detection of full thickness rotator cuff tears using ultrasound. J Bone Joint Surg Br 2008;90(7):889–892

Arslan G, Apaydin A, Kabaalioglu A, Sindel T, Lüleci E. Sonographically detected subacromial/subdeltoid bursal effusion and biceps tendon sheath fluid: reliable signs of rotator cuff tear? J Clin Ultrasound 1999;27(6):335–339

Backhaus M, Burmester G-R, Gerber T, et al.; Working Group for Musculoskeletal Ultrasound in the EULAR Standing Committee on International Clinical Studies including Therapeutic Trials. Guidelines for musculoskeletal ultrasound in rheumatology. Ann Rheum Dis 2001;60(7):641–649

Balint P, Sturrock RD. Musculoskeletal ultrasound imaging: a new diagnostic tool for the rheumatologist? Br J Rheum 1997;34(11):1141–1142

Bouffard JA, Lee SM, Dhanju J. Ultrasonography of the shoulder. Semin Ultrasound CT MRI 2000;21(3):164–191

de Jesus JO, Parker L, Frangos AJ, Nazarian LN. Accuracy of MRI, MR arthrography, and ultrasound in the diagnosis of rotator cuff tears: a meta-analysis. Am J Roentgenol 2009;192(6):1701–1707

Ellis JRC, The JL, Scott PM. Ultrasound of tendons. Imaging 2002;14:223–228
Ghozlan R, Vacher H (2000). Where is imaging going in rheumatology? Baillieres Best Pract Res Clin Rheumatol 2000;14(4): 617–633
Grassi W, Filippucci E, Busilacchi P. Musculoskeletal ultrasound. Best Pract Res Clin Rheumatol 2004; 18(6):813–826
Grassi W, Filippucci E, Farina A, Cervini C. Sonographic imaging of tendons. Arthritis Rheum 2000;43(5): 969–976
Grassi W, Filippucci E, Farina A, Salaffi F, Cervini C. Ultrasonography in the evaluation of bone erosions. Ann Rheum Dis 2001;60(2):98–103
Koski JM. Ultrasound guided injections in rheumatology. J Rheumatol 2000;27(9):2131–2138
Ostlere S. Imaging the shoulder. Imaging 2003; 15:162–173
Shirtley GS. Musculoskeletal ultrasound: its current use and its place in the ADF. ADF Health 1999;1(25):33–41
Swen WA, Jacobs JWG, Bussemaker FE, de Waard JW, Bijlsma JW. Carpal tunnel sonography by the rheumatologist versus nerve conduction study by the neurologist. J Rheumatol 2001;28(1):62–69
Tan AL, Wakefield RJ, Conaghan PG, Emery P, McGonagle D. Imaging of the musculoskeletal system: magnetic resonance imaging, ultrasonography and computed tomography. Best Pract Res Clin Rheumatol 2003; 17(3):513–528
Teefey SA, Rubin DA, Middleton WD, Hildebolt CF, Leibold RA, Yamaguchi K. Detection and quantification of rotator cuff tears. Comparison of ultrasonographic, magnetic resonance imaging, and arthroscopic findings in seventy-one consecutive cases. J Bone Joint Surg Am 2004;86-A(4):708–716
Wakefield RJ, Gibbon WW, Emery P. The current status of ultrasonography in rheumatology. Rheumatology (Oxford) 1999;38(3):195–201
Weidner S, Kellner W, Kellner H. Interventional radiology and the musculoskeletal system. Best Pract Res Clin Rheumatol 2004;18(6):945–956

Local Anesthetics and Corticosteroids

The musculoskeletal injections described in this book involve a combination of local anesthetics, which provide some immediate analgesia, confirmation of diagnosis, and correct needle placement, and corticosteroids, which have a more long-term therapeutic effect.

Local Anesthetics

In the normal resting state, the axon membrane of a nerve is polarized and permeable to potassium ions while remaining relatively impermeable to sodium ions. This results in the inside of the axon being negatively charged in relation to the outside, which is relatively positively charged. Stimulation of the axon changes this resting state so that the permeability of the nerve is altered and the axon becomes depolarized. This change in permeability of the axon membrane opens channels allowing the influx of sodium ions, which results in the inside of the axon becoming positively charged. Excitation of the axon is brought about by a sequential opening and closing of the sodium and potassium channels in the cell membrane. The variation in the cell membrane potential which accompanies these changes is called an action potential, with the result that each region of the axon in turn excites the next region and the impulse is propagated along the axon fiber.

Local anesthetics are membrane-stabilizing drugs which are able to penetrate the nerve sheath and axon membrane reversibly, decreasing the rate of depolarization and repolarization of excitable membranes. Local anesthetics act mainly by inhibiting sodium influx through sodium-specific ion channels in the cell membrane. When this sodium influx is interrupted, an action potential is unable to be initiated and the signal conduction is inhibited.

Although all nerve fibers are sensitive to the effects of local anesthetics, due to a combination of axon diameter and myelination, different fibers have different sensitivities to local anesthetic blockade, termed differential blockade. Type B fibers (sympathetic) are the most sensitive, followed by type C (pain), type A delta (temperature), type A gamma (proprioception), type A beta (sensory touch and pressure), and type A alpha (motor). Although type B fibers are thicker than type C fibers, they are myelinated and therefore are blocked before the unmyelinated thin C fibers (Rang et al 1995).

The local anesthetics frequently used in musculoskeletal medicine are lidocaine hydrochloride (lignocaine hydrochloride) and Marcaine (bupivacaine hydrochloride). Lidocaine is the most commonly used local anesthetic; it acts rapidly, with the effects becoming manifest in seconds, and the duration of the block is approximately 30 minutes. Marcaine has a slower onset of action, taking approximately 30 minutes to reach maximum effect; however, duration of block is up to 8 hours.

In this book, the use of lidocaine (1%, Braun) is advocated as the delayed onset of Marcaine in an outpatient setting prevents the immediate diagnostic effect of the local anesthetic afforded by lidocaine. In addition, there is little evidence to support any long-term advantage of Marcaine over lidocaine (Sölveborn et al 1995). More recent evidence also suggests that intra-articular injection of high-dose local anesthetic, particularly Marcaine, may cause cartilage damage. This chondrotoxicity resulted in cellular death rates which were higher in osteoarthritic compared with intact cartilage (Breu et al 2013). Chondrotoxicity of local anesthetics appears to be enhanced if administered with vasoconstrictors, and the use of either lidocaine or Marcaine with added adrenaline is not recommended (MacMahon et al 2009).

Local Anesthetic and Musculoskeletal Injections

The use of local anesthetics during musculoskeletal injections helps ensure that the procedure is well tolerated by the patient and increases the confidence of the patient with the clinician performing the injection. In addition, their use has a number of other functions, including the following.

- *Aid to diagnosis*: Immediate pain relief following injection helps establish the diagnosis (Crawford et al 1998), differentiate local from referred pain (Rifat and Moeller 2002, Tallia and Cardone 2003), and confirm correct needle positioning.

- *Volume effect*: Stretching of the joint capsule, bursa, or tendon sheath may help with disruption of adhesions (Buchbinder and Green 2004).
- *Dilution effect*: Increasing the injectable volume by the addition of local anesthetic may help spread the corticosteroid around the joint, bursa, or tendon sheath (Inês and da Silva 2005).

Corticosteroids

The injectable corticosteroids commonly used in musculoskeletal medicine are synthetic analogues of the adrenal glucocorticoid hormone cortisol, which is secreted naturally by the zona reticularis of the adrenal cortex. The primary action of corticosteroids is in the modulation of the transcription of a number of genes involved in both the immune and inflammatory responses. They achieve this by their direct action on nuclear steroid receptors to control the rate of mRNA synthesis in addition to reducing the number of proinflammatory mediators including cytokines.

A number of corticosteroids are commonly used as injectable agents in musculoskeletal medicine, including methylprednisolone acetate (Depo-Medrone, 40 mg/mL) and triamcinolone acetonide (Kenalog, 40 mg/mL, and Adcortyl, 10 mg/mL—Squibb & Sons Ltd). Both methylprednisolone and triamcinolone have a similar duration of action of up to 3 weeks and a similar potency.

There is little evidence to guide the selection of corticosteroids used in musculoskeletal medicine injections, and most recommendations are based on personal preference and clinical experience. The corticosteroid described in this book is Depo-Medrone (40 mg/mL—Pfizer Ltd). The exact dose will be dependent on the structure to be injected, with 40 mg being injected into larger joints such as the hip and shoulder, while smaller joints and bursae are injected with 10 to 20 mg.

Corticosteroids and Musculoskeletal Injections

Although injectable corticosteroids have been used in the management of musculoskeletal pathologies for several decades, being first described in the 1950s in the United States to treat arthritic joints (Hollander et al 1951), little is known about their exact pharmacological effects. They are thought to act by a number of mechanisms, including the following.

- *Inflammatory suppression*: Corticosteroids are able to suppress inflammation in cases of inflammatory and degenerative arthritis (Franz and Burmester 2005, Kirwan and Rankin 1997). They are able to reduce blood flow and lower the local leukocyte and inflammatory response (Lavelle et al 2007).
- *Chondroprotective*: Corticosteroids may also have a chondroprotective effect via direct action on the metabolism of the cartilage at low dose and short culture duration which is not directly due to their anti-inflammatory action (Wernecke et al 2015).
- *Analgesia*: In cases of tendinopathy when the pain experienced by patients may be caused by the stimulation of nociceptors through chemicals such as substance P and glutamate released by the damaged tendon, corticosteroids may inhibit the release of these chemicals and hence reduce pain (Gialanella and Prometti 2011).

Risks and Side Effects

Corticosteroid and local anesthetic injections used in musculoskeletal medicine are largely very safe procedures and adverse events are rare. However, there are several possible issues that need to be considered and declared to the patient when consenting prior to injecting. These include the following:

- *Post-injection flare*: Some patients may experience a degree of post-injection inflammation and pain. This inflammation is caused by the corticosteroid crystals mimicking a septic arthritis (Cole and Schumacher 2005). However, a true septic arthritis would usually occur later than a post-injection flare and be more enduring. The incidence of a post-injection flare seems to vary between 2% (Kumar and Newman 1999) and 10.7% (Gaujoux-Viala et al 2009).
- *Septic arthritis*: Although a serious possible complication following intra-articular injection, the risk of septic arthritis is very low with a reported incidence of less than 0.03% (Charalambous et al 2003). There does not seem to be any clinical evidence in the literature to suggest that anything more than skin cleansing needs to be employed prior to injection in an office-based setting, with reported infection rates for this approach of approximately 1:50,000 (Gray et al 1981).

- *Hyperglycemia*: Diabetic patients may experience a modest and transient rise in their blood sugars following corticosteroid injection (Black and Filak 1989). This usually lasts no more than 2 weeks when it does occur (Mader et al 2005).
- *Hypopigmentation and fat atrophy*: In a meta-analysis looking at injections given into the shoulder and elbow, skin changes were said to have a frequency of approximately 4% (Gaujoux-Viala et al 2009). Nichols (2005), in a study evaluating the complications associated with the use of corticosteroids in the treatment of athletic injuries, described a risk of fat atrophy of 2.4% and skin depigmentation of 0.8%. Skin changes are more likely to be seen in superficial injections and when the patient has dark skin. If manifest, local fat atrophy appears within a 1- to 4-month period and may take 2 years or more to resolve (Cassidy and Bole 1966).
- *Tendon rupture*: Tendon and fascia rupture have been reported as complications following corticosteroid injection (Boussakri and Bouali 2014, Mahler and Fritschy 1992, Saxena and Fullem 2004). However, so long as repeated injections into load-bearing tendons are avoided, the risk of rupture appears to be small and low-dose peritendinous injections are relatively safe (Gills et al 2004).
- *Facial flushing*: A systemic side effect, this may occur 24 to 48 hours postinjection and last for up to 2 days. It has a reported incidence of less than 1% (Stephens et al 2008).
- *Bleeding*: Some bleeding at or around the injection site may occur. This is more likely in patients who are anticoagulated or who are taking an oral anti-inflammatory medicine with an antiplatelet activity (e.g., naproxen). Overall, the risk of hemarthrosis is small even in those taking antiplatelet medicines (Goupille et al 2008, Thumboo and O'Duffy 1998). However, it would be advisable to either discontinue or reverse the effects of these anticoagulation medicines prior to injection following discussion with the patient's general practitioner.

It should be noted that there is little evidence of intra-articular corticosteroid injections leading to a progression of osteoarthritis (Creamer 1999, Raynauld et al 2003). Repeated corticosteroid injections into the knee joint every 3 months were reported as being safe over a 2-year period (Raynauld et al 2003).

Contraindications to Corticosteroid Injections

Corticosteroid injections should not be given in the following cases:

- Local or intra-articular sepsis. If there is any doubt, the joint should be aspirated, with a sample sent to pathology for analysis, prior to any injection being given.
- Intra-articular fracture.
- Known hypersensitivity to one of the constituents of the injection.

References

Black DM, Filak AT. Hyperglycemia with non-insulin-dependent diabetes following intraarticular steroid injection. J Fam Pract1989;28(4):462–463

Boussakri H, Bouali A. Subcutaneous rupture of the extensor pollicis longus tendon after corticosteroid injections for DeQuervain's stenosing tenovaginitis. Case Rep Orthop 2014;2014:934384. doi: 10.1155/2014/934384. Epub 2014 Oct 12

Breu A, Rosenmeier K, Kujat R, Angele P, Zink W. The cytotoxicity of bupivacaine, ropivacaine, and mepivacaine on human chondrocytes and cartilage. Anesth Analg 2013;117(2):514–522

Buchbinder R, Green S. Effect of arthrographic shoulder joint distension with saline and corticosteroid for adhesive capsulitis. Br J Sports Med 2004;38(4): 384–385

Cassidy JT, Bole GG. Cutaneous atrophy secondary to intra-articular corticosteroid administration. Ann Intern Med 1966;65(5):1008–1018

Charalambous CP, Tryfonidis M, Sadiq S, Hirst P, Paul A. Septic arthritis following intra-articular steroid injection of the knee: a survey of current practice regarding antiseptic technique used during intra-articular steroid injection of the knee. Clin Rheumatol 2003;22(6):386–390

Cole BJ, Schumacher HR Jr. Injectable corticosteroids in modern practice. J Am Acad Orthop Surg 2005; 13(1):37–46

Crawford RW, Gie GA, Ling RS, Murray DW. Diagnostic value of intra-articular anaesthetic in primary osteoarthritis of the hip. J Bone Joint Surg Br 1998; 80(2):297–281

Creamer P. Intra-articular corticosteroid treatment in osteoarthritis. Curr Opin Rheumatol 1999;11(5): 417–421
Franz JK, Burmester GR. The needle and the damage done. Ann Rheum Dis 2005;64(6):798–800
Gaujoux-Viala C, Dougados M, Gossec L. Efficacy and safety of steroid injections for shoulder and elbow tendonitis: a meta-analysis of randomised controlled trials. Ann Rheum Dis 2009;68(12):1843–1849
Gialanella B, Prometti P. Effects of corticosteroids injection in rotator cuff tears. Pain Med 2011;12(10): 1559–1565
Gills S, Gelbke MK, Matson SL. Fluoroscopically guided low-volume peritendinous corticosteroid injection for Achilles tendinopathy. A safety study. J Bone Joint Sur Am 2004;86-A(4):802–806
Goupille P, Thomas T, Noël E; GREP. A practice survey of shoulder glucocorticoid injections in patients on antiplatelet drugs or vitamin K antagonists. Joint Bone Spine 2008;75(3):311–314
Gray RG, Tenenbaum J, Gottlieb NL. Local corticosteroid injection treatment in rheumatic disorders. Semin Arthrits Rheum 1981;10(4):231–254
Hollander JL, Brown EM Jr., Jessar RA, Brown CY. Hydrocortisone and cortisone injected into arthritic joint; comparative effects of and use of hydrocortisone as a local antiarthritic agent. J Am Med Assoc 1951; 147(17);1629–1635
Inês LP, da Silva JA. Soft tissue injections. Best Pract Res Clin Rheumatol 2005;19(3);503–527
Kirwan JR, Rankin E. Intra-articular therapy in osteoarthritis. Baillieres Clin Rheumatol 1997;11(4): 769–794
Kumar N, Newman RJ. Complications of intra- and peri-articular steroid injections. Br J Gen Pract 1999; 49(443):465–466
Lavelle W, Lavelle ED, Lavelle L. Intra-articular injections. Med Clin North Am 2007;91(2):241–250
MacMahon PJ, Eustace SJ, Kavanagh EC. Injectable corticosteroid and local anesthetic preparations: a review for radiologists. Radiology 2009;252(3): 647–661
Mader R, Lavi I, Luboshitzky R. Evaluation of the pituitary-adrenal axis function following single intraarticular injection of methylprednisolone. Arthritis Rheum 2005;52(3):924–928
Mahler F, Fritschy D. Partial and complete ruptures of the Achilles tendon and local corticosteroid injections. Br J Sports Med 1992;26(1):7–14
Nichols AW. Complications associated with the use of corticosteroids in the treatment of athletic injuries. Clin J Sport Med 2005;15(5):370–375
Rang HP, Dale MM, Ritter JM. Pharmacology. 3rd ed. New York, NY: Churchill Livingstone; 1995
Raynauld JP, Buckland-Wright C, Ward R, et al. Safety and efficacy of long-term intraarticular steroid injections in osteoarthritis of the knee: a randomized, double-blind, placebo-controlled trial [published correction in Arthritis Rheum 2003;48(11):3300]. Arthritis Rheum 2003;48(2):370–377
Rifat SF, Moeller JL. Injection and aspiration techniques for the primary care physician. Compr Ther 2002; 28(4):222–229
Saxena A, Fullem F. Plantar fascia ruptures in athletes. Am J Sports Med 2004;32(3):662–665
Sölveborn SA, Buck F, Mallmin H, Adalberth G. Cortisone injection with anesthetic additives for radial epicondylalgia (tennis elbow). Clin Orthop Relat Res 1995;(316):99–105
Stephens MB, Beutler AI, O'Connor FG. Musculoskeletal injections: a review of the evidence. Am Fam Physician 2008;78(8):971–976
Tallia AF, Cardone DA. Diagnostic and therapeutic injection of the shoulder region. Am Fam Physician 2003;67(6):1271–1278
Thumboo J, O'Duffy JD. A prospective study of the safety of joint and soft tissue aspirations and injections in patients taking warfarin sodium. Arthritis Rheum 1998;41(4):736–739
Wernecke C, Braun HJ, Dragoo JL. The effect of intra-articular corticosteroids on articular cartilage: a systematic review. Orthop J Sports Med 2015;3(5): 2325967115581163

1 Diagnostic Ultrasound and Guided Injection

Abstract
Given its comparative ease of availability, short scanning time, and ability to dynamically assess tissue and structure interplay, ultrasound is rapidly becoming the investigation of choice for many musculoskeletal conditions. This chapter outlines both the normal and common pathological ultrasound appearance of tendons, joints, bursae, muscles, and nerves as well as the use of ultrasound to ensure accurate needle placement during interventional procedures.

In addition to the diagnostic capabilities of ultrasound in the assessment and management of musculoskeletal conditions and in contrast to magnetic resonance imaging (MRI), ultrasound also has the capacity to be used as an interventional modality enhancing the accuracy of injection techniques.

Eustace (1997) demonstrated that even in the hands of musculoskeletal specialists only a minority of injections for shoulder pain were performed accurately with only 29% of subacromial and 42% of intra-articular injections reaching their intended target. Similar results have been demonstrated in patients with de Quervain's tenosynovitis (Zhingis 1998). Perhaps, not surprisingly, outcome has been demonstrated to significantly correlate with accuracy of injection with a systematic review and meta-analysis demonstrating that ultrasound-guided shoulder girdle injections are more accurate and more effective than landmark-guided injections (Aly et al 2014). Needle placement into smaller joint spaces is of particular difficulty, a fact in part due to the lack of aspirate from smaller joints, such as the carpometacarpal joint of the thumb, making accurate needle placement in these joints extremely difficult. For this reason injections performed under imaging are becoming more popular (Balint 1997, Ghozlan 2000, Koski 2000, Weidner 2004). ▶Fig. 1.1 and ▶Fig. 1.2 demonstrate the accuracy possible with ultrasound-guided injection. In ▶Fig. 1.1 an injection is given between the flexor tendon sheath and the tendon of flexor pollicis longus at the level of the metacarpophalangeal joint of the thumb. In ▶Fig. 1.2 a needle is placed immediately deep to the median nerve in the carpal tunnel.

Accurate needle placement is also of importance in more deeply placed structures such as the hip joint in order that both the correct target is injected and that neurovascular structures are avoided. A study by Leopold (2001) assessed the accuracy of needle placement with intra-articular hip injection using only anatomical landmarks as a guide. Using this "blind" approach the needle pierced or contacted the femoral nerve in 27% of anterior injections and was within 5 mm of the femoral nerve in 60% of all anterior attempts. Using a lateral approach the needle was never within 25 mm of any neurovascular structure in any injection; however, only 80% of injections managed to reach the joint cavity. ▶Fig. 1.3 demonstrates injection of the anterior aspect of the hip joint.

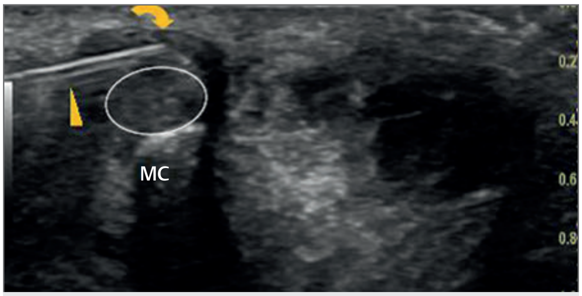

Fig. 1.1 Ultrasound-guided injection of the tendon sheath of flexor pollicis longus at the level of the metacarpophalangeal joint of the thumb (MC). The needle (*yellow arrowhead*) may be seen approaching from the left of the image. The needle rests between the flexor sheath (*yellow curved arrow*) and the tendon itself (*white oval*). In this image the sheath measures approximately 1 mm in depth and demonstrates the accuracy of needle placement possible with ultrasound guidance.

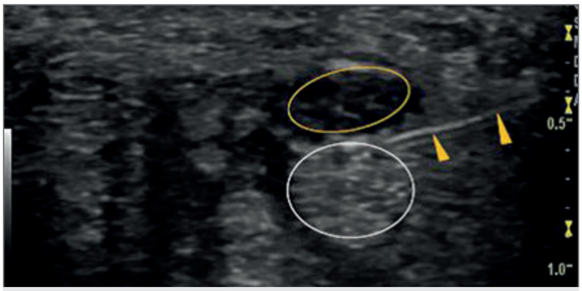

Fig. 1.2 Transverse ultrasound image of the carpal tunnel. The median nerve appears as a low echo oval-shaped foci (*yellow oval*). The tendons of flexor digitorum superficialis (*white oval*) may be seen deep to the median nerve. A needle may be seen immediately between the two (*yellow arrowheads*).

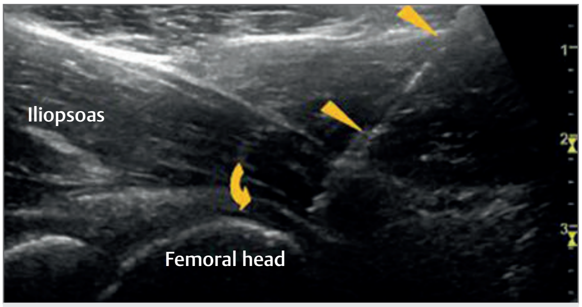

Fig. 1.3 Longitudinal image of the anterior hip joint. A needle (*yellow arrowheads*) may be seen lying up against the anterior joint capsule (*curved arrow*) prior to injection.

1.1 Diagnostic Ultrasound and Musculoskeletal Medicine

1.1.1 Tendons

Ultrasound may be considered the gold-standard investigation for examination of tendons demonstrating detailed internal structure not clearly seen with MRI (Grassi 2000, Joseph 2009). In addition to a high degree of spatial-resolution, ultrasound also has the advantage of relatively short scanning time, may be performed as a bedside procedure and, as it takes place in real time, allows the dynamic assessment of tendons and their relationship with surrounding tissue interface.

Tendons are collagenous structures with additional tenocytes, water, and other matrix components. Tendons are normally surrounded by loose connective tissue, the paratenon, which forms an elastic sleeve that allows free movement of the tendon. Where the tendon must travel through a narrow space, or come in contact with a bony area, such as the dorsal compartments of the wrist, this loose connective tissue becomes more specialized into a tenosynovial sheath, helping to reduce friction between the tendon and surrounding structures (Kannus 2000).

In the nonpathological state, normal tendon structure as imaged with ultrasound is characterized by the following key features:

- The internal fibrillar architecture is clearly visible in longitudinal scan being produced by parallel fascicles of collagen fibers. Between these echogenic fibers finer hypoechoic lines may be seen in keeping with intratendinous ground substance. With transverse imaging, this architectural arrangement produces the classic appearance of hyperechoic dots, representing collagen fascicles embedded within hypoechoic ground substance. There should be little internal irregularity with the tendon displaying a high degree of homogeneous echogenicity. These appearances may be considered analogous to a "packet of spaghetti."
- The tendon does not appear thickened with clearly delineated and regular margins distinct from surrounding tissues. A fine anechoic periphery may be noted in tendons which have a synovial sheath situated between the tendon and sheath. There should be no thickening of the sheath and no significant fluid or evidence of significant vascularity within the sheath.
- The tendon exhibits no internal vascularity or what is commonly termed "neovascularity" when examined under Power Doppler imaging.

▶Fig. 1.4 and ▶Fig. 1.5 demonstrate the normal appearance of the Achilles tendon in both longitudinal and transverse planes. The fibrillar pattern may be clearly seen.

Tendon pathology may be considered to encompass a number of distinct entities and should not be thought of as a single process but rather a spectrum of disorders, including lesions within the tenosynovium, the paratenon, the enthesis, and the tendon proper. In many cases lesions may coexist. ▶Table 1.1 outlines the individual pathological processes which may affect a tendon, either in isolation or in combination with one another.

In regard to tenosynovitis and paratenonitis, these two conditions may be considered to be pathological processes related to the tendon sheath or, when absent, the connective tissue surrounding the tendon. They may be either related to a systemic inflammatory disease or more commonly due to a mechanical overload. In many of the cases the tendon itself is relatively spared and ultrasound demonstrates no evidence of pathology within the tendon.

Characteristics of tendon sheath pathology on ultrasound include widening of the sheath due to an increase in fluid. Although usually anechoic in appearance, this fluid may appear to contain echogenic foci indicative of proteinaceous material or synovial proliferation (▶Fig. 1.6a–c; ▶Fig. 1.7). When assessed with Power Doppler, there may be an increase in blood flow within

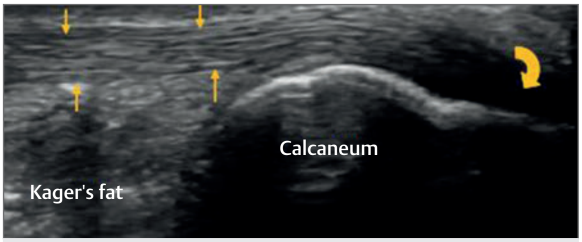

Fig. 1.4 Longitudinal image of the lower third of the Achilles tendon and its insertion onto the posterior aspect of the calcaneum (*yellow arrows*). The normal fibrillar pattern of the tendon is clearly seen. Note anisotropy at the most distal aspect of the insertion (*curved arrow*).

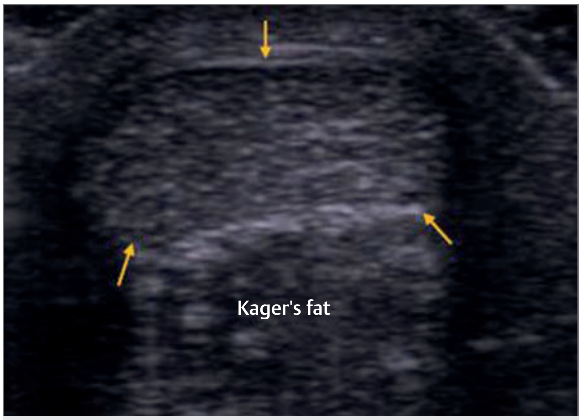

Fig. 1.5 Transverse image of the lower third of the Achilles tendon (*yellow arrows*). The image demonstrates the dot-like appearance of the collagen fascicles seen in cross-section.

Table 1.1 Summary overview of tendon pathology

Disorder	Description	Example	Clinical signs[a]
Paratenonitis	Disorder of the loose paratenon layer covering the tendon	Achilles paratenonitis	Pain, tenderness, diffuse swelling, crepitus, and warmth
Tenosynovitis	Disorder of the tendon sheath	de Quervain's tenosynovitis	Pain, tenderness, swelling within the sheath, crepitus, and warmth
Tendinopathy	An intratendinous disorder	Rotator cuff, patellar tendon, common extensor origin	Pain, focal tenderness, palpable swelling
Enthesiopathy	An intratendinous disorder affecting the tendon origin or insertion	Insertional Achilles tendinopathy	Tenderness and swelling at tendon insertion
Tear	Loss of normal tendon integrity leading to a partial or complete rupture	Ruptured supraspinatus, Achilles tendon	Pain and weakness. Possible palpable gap

[a]These clinical signs are variable and patients may present with more than one condition. For example, in chronic cases of de Quervain's tenosynovitis there may coexist a degree of tendinopathy within the tendon and a tenosynovitis within the tendon sheath.

the synovial lining of the tendon sheath indicative of an active inflammatory process (▶Fig. 1.6c, ▶Fig. 1.8).

With regard to both tendinopathy and enthesiopathy these two conditions may be considered intratendinous different only in their geographical location with enthesiopathy being an insertional tendinopathy. As such, tendinopathy has been shown to have either absent or minimal inflammatory cell infiltrate (Ollivierre 1996). Rather, the condition is better considered to be "degenerative" in nature affecting the Achilles tendon (Astrom 1995, Movin 1997), the rotator cuff (Hashimoto 2003), the patellar tendon (Khan 1998), and the common extensor tendon at the elbow (Potter 1995). Macroscopically, the tendon becomes soft and disorganized with tissue looking yellow or brown in appearance, a condition termed mucoid degeneration. In addition, there is a loss of the normally tightly bundled collagen fibers (Khan 1999). Microscopically, there is degeneration and disorganization of collagen with fibrosis (Maffulli 2000) and extensive neovascularization may be present (Khan 1999, Maffulli 2000). Importantly, tendinopathy may not be symptomatic and the degree of pathological change does not necessarily correlate well with clinical symptoms (Maffulli 2003).

Although the term tendinopathy has replaced that of tendonitis, given the degenerative-like change which exists, more recent evidence would suggest that this may be an oversimplification and it is likely that elements of the inflammatory response play a role in the progression or continuation of tendon disrepair. Schubert (2005) demonstrated the presence of macrophages and T and B lymphocytes in chronic Achilles tendinopathy. This has been supported by other studies demonstrating increased levels of macrophage-derived interleukin 1 (IL 1) (Gotoh 1997), cyclo-oxygenase 1(COX-1) (Sullo 2001), COX-2 (Zhang 2010, Khan 2005), IL-6 (Legerlotz 2012), isoforms of transforming growth factor β (TGF-β) (Fenwick 2000), and increased substance P (Gotoh 1998) in chronic tendinopathy.

In particular, substance P has been demonstrated as a proinflammatory mediator (Garrett 1992) and together with calcitonin gene-related peptide (CGRP) these nociceptive mediators have been shown to be significantly expressed in chronic tendinopathy. In addition to being a proinflammatory mediator, substance P has also been shown to exert a proliferative effect on tenocytes initiating an increase in the ratio of type III to type I collagen mRNA contributing to formation of the smaller collagen fibers seen in tendinopathic tendons (Fong 2013). Consequently, although it would seem that the idea of "tendonitis" cannot be supported, there is evidence that tendinopathy, considered an ongoing tendon degenerative process, does contain many elements of an inflammatory-mediated response.

In clinical practice and on ultrasound, it is worth noting that patients may present with either a tenosynovitis or tendinopathy but also not uncommonly a combination of both pathologies (▶Fig. 1.9).

In relation to ultrasound, tendinopathic changes may manifest as one or more of the following findings:

- Tendon thickening with heterogeneous echogenicity.
- Hypoechoic foci representing intrasubstance tears (defined as linear hypoechoic foci associated with discontinuity of tendon fibers).
- Calcifications and enthesophytes at the tendon attachment.
- Neovascularization on Power Doppler (Levin 2005, Zanetti 2003) (▶Fig. 1.10, ▶Fig. 1.11).

Although intrasubstance tears may be considered as one of the characteristics of tendinopathy, ultrasound is also capable of assessing more significant tears and complete ruptures which may be the consequence of a chronic tendinopathy, trauma, or often a combination of both (▶Fig. 1.12, ▶Fig. 1.13).

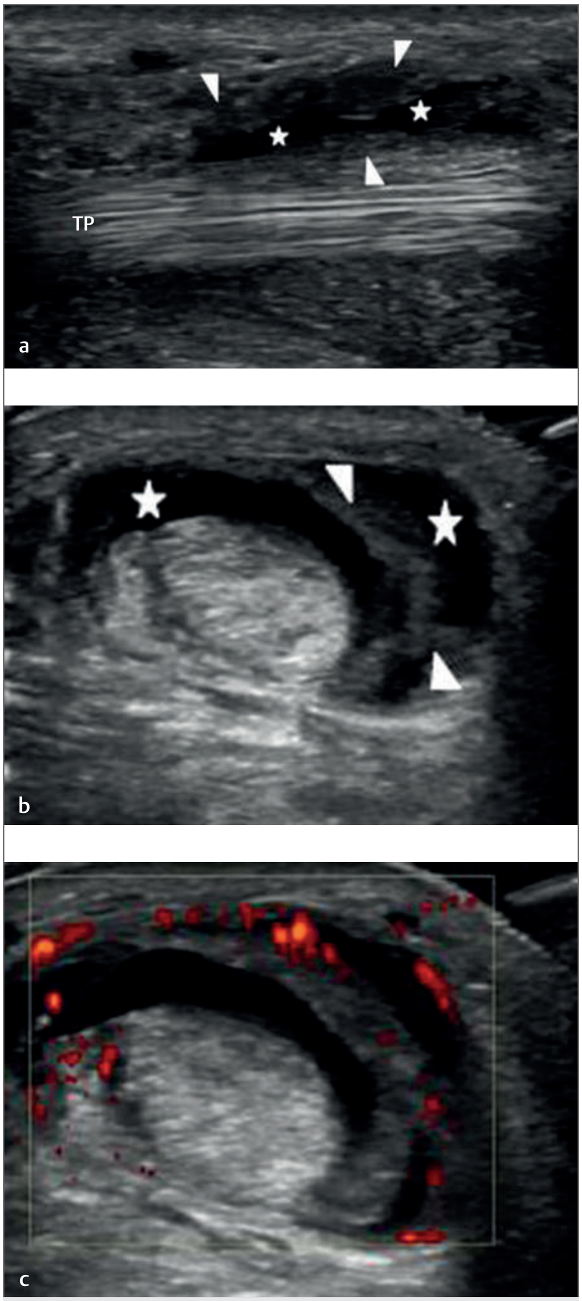

Fig. 1.6 (a) Longitudinal image of the tendon of tibialis posterior (TP). The tendon itself appears intact and of a good fibrillar pattern. However, there is a marked synovial thickening (*arrowheads*) and fluid (*white stars*) around the tendon within the sheath. These findings are in keeping with a tenosynovitis. **(b)** Transverse image of the tendon of TP. The tendon appears intact. There is, however, marked effusion (*white stars*) and synovial thickening (*arrowheads*) around the tendon. Findings are in keeping with a tenosynovitis. **(c)** This is the same image as in part (b). Power Doppler demonstrates that in addition to synovial thickening and effusion there is an increased vascularity within the synovial thickening.

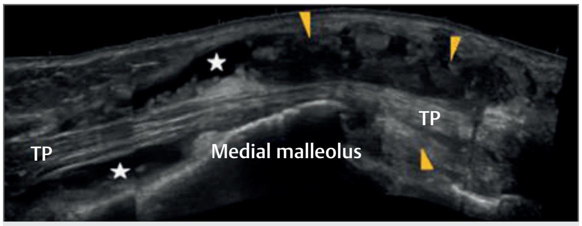

Fig. 1.7 Longitudinal image of the tendon of tibialis posterior (TP) around the medial malleolus. The tendon itself appears of good echogenicity and fibrillar pattern. There is, however, marked synovial thickening (*yellow arrowheads*) and effusion (*white stars*) within the tendon sheath in keeping with a chronic tenosynovitis.

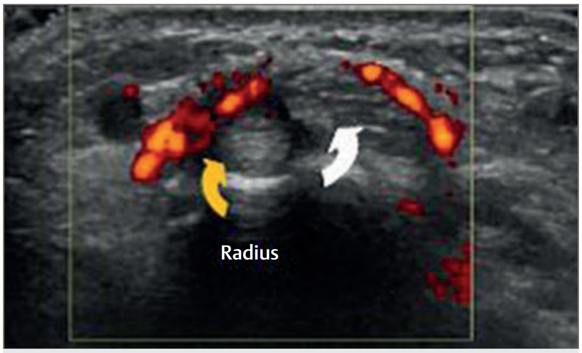

Fig. 1.8 Transverse image of the first dorsal compartment of the wrist and the tendons of abductor pollicis longus (*curved yellow arrow*) and extensor pollicis brevis (*curved white arrow*). Although there appears to be no effusion or synovial thickening within the sheath, Power Doppler imaging demonstrates a marked synovitis in keeping with a de Quervain's tenosynovitis.

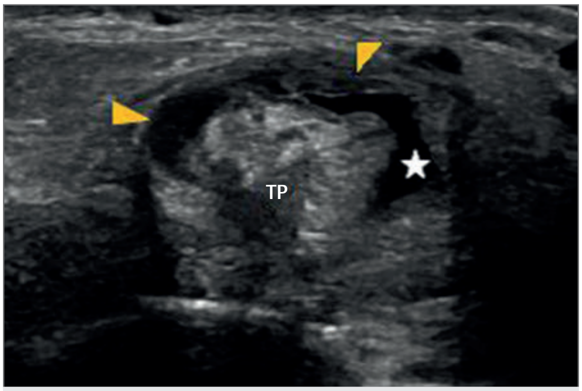

Fig. 1.9 Transverse image of the tendon of tibialis posterior (TP). There is synovial thickening (*yellow arrowheads*) and effusion (*white star*) in keeping with a tenosynovitis. In addition, there is a loss of the normal oval-shaped tendon which appears of a heterogeneous echogenicity. These findings are in keeping with both a tenosynovitis of the tendon sheath and tendinopathy affecting the tendon itself.

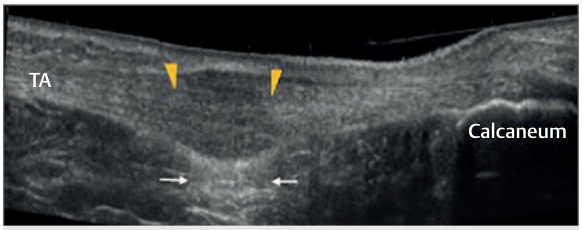

Fig. 1.10 Longitudinal image of the Achilles tendon. There is a significant fusiform swelling within the midsubstance of the tendon with associated loss of echogenicity (*yellow arrowheads*). Deep to the tendon there is a clear enhancement (*white arrows*) indicating that although the tendon is thickened, it is less dense. These findings are in keeping with a midsubstance tendinopathy. TA, tendo Achilles.

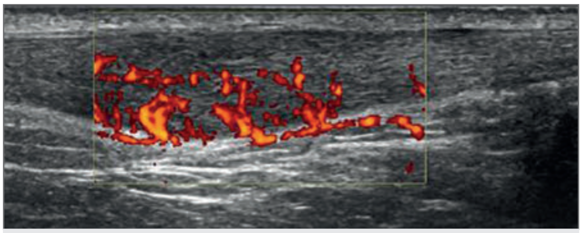

Fig. 1.11 Longitudinal image of the Achilles tendon. In addition to a marked fusiform swelling within the midsubstance of the tendon, Power Doppler demonstrates a significant neovascularity throughout the tendon imaged.

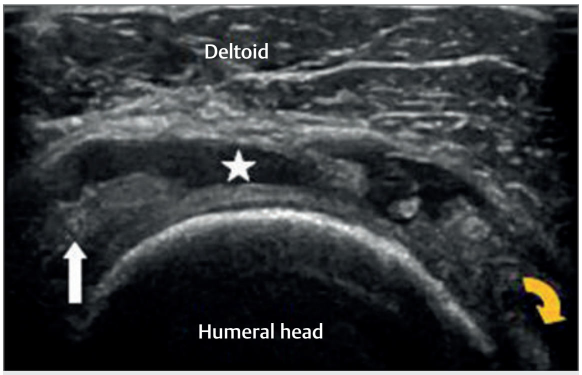

Fig. 1.12 Transverse image over the humeral head. There is a complete loss of the normal tendon structure of supraspinatus with the gap being filled with fluid (*white star*). Anteriorly, the long head of biceps may be seen (*yellow curved arrow*). Posteriorly, the tendon of infraspinatus may be seen (*white arrow*). These findings indicate a rupture of the tendon of supraspinatus with retraction of the tendon proximally.

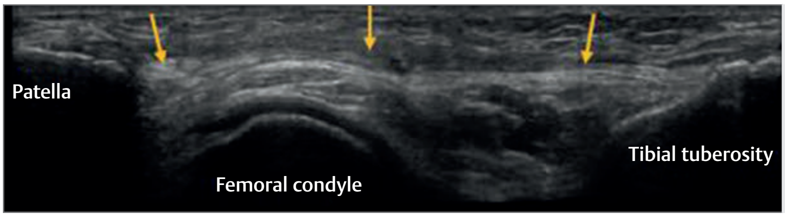

Fig. 1.13 Longitudinal image of the infrapatellar region. The image demonstrates a complete absence of normal patella tendon architecture (*yellow arrows*) in keeping with a chronic complete rupture of the tendon and subsequent patella alta.

1.1.2 Joints

Ultrasound may be used to assess the joints of the appendicular skeleton and is capable of providing detailed information relating to acute injury and degenerative and inflammatory processes. However, the clinician should be aware of its limitations in regard to the deeper joints such as the shoulder and, in particular, the hip from which little detail of internal structure may be determined (Koski 1990, Hermann 2003).

Structures to consider when assessing joints are bone, cartilage, and capsule together with the supporting ligaments which may appear as thickenings of the joint capsule or as distinct entities standing slightly apart from the capsule. In addition to the static assessment of these structures, use should be made of the ability of ultrasound to assess the dynamic integrity of the joint and supporting ligaments. Dynamic assessment of the joint with both passive and active movements also allows some evaluation of the internal structure of the joint not visible in a static image and is able to demonstrate movement of intra-articular fluid and, if present, loose bodies.

The appearance of bone is easy to detect as a distinct hyperechoic line. Normal cartilage appears as a subtler anechoic layer covering the bone with clear margins at both its osteochondral and chondrosynovial boundaries. Synovial fluid should normally have an anechoic appearance and a small amount present within the joint between the cartilage and synovial membrane lining the capsule may be considered to be normal (▶Fig. 1.14).

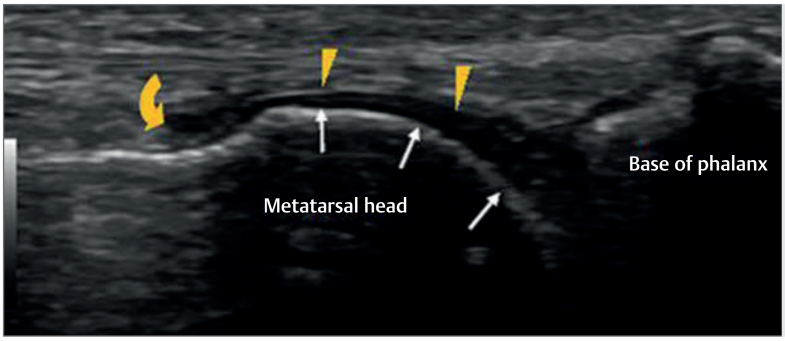

Fig. 1.14 Longitudinal image of the first metatarsophalangeal joint of the great toe. The subchondral bone of the metatarsal head may be seen as a hyperechoic line (*white arrows*). The overlying cartilage appears as a hypoechoic layer with a brighter line at its superficial surface (*yellow arrowheads*). The metatarsal recess contains a small amount of anechoic fluid well within what would be considered normal limits (*curved yellow arrow*).

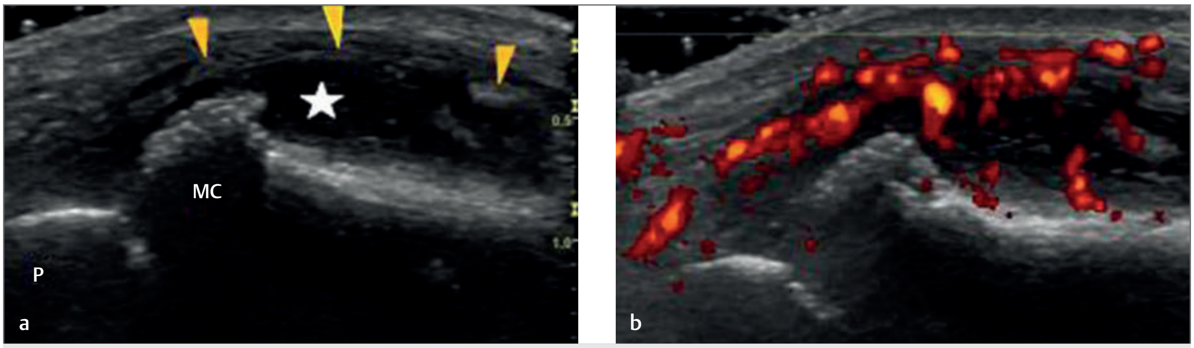

Fig. 1.15 **(a)** Longitudinal image of the metacarpophalangeal joint of the thumb. The head of the metacarpal (MC) appears prominent in relation to the phalanx (P) indicative of subluxation. In addition, there appears to be a significant effusion (*white star*) and synovial thickening (*yellow arrowheads*). The patient had a chronic and active rheumatoid arthritis. **(b)** This is the same image as in part (a), except Power Doppler imaging has been used to demonstrate that the thickened synovium is actively inflamed.

When present, ultrasound is capable of demonstrating pathological features affecting both intra- and periarticular structures around the joint. In acute trauma or in acute and chronic synovitis, joint cavity distension with fluid is most characteristic with ultrasound being able to give useful information as to the nature of the fluid. A simple effusion will appear relatively anechoic while a more chronic inflammatory condition or a joint infection may contain fluid of mixed echogenicity indicating proteinaceous material or synovial proliferation.

In addition to synovial proliferation, an active synovitis is also characterized by a significant increase in vascularity within the synovial membrane well demonstrated with the use of Power Doppler imaging. In this respect, ultrasound has been shown to provide detailed and early objective quantitative and qualitative information on the degree and activity of joint inflammation (Karim 2004, Koski 1990, Backhaus 1999) (▶Fig. 1.15a,b).

Ultrasound may detect a number of cartilaginous changes in patients with osteoarthritis or inflammatory arthritis. Changes include a loss of the normal clear, well-defined outer margin, a loss of the clarity of the cartilaginous layer itself, thinning of the cartilage, and irregularities of the subchondral bone. The high spatial resolution of ultrasound allows the identification of early and minimal subchondral bone changes in patients with inflammatory arthritis with erosions as small as 1 mm being visible particularly in areas of known early bone reabsorption such as the second metacarpophalangeal joint (Grassi 2001). In this regard, ultrasound has been demonstrated to be able to detect more erosions than plain X-ray in early rheumatoid arthritis (Wakefield 2000) (▶Fig. 1.16).

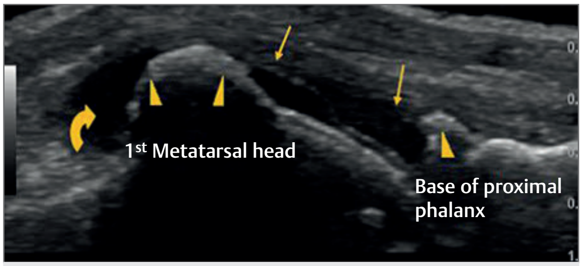

Fig. 1.16 Longitudinal image of the first metatarsophalangeal joint of the great toe. The image demonstrates marked degenerative change with bony exostosis at both the head of the metatarsal and at the base of the proximal phalanx (*yellow arrowheads*). Effusion is noted in the joint and also the metatarsal recess (*yellow curved arrow*). There is hypertrophy of the joint capsule with synovial thickening (*yellow arrows*).

1.1.3 Bursae

In the nonpathological state most bursae are not clearly discernible. When they are visible on ultrasound they ordinarily appear as a thin hypoechoic line bounded by equally thin echogenic borders corresponding to the tissue–fluid–tissue interface (▶Fig. 1.17).

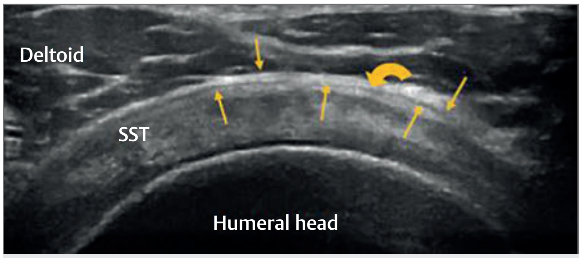

Fig. 1.17 Transverse image of the subacromial bursa overlying the supraspinatus tendon (SST). The bursa may be seen to be composed of a thin hypoechoic line (*curved yellow arrow*) bounded by two hyperechoic borders (*yellow arrows*) corresponding to the tissue–fluid–tissue interface.

Fig. 1.18 Longitudinal image of the patella and infrapatellar region of the knee. The patella tendon (*yellow arrows*) appears intact; however, a hybrid anechoic/low echo swelling (*yellow arrowheads*) is seen overlying the lower half of the patella and upper third of the patellar tendon (note the posterior acoustic enhancement). These findings are indicative of a prepatellar bursitis.

In the pathological state a bursa may appear thickened and/or distended with fluid. This may be simple in nature in which case it is characteristically anechoic in appearance or contain proteinaceous material or synovial proliferation in which case the bursal contents will demonstrate a degree of echogenicity consistent with the underlying cause and duration of symptoms (▶Fig. 1.18).

1.1.4 Muscle

The high spatial resolution of ultrasound allows a thorough examination of muscle for a variety of pathology. Within the remit of musculoskeletal and sports medicine, ultrasound is particularly useful in the assessment of muscular contusions and tears being able to assess the degree of pathology and monitor the muscle as it repairs in order to be able to guide and direct rehabilitation (Peetrons 2002).

In the longitudinal view, normal muscle tissue typically demonstrates low echo fascicles surrounded by hyperechoic lines representing the internal fibroadipose septa, the perimysium, and endomysium. The whole muscle is in turn surrounded by the hyperechoic fascial sheath, the epimysium. In the longitudinal plane, the perimysium are commonly arranged in parallel to the long axis of the muscle or angled toward a central tendon in a herringbone arrangement in muscles such as the rectus femoris of the thigh. In the transverse plane, the perimysium is seen as a series of hyperechoic dots or short lines scattered throughout the more hypoechoic background representing the muscle fibers (▶Fig. 1.19, ▶Fig. 1.20).

Trauma may result in a contusion, strain, or tear of the muscle either within the muscle belly or more commonly at the musculotendinous junction. Muscle tears are commonly graded I, II, or III. A grade I muscle strain will either appear normal on ultrasound imaging or demonstrate only subtle changes comprising either hypoechoic or hyperechoic areas within the muscle in addition to possible perifascial edema (Takebayashi 1995).

A grade II muscle strain represents intrasubstance partial tearing with more than a 5% disruption of muscle fibers. Ultrasound demonstrates discontinuity of muscle fibers and the hyperechoic perimysium. Power Doppler may demonstrate a surrounding hypervascularity. In addition, the cavity formed by retraction of muscle fibers may fill with hematoma. Initially, blood may appear hyperechoic but within 2 to 3 days the collection will appear anechoic with a

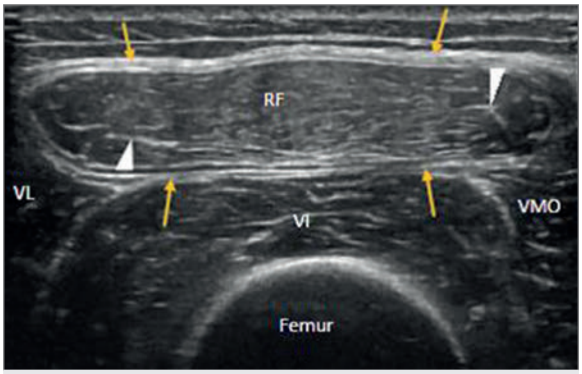

Fig. 1.19 Transverse image of the mid-third of the thigh. The four parts of the quadriceps can be seen overlying the femur, vastus lateralis (VL), vastus medialis obliquus (VMO), vastus intermedius (VI), and rectus femoris (RF). The internal perimysium and may be seen as hyperechoic short lines. The internal epimysium is seen as slightly thicker and longer lines (*arrowheads*). The surrounding epimysium may be seen as a hyperechoic border (*yellow arrows*).

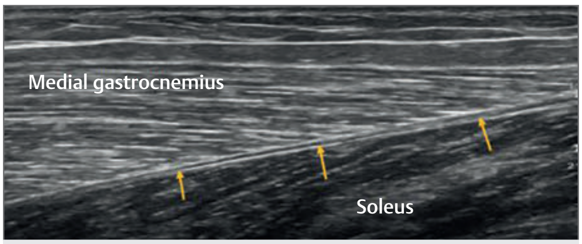

Fig. 1.20 Longitudinal image of the medial gastrocnemius and soleus muscles as they join onto the medial aponeurosis (*yellow arrows*) in the midcalf region. The internal perimysium may be seen as a series of hyperechoic lines surrounded by the hypoechoic muscle fibers.

hyperechoic surrounding halo (Bianchi 1998). Grade II muscle strains may also occur at the musculotendinous junction such as in a “tennis leg” where the medial head of the gastrocnemius muscle detaches from its shared aponeurosis with the soleus muscle (▶Fig. 1.21). As the tear heals, the central anechoic region will appear to shrink with ingrowth of hyperechoic fibrous tissue (▶Fig. 1.22).

Grade III strains represent a complete tear of the muscle either within the midbelly or commonly at the musculoskeletal junction with a palpable defect or soft tissue mass often present. On imaging, there is a complete discontinuity of muscle fibers with loss of normal muscle architecture and associated hematoma (▶Fig. 1.23). The retracted echogenic muscle stump may be seen to be surrounded by hypoechoic hematoma.

As the muscle tear heals, the resultant scar tissue may appear hypoechoic and should not be mistaken for an acute tear (▶Fig. 1.24).

In more chronic cases, a soft tissue mass may develop with a marked peripheral vascularization. This may represent evidence of an early myositis ossificans with subsequent and characteristic calcification particularly noticeable around the periphery of the lesion (▶Fig. 1.25). Care should, however, be exercised in such cases even in the presence of trauma as a more sinister lesion such as a sarcoma cannot always be excluded on ultrasound alone.

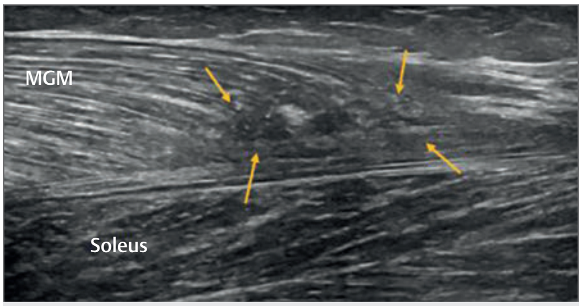

Fig. 1.21 Longitudinal image of the medial calf. The medial head of the gastrocnemius muscle (MGM) demonstrates a loss of normal fibrillar pattern toward its distal insertion onto the medial aponeurosis (*yellow arrows*). The deeper soleus muscles appear intact. The image is in keeping with a grade II tear of the medial gastrocnemius muscle.

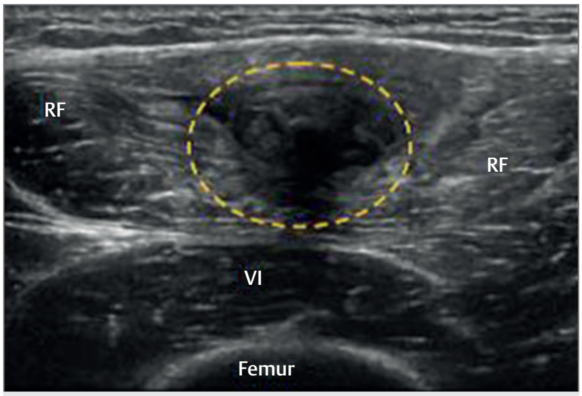

Fig. 1.22 Transverse image of the midthigh. The rectus femoris muscle (RF) contains a large area of low echogenicity within its midsubstance with a loss of normal perimysium. The image is in keeping with a large intrasubstance tear (*yellow oval*). The underlying vastus intermedius appears intact (VI).

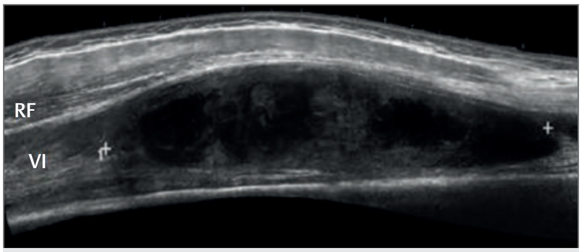

Fig. 1.23 Longitudinal image of the anterior thigh. A large low echo intramuscular collection is seen within vastus intermedius (VI) measuring approximately 16 cm longitudinally (*white crosses*). The overlying rectus femoris (RF) appears intact. The patient described a sudden onset of pain following a kicking movement during karate training. The image is in keeping with a grade III rupture of the vastus intermedius muscle and subsequent hematoma.

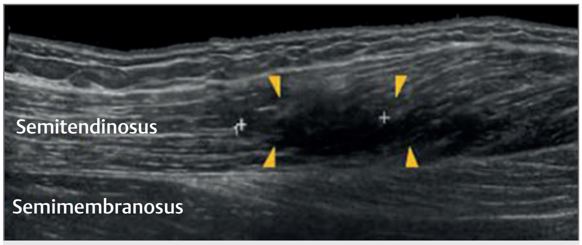

Fig. 1.24 Longitudinal image of the medial hamstring muscles. The overlying semitendinosus demonstrates a loss of normal architecture with what appears as an area of low echogenicity (*yellow arrowheads*). The underlying semimembranosus appears intact. These findings are in keeping with a chronic hamstring tear affecting the semitendinosus muscle and subsequent fibrosis.

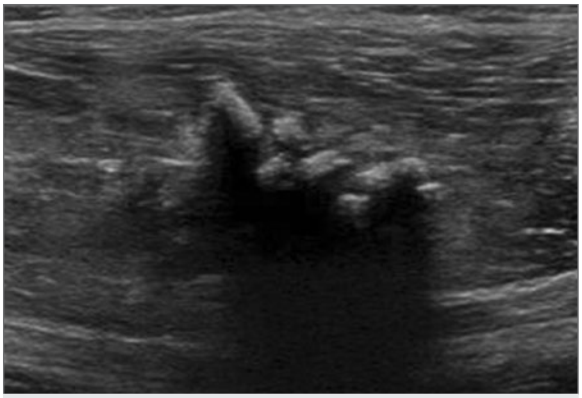

Fig. 1.25 Longitudinal image of the bicep femoris muscle. There are irregular hyperechoic foci within the muscle belly with loss of normal surrounding muscle architecture. The foci itself demonstrate posterior shadowing. The patient was a 32-year-old footballer who described a hamstring strain several months previously. Rehabilitation had not fully resolved symptoms and an ultrasound was performed. The image is in keeping with a myositis ossificans of the bicep femoris muscle.

1.1.5 Nerve

Ultrasound is capable of detecting peripheral nerves based both on their known anatomical position and their characteristic internal structure. Although similar in aspect to tendons both in longitudinal and transverse planes, the echotexture of nerves can be distinguished from that of tendons because of the coarser appearance of the nerve (▶Fig. 1.26, ▶Fig. 1.27a,b). This characteristic appearance of echoic bands in longitudinal plane and dots in transverse plane corresponds to connective tissue within the nerve. This distinctive feature has been termed as a "pepper pot" or fascicular appearance (Silvestri 1995).

Although limited in regard to recognition of nerve function, ultrasound is able to clearly identify nerve swelling as in cases of neural entrapment such as carpal tunnel syndrome. In the assessment of carpal tunnel ultrasound has been shown to have a high degree of both specificity and sensitivity of 100 and 99%, respectively (Klauser 2009, Hobson-Webb 2008). On ultrasound, the entrapped nerve will appear flattened and thickened with an increase in its normal cross-sectional area (▶Fig. 1.28). There may also be an associated intraneural hypervascularity (▶Fig. 1.29) (Ammar 2006).

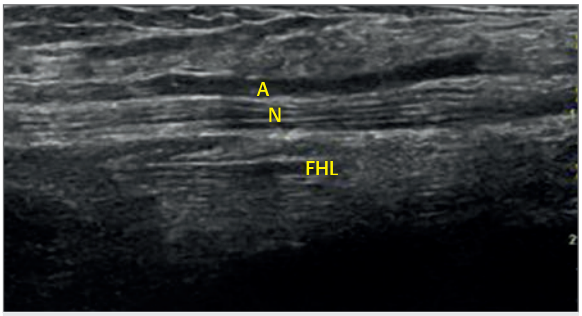

Fig. 1.26 Longitudinal image of the tarsal tunnel of the ankle. The tibial nerve (N) may be seen to sit between the posterior tibial artery (A) and the tendon of flexor hallucis longus (FHL). The nerve is of characteristic appearance with a relatively "coarse" internal architecture.

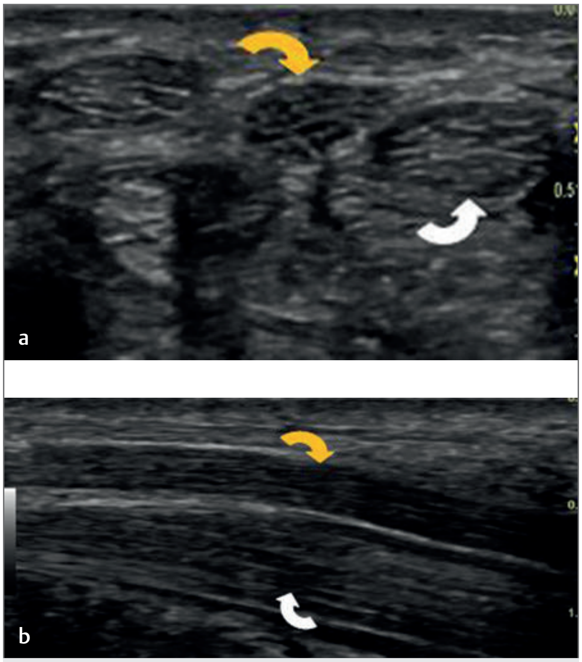

Fig. 1.27 **(a)** Transverse image of the median nerve within the carpal tunnel at the wrist. The median nerve (*yellow arrow*) may be seen to the left of one of the flexor tendons (*white arrow*). The image demonstrates the coarser more hypoechoic internal structure of the nerve compared to the tendon. **(b)** Longitudinal image of the median nerve at the wrist. The median nerve (*yellow arrow*) may be seen overlying the flexor tendon (*white arrow*). The nerve appears more hypoechoic than the tendon corresponding to the connective tissue within the nerve.

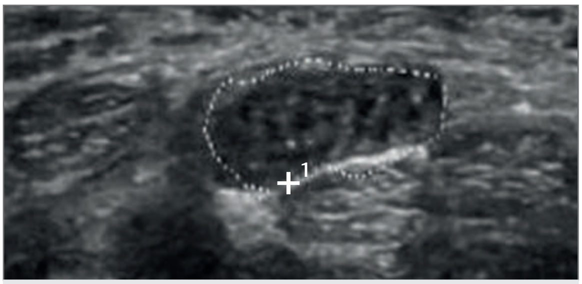

Fig. 1.28 Transverse image of the median nerve within the carpal tunnel. The nerve appears flattened and thickened. The normal cross-sectional area of the median nerve at the wrist may be considered to be between 7 and 9 mm^2. In this example the nerve has a cross-sectional area measuring 22 mm^2.

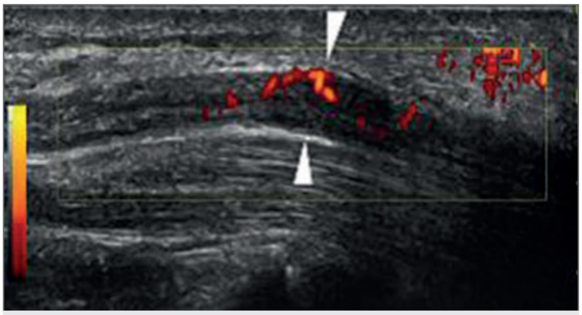

Fig. 1.29 Longitudinal image of the median nerve at the level of the carpal tunnel. There appears to be a mild swelling of the nerve as it enters the tunnel (*white arrowheads*). Doppler imaging demonstrates a mild intraneural vascularity suggestive of carpal tunnel syndrome.

2 The Shoulder: Diagnostic Imaging

Abstract
Ultrasound of the shoulder is one of the most common applications of musculoskeletal ultrasound both as a diagnostic tool and as an aid to accurate intervention. This chapter outlines the correct positioning of both patient and probe to ensure accurate visualization of the key structures around the shoulder. Of particular importance when examining the shoulder is the need to assess holistically given the interplay between structures, for example, the relevance of fluid within the subacromial bursa and bicipital sheath in a full thickness rotator cuff tear. A high-frequency (7-15 MHz) linear probe with a relatively large footprint should be used for diagnostic imaging to allow sufficient anatomical resolution.

Keywords: long head of biceps, subscapularis, subcoracoid, supraspinatus, infraspinatus, transverse ligament, coracoacromial ligament, subacromial bursa, glenohumeral joint, acromioclavicular joint, sternoclavicular joint, suprascapular notch

2.1 Diagnostic Imaging of the Shoulder: Introduction

The shoulder joint should be considered as a whole, given the interplay between the tendons of the rotator cuff, the bursae, the tendon of the long head of biceps and the acromioclavicular joint. In particular, ultrasound of the shoulder should include dynamic scanning of structures to assess for impingement syndromes.

Imaging includes the following:

- Long head of biceps tendon.
- Subscapularis tendon.
- Dynamic assessment for long head of biceps subluxation and subcoracoid/anterior impingement.
- Supraspinatus tendon and subacromial bursa.
- Infraspinatus tendon and posterior glenohumeral joint.
- Suprascapular notch and suprascapular nerve.
- Acromioclavicular joint.
- Sternoclavicular joint.

2.1.1 Long Head of Biceps Tendon

Transverse Scan

The patient is seated with the elbow flexed to 90 degrees and the arm supported on a pillow. The arm may be placed in slight internal rotation. The probe is placed in the anatomical transverse plane so that it is positioned transversely over the long biceps tendon found in the bicipital groove between the greater and lesser tuberosities. Scan proximally as far as possible before the tendon passes form view below the acromion and distally to the musculotendinous junction at the level of the pectoralis major tendon (▶Fig. 2.1, ▶Fig. 2.2, ▶Fig. 2.3, ▶Fig. 2.4, ▶Fig. 2.5).

The subacromial–subdeltoid bursa (SSB) is located deep to the deltoid muscle and the coracoacromial arch and extends laterally beyond the humeral attachment of the rotator cuff anteriorly over the intertubercular groove, medially to the acromioclavicular joint, and posteriorly over the rotator cuff. It is important when scanning this region to follow the bursa to its most inferior margin as this is often where fluid is seen.

The bicipital sheath may be seen to extend some way inferiorly below the greater and lesser tuberosities. Scanning should include this region to ensure that any fluid distension of the bicipital sheath is not missed.

Longitudinal Scan

The probe is returned to the level of the bicipital groove and turned through 90 degrees so that it is positioned in the anatomical sagittal plane to view the tendon longitudinally (▶Fig. 2.6, ▶Fig. 2.7).

Fig. 2.1 Transverse scan of the long head in the bicipital groove.

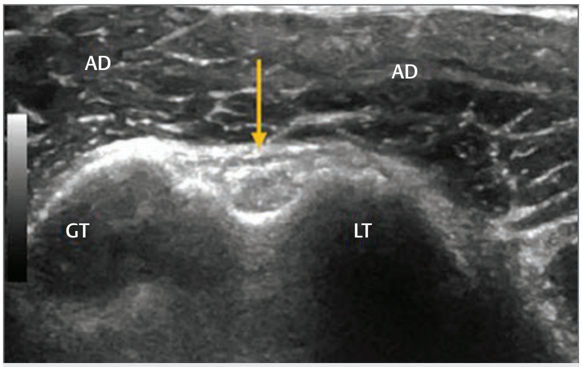

Fig. 2.2 Transverse image of long head of biceps in bicipital groove. AD, anterior deltoid; GT, greater tuberosity; LT, lesser tuberosity.

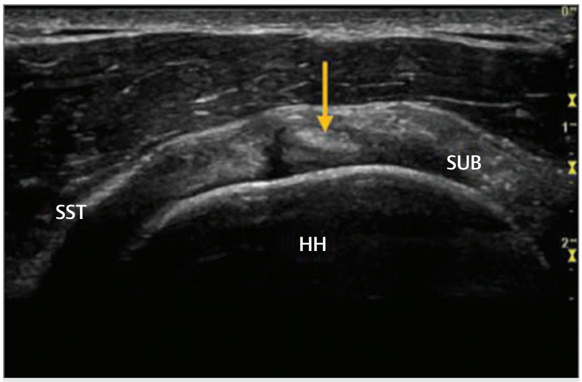

Fig. 2.3 Transverse image of long head of biceps proximal to the bicipital groove. Note the tendon is oval in appearance as it turns medially to run over the humeral head. HH, humeral head; SST, supraspinatus tendon; SUB, subscapularis tendon.

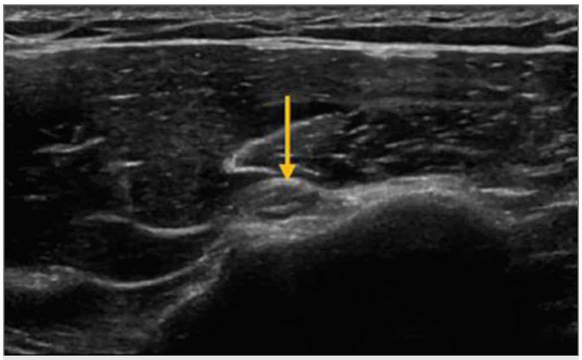

Fig. 2.4 Transverse image of the long head of biceps (*yellow arrow*) distal to the bicipital groove at the level of the pectoralis major tendon.

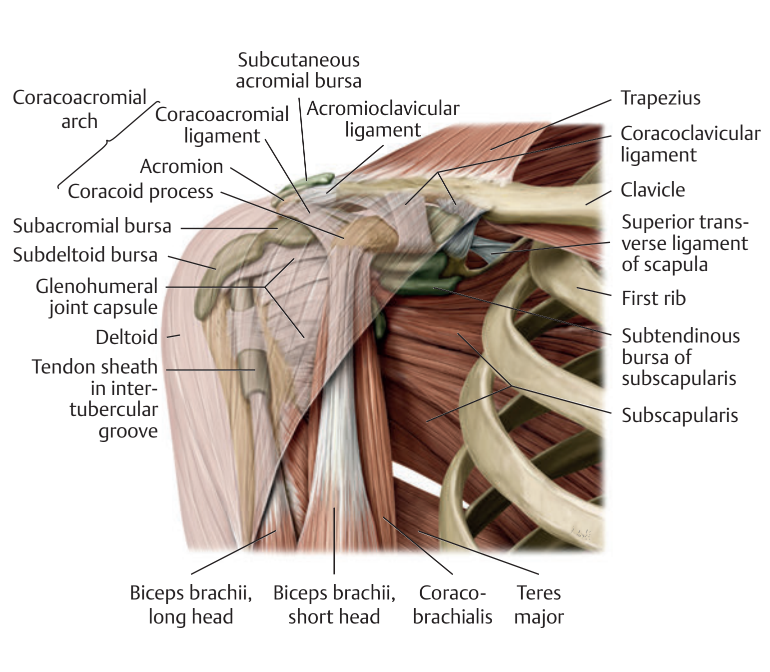

Fig. 2.5 Anterior coronal view of the right glenohumeral and acromioclavicular joints. The subacromial bursa is the synovial cavity located just below the acromion, which communicates with the subdeltoid bursa in most individuals, forming the so-called subacromial–subdeltoid bursa (SSB). The SSB is located deep to the deltoid muscle and the coracoacromial arch and extends laterally beyond the humeral attachment of the rotator cuff anteriorly over the intertubercular groove, medially to the acromioclavicular joint, and posteriorly over the rotator cuff. It is important when scanning this region to follow the bursa to its most inferior margin as this is often where fluid is seen. The bicipital sheath may be seen to extend some way inferiorly below the greater and lesser tuberosities. Scanning should include this region to ensure that any fluid distension of the bicipital sheath is not missed. (Reproduced from Schuenke, Schulte, and Schumacher, Atlas of Anatomy, 2nd edition, ©2014, Thieme Publishers, New York. Illustration by Karl Wesker/Markus Voll.)

Fig. 2.6 Longitudinal scan of the long head of biceps. The probe is placed in the anatomical sagittal plane over the tendon in the bicipital groove.

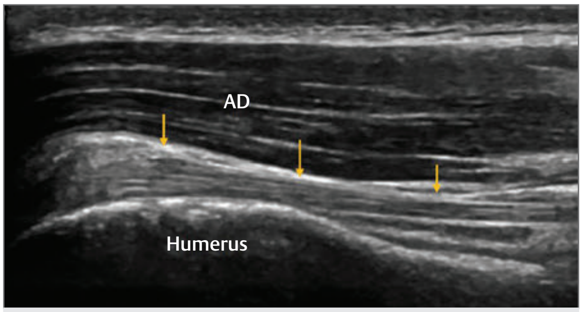

Fig. 2.7 Longitudinal image of the long head of biceps in the bicipital groove. The tendon appears as a fibrillar band (*yellow arrows*) below the anterior deltoid (AD) muscle.

The Long Head of Biceps: Pathology

See ▶Fig. 2.8, ▶Fig. 2.9, ▶Fig. 2.10; ▶Fig. 2.11a,b; ▶Fig. 2.12a,b; ▶Fig. 2.13a,b.

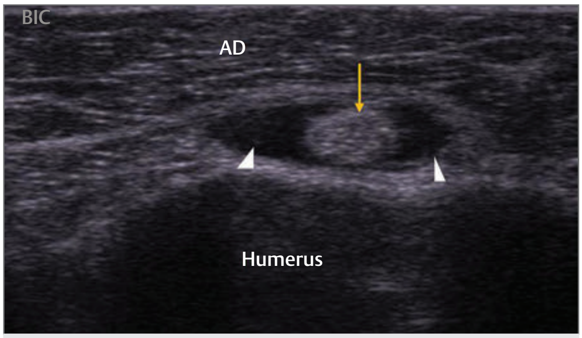

Fig. 2.8 Transverse image of the long head biceps (*yellow arrow*). The image demonstrates fluid around the tendon within the bicipital sheath (*white arrowheads*). The fluid extends both medially and laterally around the tendon due to the pressure of the probe. A longitudinal scan over the tendon would not have demonstrated any fluid. AD, anterior deltoid.

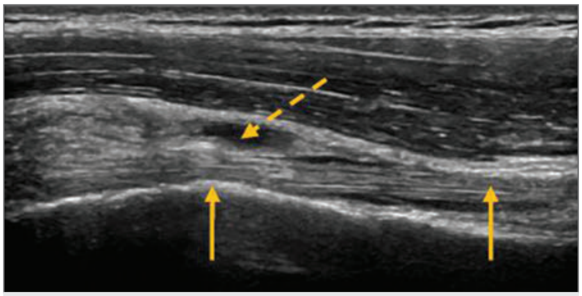

Fig. 2.10 Longitudinal image of the long head of biceps tendon (*yellow arrows*). The tendon appears intact with a good fibrillar pattern. However, fluid and some synovial thickening are noted surrounding the tendon within the bicipital groove (*yellow dashed arrow*).

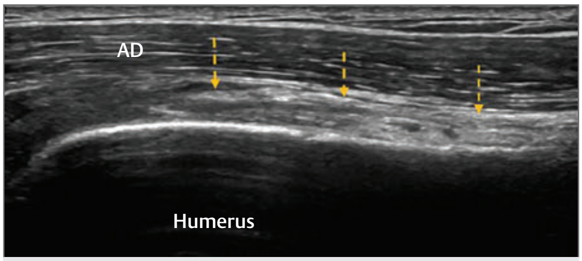

Fig. 2.9 Longitudinal view of the bicipital groove. The image fails to demonstrate the normal linear fibrillar pattern of the tendon in keeping with a tendon rupture. Instead the bicipital groove appears filled with echogenic material (*dashed yellow arrows*). AD, anterior deltoid; yellow arrow dashed, bicipital groove demonstrating no clear long head of biceps tendon.

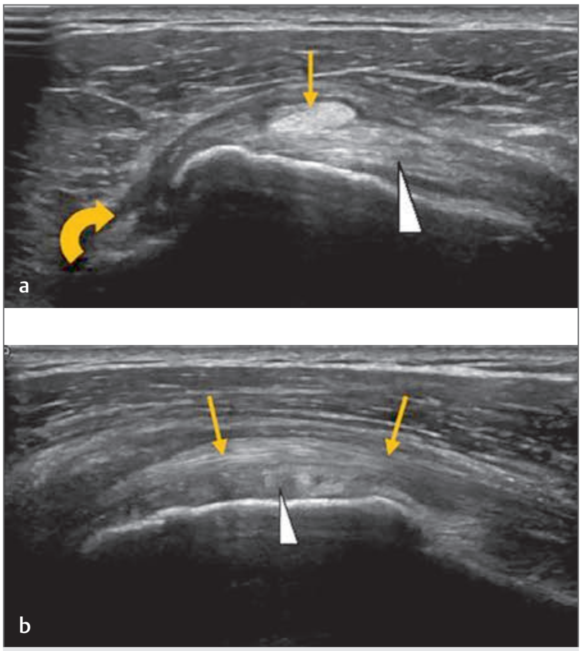

Fig. 2.11 (**a**) Transverse image of the long head of biceps at the level of the bicipital groove. The image demonstrates the long head biceps (*yellow arrow*) as being subluxed medially and overlying the subscapularis tendon (*white arrowhead*). The bicipital groove appears empty (*curved yellow arrow*). (**b**) Longitudinal image confirms that the long head biceps is intact (*yellow arrows*) but subluxed medially and is overlying the subscapularis tendon (*white arrowhead*).

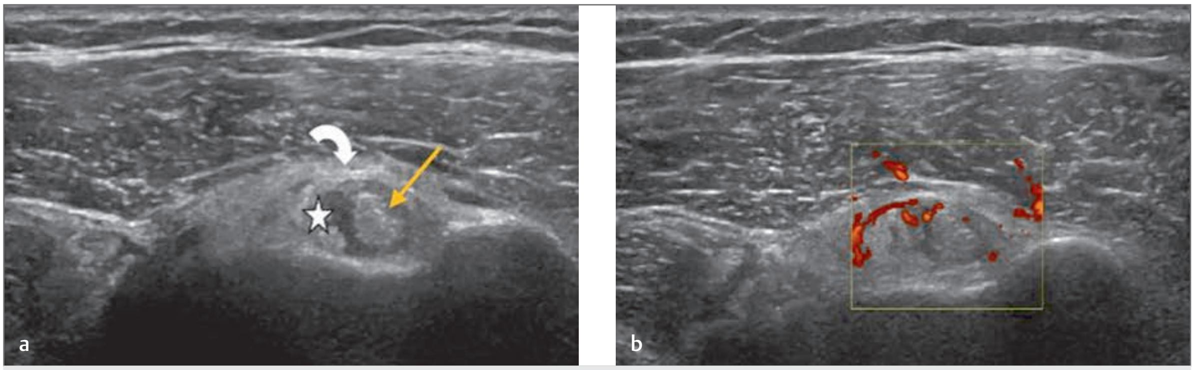

Fig. 2.12 (**a, b**) Transverse image of the bicipital groove. The image demonstrates a tendinopathic long head of biceps (*yellow arrow*). In addition, there is synovial thickening within the bicipital sheath (*white star*) with bowing of the transverse ligament (*white curved arrow*). The right hand image demonstrates the associated Doppler signal within the bicipital sheath indicating tenosynovitis.

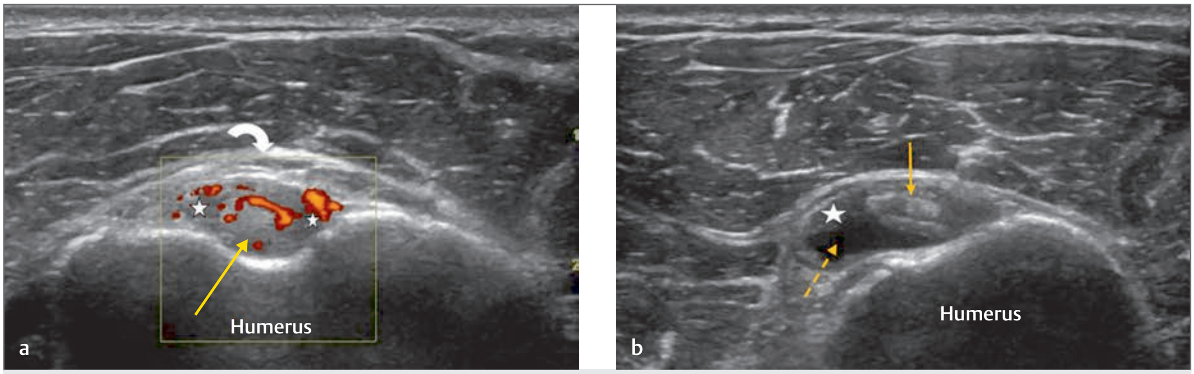

Fig. 2.13 (**a**) Transverse images of the long head of biceps. The image above demonstrates a tendinopathic tendon (*yellow arrow*) at the level of the bicipital groove with bowing of the transverse ligament (*white curved arrow*) and synovial thickening (*white stars*). Doppler imaging also demonstrates an associated synovitis. (**b**) This image is taken distally to the bicipital groove and demonstrates fluid within the sheath (*dashed yellow arrow*).

2.1.2 Subscapularis Tendon

Longitudinal Scan

The patient is seated with the elbow flexed to 90 degrees and the arm supported on a pillow. The arm should be placed in slight external rotation. The long head of the biceps may be used as a landmark. The probe is placed in the anatomical transverse plane to image the subscapularis tendon longitudinally. The arm should be externally and internally rotated to view the greatest extent of the tendon possible and to assess for anterior impingement (▶Fig. 2.14, ▶Fig. 2.15).

Fig. 2.14 Longitudinal scan of the subscapularis tendon. The probe is placed in the anatomical transverse plane with its lateral edge over the bicipital groove which may be used as a landmark.

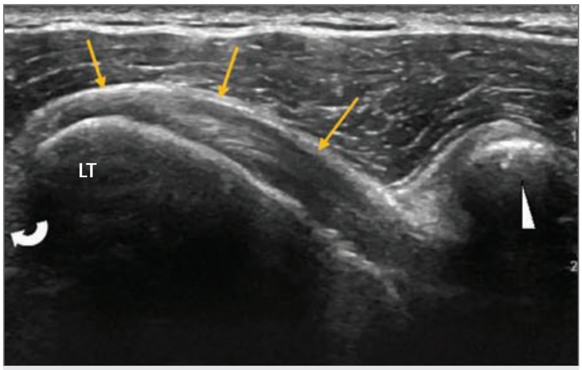

Fig. 2.15 Longitudinal image of the subscapularis tendon (*yellow arrows*). The tendon may be seen to extend from below the coracoid (*white arrowhead*) and to travel laterally to insert onto the lesser tuberosity (LT). The bicipital groove may be used as a landmark and can just be seen to the left of the image (*curved arrow*).

Transverse Scan

To view the subscapularis tendon transversely, the probe is turned through 90 degrees to be positioned in the sagittal plane. If the probe is angled in a slight posterolateral alignment, a better image may be obtained (▶Fig. 2.16, ▶Fig. 2.17).

Fig. 2.16 Transverse scan of the subscapularis tendon. The probe is placed in the anatomical sagittal plane over the tendon. A better image may be obtained if the probe is angled in a slight posterolateral alignment.

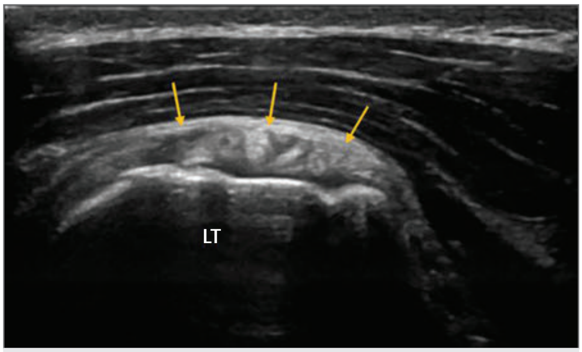

Fig. 2.17 Transverse image of the subscapularis tendon (*yellow arrows*). The tendon may be seen to lay over the lesser tuberosity (LT). Note the fascicular pattern of the tendon which is entirely normal.

2.1.3 Dynamic Examination for Subcoracoid Impingement

See ▶Fig. 2.18.

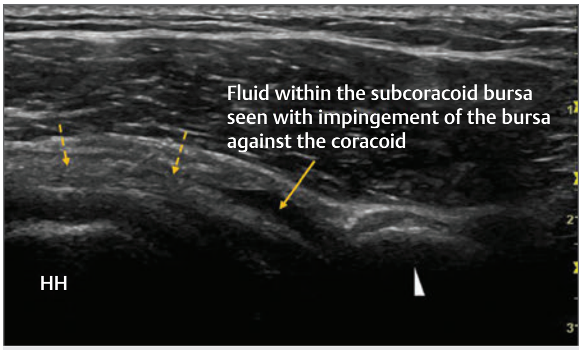

Fig. 2.18 Longitudinal image of the medial portion of the subscapularis tendon (*yellow dashed arrows*) at the level of the coracoid (*white arrowhead*). The subject has been asked to internally rotate the shoulder. A small amount of fluid is seen with in the subcoracoid bursa as it impinges against the lateral aspect of the coracoid (*yellow arrow*). HH, humeral head.

Subscapularis: Pathology

See ▶Fig. 2.19a–c.

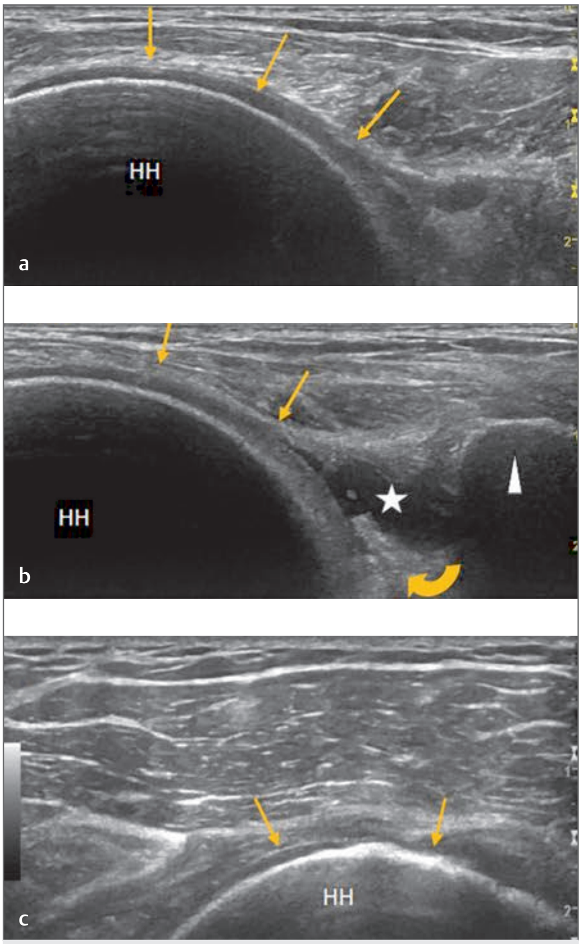

Fig. 2.19 (**a**) Longitudinal image of the tendon of subscapularis tendon fails to demonstrate a tendon over the anterior aspect of the humeral head (HH) in keeping with a complete rupture (*yellow arrows*). (**b**) In addition, there is retraction of the proximal component of the tendon (*curved arrow*) with some fluid noted deep to the coracoid (*white star*). (**c**) Transverse image of the subscapularis also failed to demonstrate a tendon over the humeral head (*yellow arrows*). White arrowhead, coracoid; yellow arrows, absence of subscapularis tendon over the humeral head.

2.1.4 Supraspinatus Tendon and Subacromial Bursa (Including Dynamic Imaging as Indicated)

Transverse Scan

The patient is asked to place his or her hand on the posterior aspect of the hip while keeping the elbow tucked in.

Find the long head of the biceps in transverse view and then move the probe posteriorly to view the supraspinatus tendon in transverse section. It is important to scan distally as far as the greater tuberosity and proximally following the tendon of supraspinatus until it disappears below the acromion (▶Fig. 2.20, ▶Fig. 2.21, ▶Fig. 2.22).

Fig. 2.20 Transverse scan of the supraspinatus tendon. The medial edge of the probe is placed over the long head of the biceps tendon within the rotator interval to ensure that the anterior free edge of the supraspinatus tendon and midsubstance are both imaged.

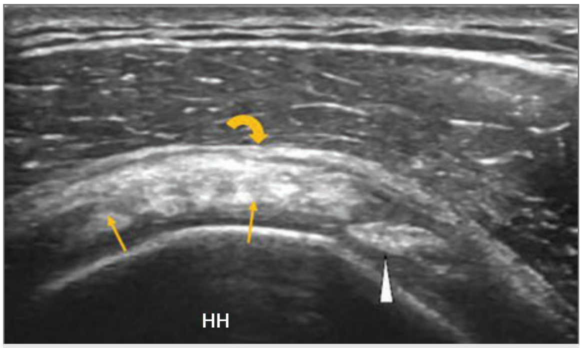

Fig. 2.21 Transverse image of the supraspinatus tendon. Note the long head of biceps tendon in the rotator interval (*white arrowhead*). The subacromial bursa (*curved arrow*) may be seen overlying the supraspinatus tendon (*yellow arrows*). In this image the bursa is not thickened.

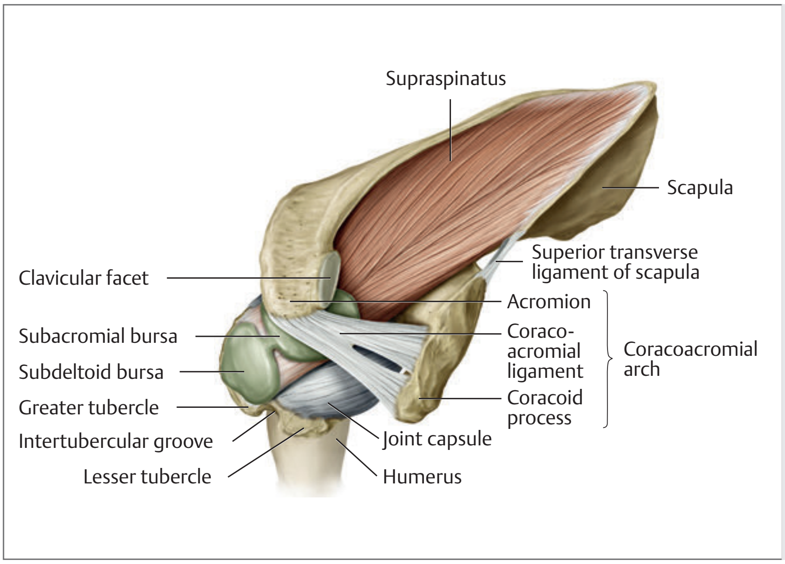

Fig. 2.22 Superior transverse view of the right glenohumeral joint. In the illustration, the clavicle has been removed to allow visualization of the subacromial/ subdeltoid bursa and the underlying muscle and tendon of supraspinatus. Note the extent to which the bursa extends beneath the coracoacromial arch formed by the acromium, coracoacromial ligament, and coracoid. When scanning the tendon of supraspinatus, the probe should move as far as the lateral edge of the coracoacromial arch to ensure maximum visualization of the tendon. Note the position of the superior transverse scapular ligament of the scapular notch. (Reproduced from Schuenke, Schulte, and Schumacher, Atlas of Anatomy, 2nd edition, ©2014, Thieme Publishers, New York. Illustration by Karl Wesker/Markus Voll.)

Longitudinal Scan

The probe is turned through 90 degrees to find the long head of biceps running longitudinally through the rotator interval. Moving the probe in a superolateral direction allows the full visualization of the supraspinatus tendon form its anterior free edge through its midsubstance to the tendon of infraspinatus posteriorly (▶Fig. 2.23, ▶Fig. 2.24).

Fig. 2.23 Longitudinal scan of the supraspinatus tendon. The long head of biceps tendon can be found in the bicipital groove in longitudinal section. The probe is then moved posteriorly to view the tendon of supraspinatus.

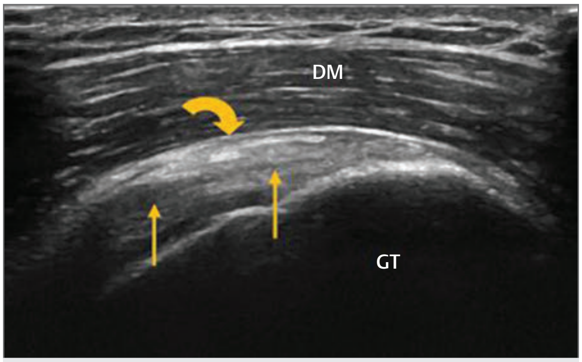

Fig. 2.24 Longitudinal image of the supraspinatus tendon (*yellow arrows*). The subacromial bursa may be seen overlying the tendon (*curved arrow*). In a nonpathological state, the subacromial bursa appears as two parallel echogenic lines separated by a low echo central region. DM, deltoid muscle; GT, greater tuberosity.

Supraspinatus: Pathology

See ▶Fig. 2.25a,b; ▶Fig. 2.26, ▶Fig. 2.27, ▶Fig. 2.28a,b; ▶Fig. 2.29, ▶Fig. 2.30a,b; ▶Fig. 2.31a–c.

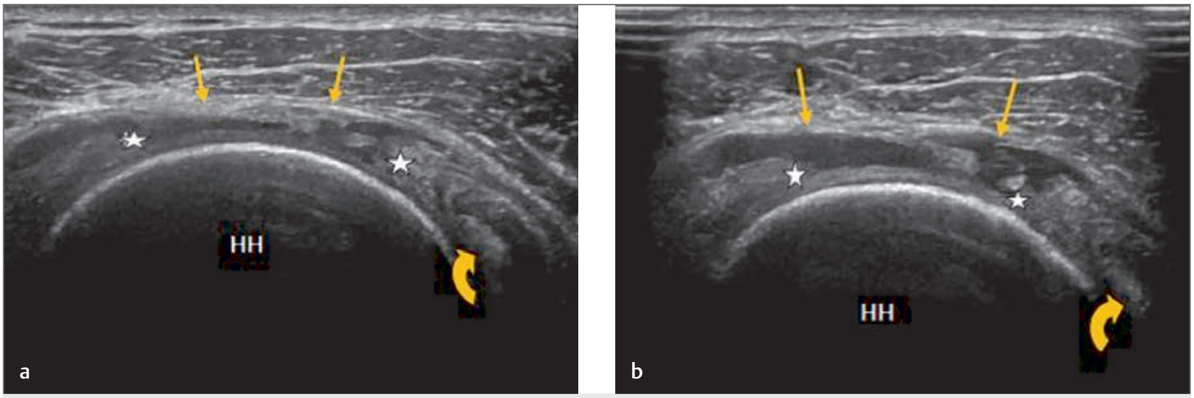

Fig. 2.25 (**a**) Transverse image of the supraspinatus tendon demonstrating loss of normal tendon structure over the humeral head in keeping with a full-thickness tear. The overlying subacromial bursa (*yellow arrows*) has collapsed down onto the humeral head. The size of the tear can be seen between the white stars measuring 2 cm. The long head of biceps can be seen toward the bottom right of the image (*curved arrow*). (**b**) Transverse image of the supraspinatus tendon. This image is the same as part (a) except pressure from the probe has been reduced (note loss of contact at the edges of the image). This decreased pressure has allowed fluid to fill the subacromial bursa (*yellow arrows*) through the full-thickness tear. HH, humeral head.

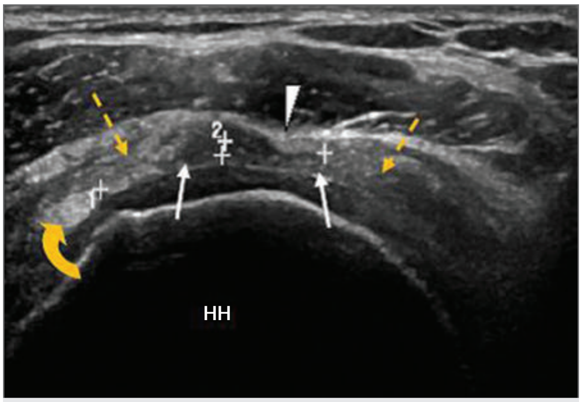

Fig. 2.26 Transverse image of the supraspinatus tendon (*yellow dashed arrows*). There is a low echo foci within the midsubstance of the tendon with associated bowing of the overlying subacromial bursa into this region (*white arrowhead*). In addition, an “articular cartilage sign” is seen (*white arrows*). Findings in keeping with a full-thickness tear. The tear measures approximately 7 mm in length (calipers 2) and is situated 9 mm posterior to the anterior edge of the tendon (calipers 1). Yellow curved arrow, long head biceps; HH, humeral head.

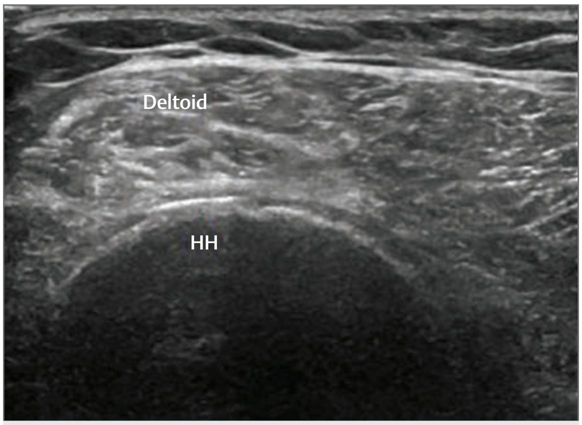

Fig. 2.27 Transverse image over the humeral head. The tendon of supraspinatus cannot be clearly seen. The overlying deltoid muscle is in direct contact with the humeral head. Findings in keeping with a complete rupture of the supraspinatus tendon with retraction of the tendon proximally. HH, humeral head.

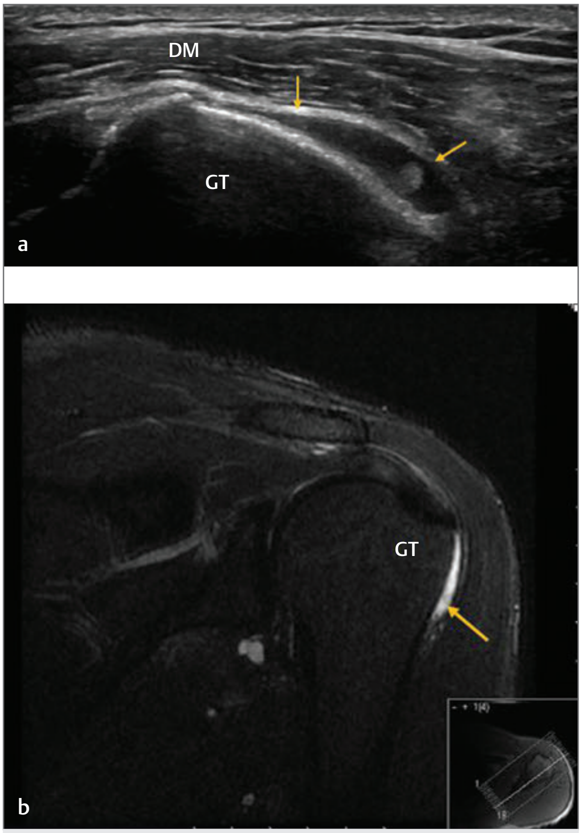

Fig. 2.28 (**a**) Longitudinal image of the greater tuberosity. The subacromial bursa is seen to be distended (*yellow arrows*) as it overlays the lateral aspect of the greater tuberosity (GT). (**b**) MRI (coronal STIR). The image is of the same shoulder as in part (a). The image demonstrates high signal in the subacromial bursa (*yellow arrow*). DM, deltoid muscle.

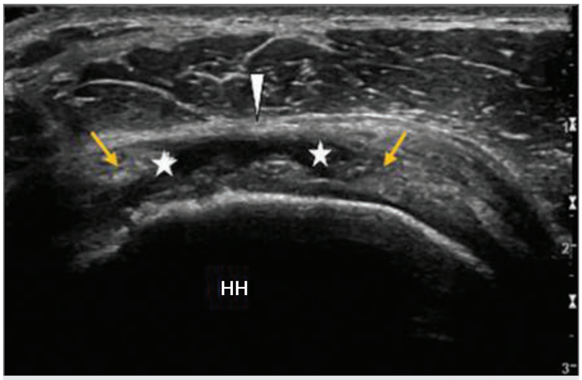

Fig. 2.29 Transverse image of the tendon of supraspinatus (*yellow arrows*). A low echo region is demonstrated within the midsubstance of the tendon toward its insertion onto the greater tuberosity measuring approximately 1.3 cm (*white stars*). Findings in keeping with a full-thickness tear. The overlying subacromial bursa appears to indent the torn tendon (*white arrowhead*). HH, humeral head.

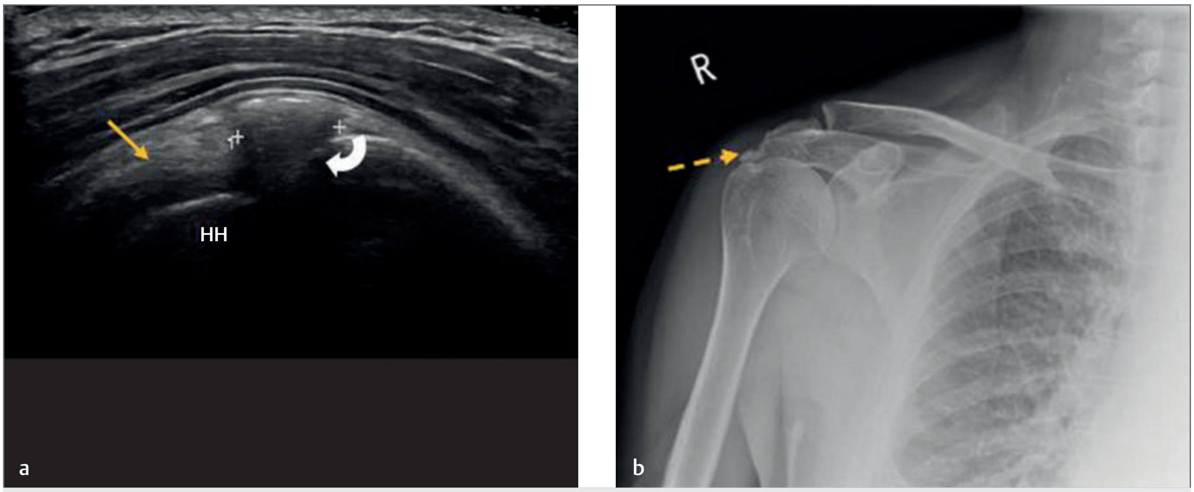

Fig. 2.30 (**a**) Longitudinal image of the tendon of supraspinatus (*yellow arrow*). A relatively large calcific region measuring approximately 0.8 mm can be seen within the distal part of the tendon toward its insertion on the greater tuberosity (*white crosses*). Note the posterior shadowing (*curved arrow*). (**b**) X-ray of the same shoulder as in part (a) demonstrates the calcific foci (*dashed yellow arrow*). HH, humeral head.

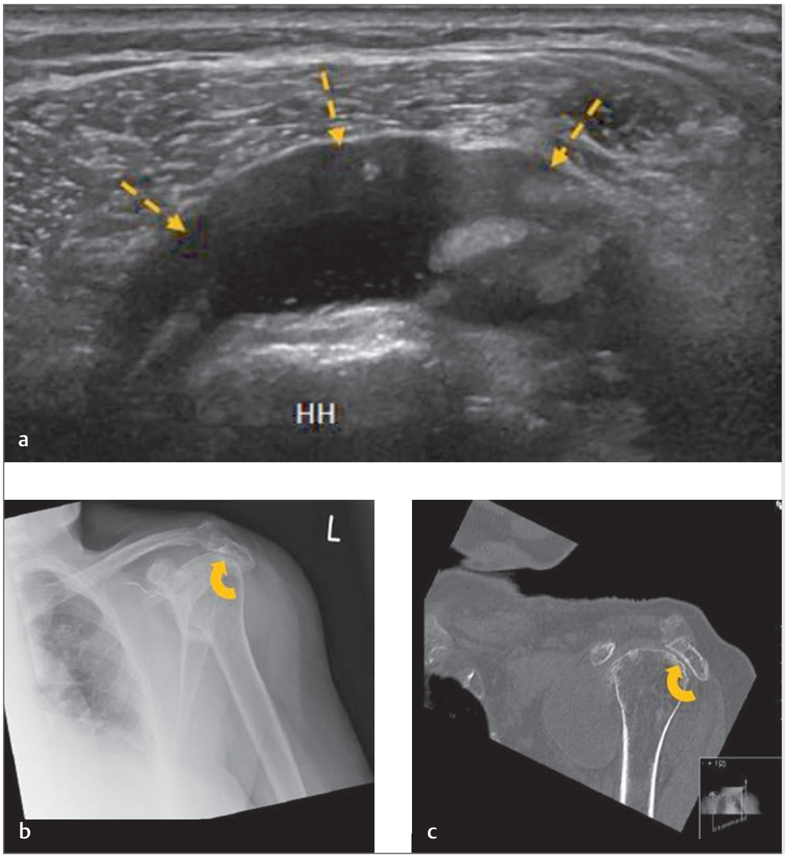

Fig. 2.31 (**a**) Transverse image of the tendon of supraspinatus. The tendon cannot be seen over the humeral head in keeping with a complete rupture. In addition, there was a large subacromial bursal effusion with associated bursal thickening (*dashed arrows*). (**b**) X-ray of the same shoulder demonstrates a marked reduction in the acromiohumeral space in keeping with a complete rupture of the supraspinatus tendon (*curved arrow*). (**c**) CT of the same shoulder demonstrating an advanced osteoarthrosis involving the glenohumeral joint with marked loss of joint space, large osteophyte formation, subchondral sclerosis and cyst formation, and a decreased acromiohumeral space (*curved arrow*). HH, humeral head.

2.1.5 Infraspinatus Tendon

Longitudinal Scan

The patient is asked to place the hand of the shoulder to be imaged on the opposite shoulder with the elbow resting on the chest. In this position the tendon of infraspinatus runs horizontally and is parallel to and immediately below the spine of the scapula. Scan from the musculotendinous junction posterior to the humeral head to the insertion of the tendon onto the greater tuberosity which is situated relatively laterally (▶Fig. 2.32, ▶Fig. 2.33a,b).

Fig. 2.32 Longitudinal scan of the tendon of supraspinatus tendon. Place the probe parallel to and immediately below the spine of the scapula. The tendon insertion itself is situated relatively laterally.

Infraspinatus: Pathology

See ▶Fig. 2.34, ▶Fig. 2.35.

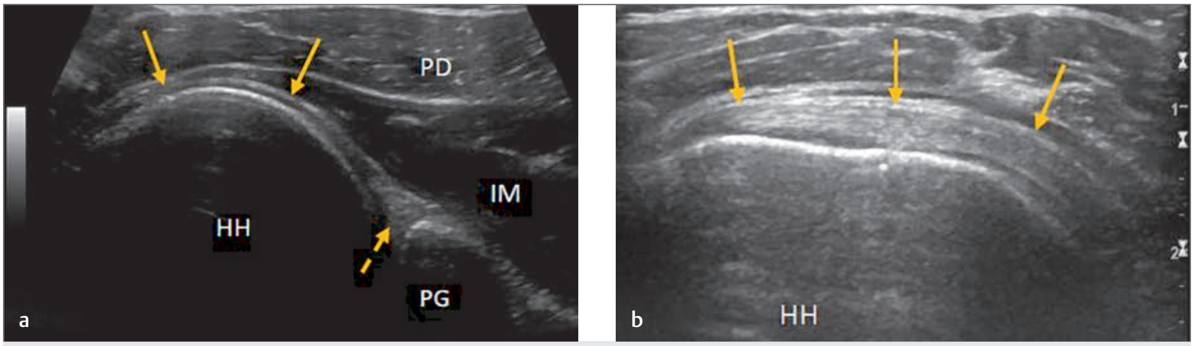

Fig. 2.33 (**a**) Longitudinal image of the posterior aspect of the shoulder joint. Both the tendon (*yellow arrows*) and muscle of infraspinatus (IM) can be seen deep to the posterior deltoid (PD) muscle. Note the posterior glenoid labrum demonstrated here as a hyperechoic triangle (*dashed yellow arrow*). (**b**) Longitudinal image of the tendon of infraspinatus (*yellow arrows*). The tendon can be seen to insert onto the posterior aspect of the greater tuberosity. HH, humeral head; IM, infraspinatus muscle; PD, posterior deltoid; PG, posterior glenoid.

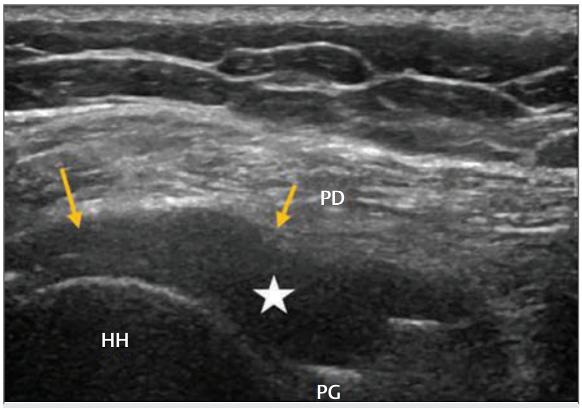

Fig. 2.34 Longitudinal image of the posterior aspect of the humeral head (HH) and glenohumeral joint. The tendon of infraspinatus cannot be seen in keeping with complete rupture and retraction of the tendon proximally (*yellow arrows*). In addition, there is a significant effusion extending out from the posterior aspect of the glenohumeral joint which is lifting the posterior deltoid muscle away from the humeral head (*white star*). PD, posterior deltoid; PG, posterior glenoid.

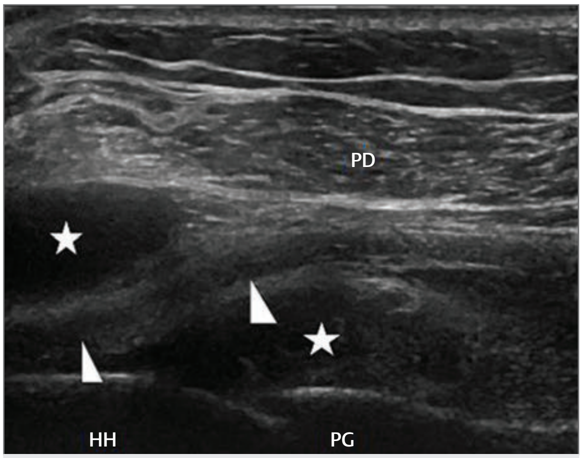

Fig. 2.35 Longitudinal image of the posterior aspect of the humeral head (HH) and glenohumeral joint. There is an effusion deep to the infraspinatus tendon which can be seen to extend to the superficial aspect of the tendon (*white star*). The tendon itself appears intact (*white arrowheads*). PD, posterior deltoid; PG, posterior glenoid.

2.1.6 Suprascapular Notch and Suprascapular Nerve

The patient sits with his or her arm by the side. The probe is placed in a coronal oblique plane over the supraspinous fossa. The suprascapular notch and nerve may be seen in longitudinal view immediately medial to the acromioclavicular joint deep to the upper trapezius and supraspinatus muscle (▶Fig. 2.36, ▶Fig. 2.37, ▶Fig. 2.38).

Fig. 2.36 Longitudinal scan over the suprascapular notch and nerve. The probe should be positioned in a coronal oblique plane so that it lies over the supraspinous fossa. The suprascapular notch may be seen deep to the upper trapezius and supraspinatus muscles.

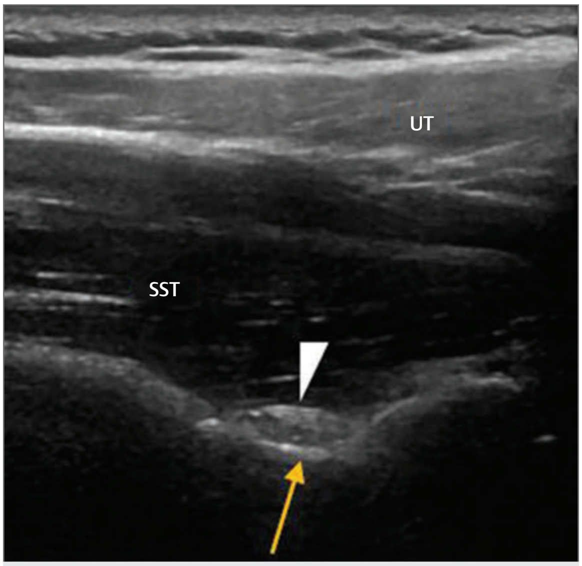

Fig. 2.37 Longitudinal image of the suprascapular nerve (*white arrowhead*) lying within the suprascapular notch (*yellow arrow*). Overlying the nerve can be seen the muscle bellies of supraspinatus tendon (SST) and upper trapezius (UT).

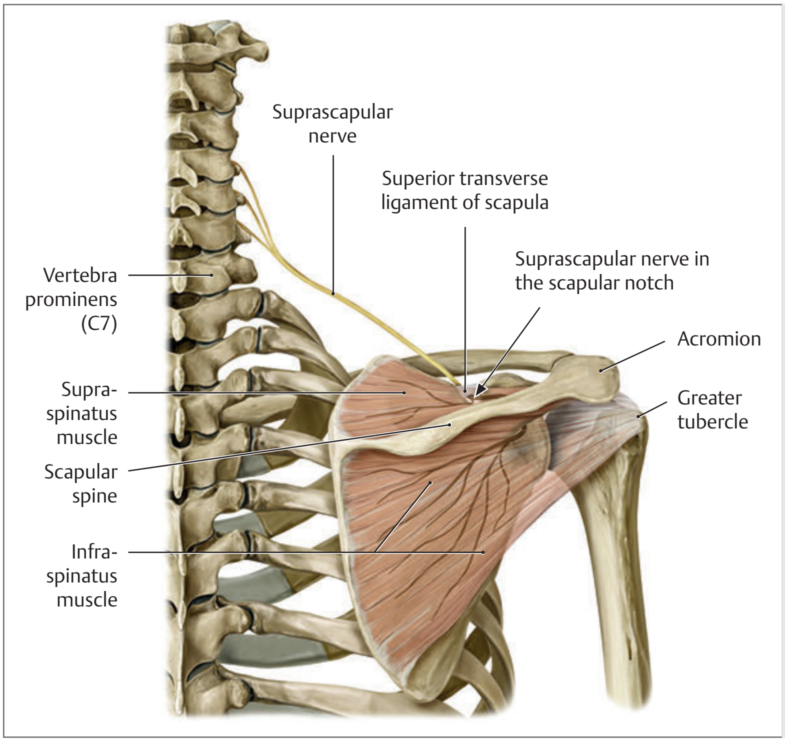

Fig. 2.38 Posterior coronal view of the right glenohumeral joint and suprascapular notch. Note the superior transverse ligament and underlying suprascapular notch containing the suprascapular nerve. The suprascapular artery travels superiorly to the superior transverse ligament. The superior transverse ligament may be ossified. Injection here can provide symptomatic relief in painful shoulders related to degenerative change and large rotator cuff tears when conservative treatment has failed and surgery is not an option. (Reproduced from Schuenke, Schulte, and Schumacher, Atlas of Anatomy, 2nd edition, ©2014, Thieme Publishers, New York. Illustration by Karl Wesker/Markus Voll.)

2.1.7 The Acromioclavicular Joint

The patient is positioned with the arm by the side. The acromioclavicular joint is viewed longitudinally with the probe placed in a coronal oblique plane (▶Fig. 2.39, ▶Fig. 2.40, ▶Fig. 2.41).

Fig. 2.39 Longitudinal scan of the acromioclavicular joint. The probe is placed in a coronal oblique plane over the joint.

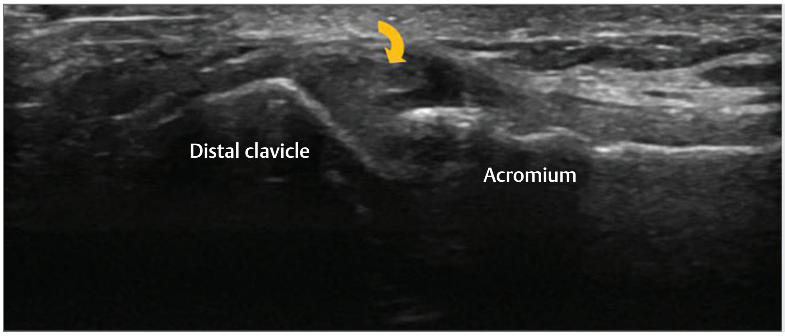

Fig. 2.40 Longitudinal image of the acromioclavicular joint. The acromium is seen to the right of the image and appears inferior to the distal clavicle positioned to the left of the image. The joint capsule is indicated by the *curved arrow*. Curved arrow, acromioclavicular joint capsule.

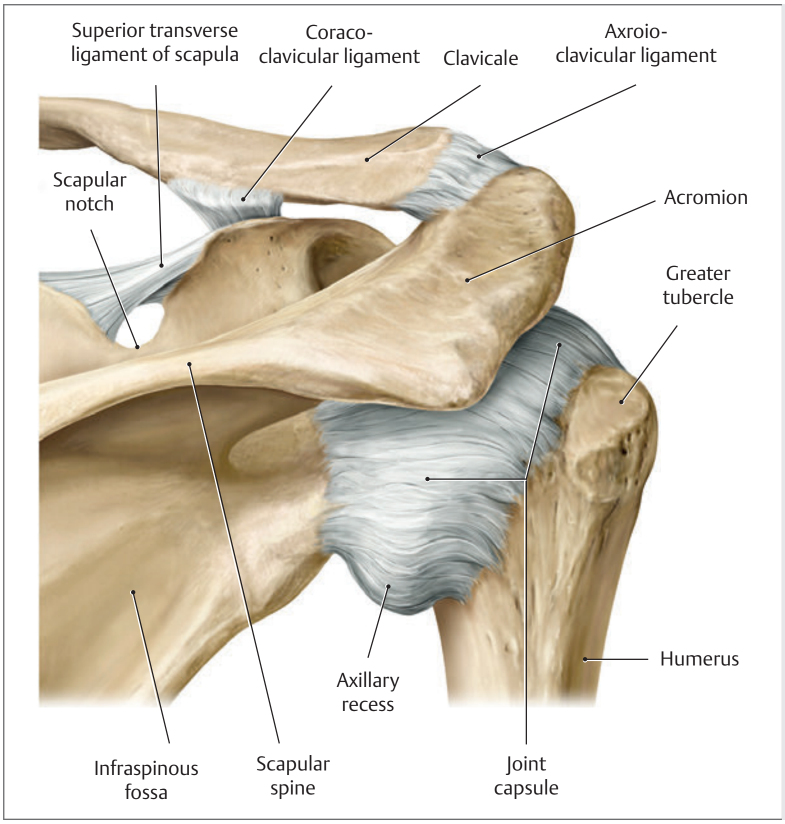

Fig. 2.41 Posterior coronal view of the right glenohumeral and acromioclavicular joints. The illustration also demonstrates the scapular notch through which the suprascapular nerve passes deep to the superior transverse ligament. The suprascapular artery travels superiorly to the ligament. (Reproduced from Schuenke, Schulte, and Schumacher, Atlas of Anatomy, 2nd edition, ©2014, Thieme Publishers, New York. Illustration by Karl Wesker/Markus Voll.)

Acromioclavicular Joint: Pathology

See ▶ Fig. 2.42, ▶ Fig. 2.43, ▶ Fig. 2.44, ▶ Fig. 2.45.

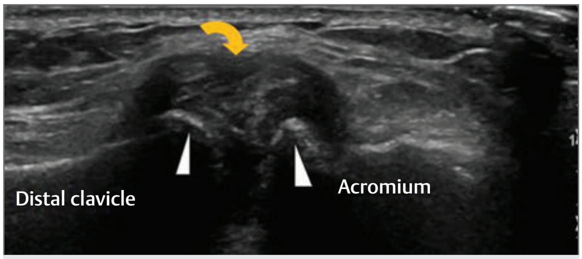

Fig. 2.42 Longitudinal image of the acromioclavicular joint demonstrating marked degenerative change with osteophytic lipping (*white arrowheads*). In addition, there is marked joint hypertrophy (*curved arrow*).

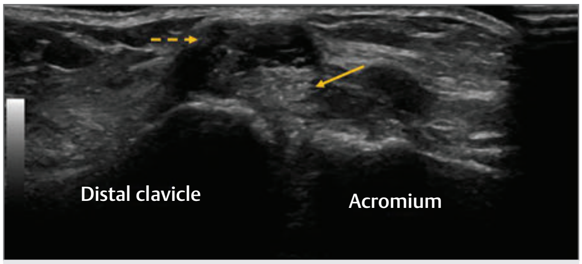

Fig. 2.43 Ultrasound image of the acromioclavicular joint demonstrating degenerative change with extrusion of the fibrocartilage (*yellow arrow*). In addition, there appears to be distension of the capsule with fluid and an associated cyst (*dashed arrow*) extending from the joint over the acromion measuring approximately 3 cm in longitudinal axis.

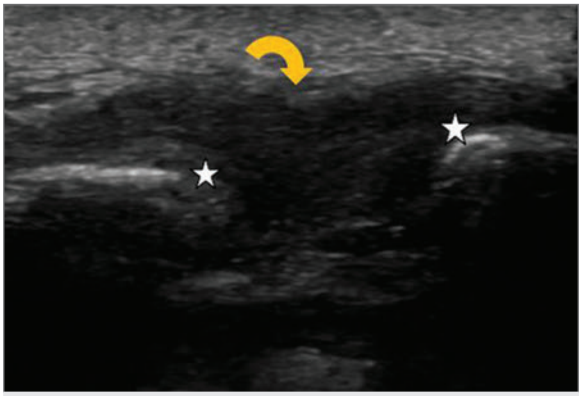

Fig. 2.44 Ultrasound image of the acromioclavicular joint demonstrating increased widening of the joint (*white stars*) in keeping with previous surgical excision of the distal clavicle. In addition, hypertrophy of the capsule is seen (*curved arrow*).

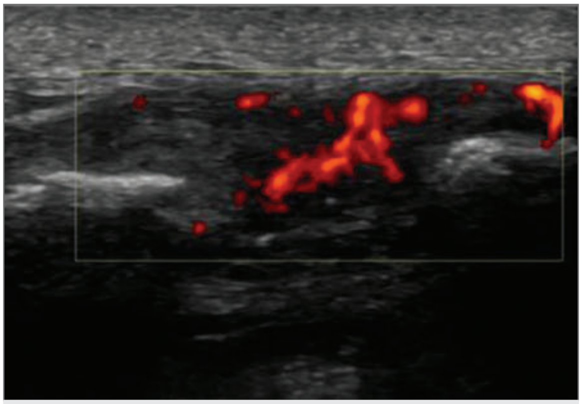

Fig. 2.45 Ultrasound image of the acromioclavicular joint outlined in ▶ Fig. 2.44. Power Doppler demonstrates that in addition to joint hypertrophy there is a marked synovial vascularity in keeping with synovitis.

2.1.8 Sternoclavicular Joint

The patient is positioned in supine lying with the arms resting on the abdomen. The probe is placed longitudinally over the sternoclavicular joint (▶Fig. 2.46, ▶Fig. 2.47, ▶Fig. 2.48).

Fig. 2.46 Ultrasound scan of the sternoclavicular joint. The probe is placed longitudinally over the sternoclavicular joint. In this figure, the probe is being used to guide a needle into the joint.

Sternoclavicular Joint: Pathology

See ▶Fig. 2.49a,b.

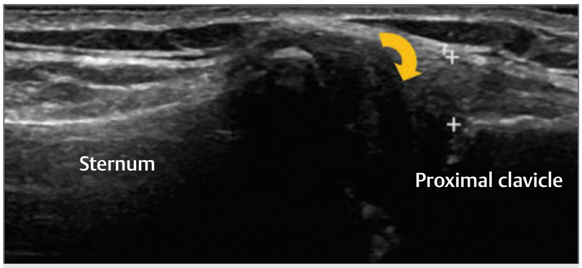

Fig. 2.47 Longitudinal image of the sternoclavicular joint. The sternum is to the left of the image and the proximal end of the clavicle to the right. The joint is indicated by the curved arrow. The sternum is normally seen as slightly superior to the proximal clavicle (*white crosses*).

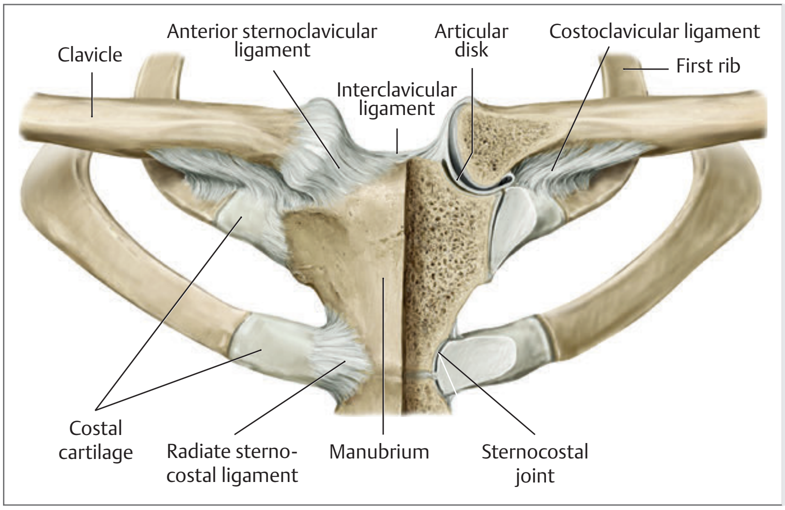

Fig. 2.48 Anterior coronal view of the manubrium and sternoclavicular joints. The sternoclavicular joint is structurally classed as a synovial double-plane joint and functionally classed as a diarthrotic joint. Note the normal offset alignment of the sternoclavicular joints with the proximal clavicle in a relatively more superior position than the manubrium. This is seen in the coronal plane; however, when scanning the joint longitudinally over its anterior border, the proximal clavicle will appear more superior in relation to the sternum. (Reproduced from Schuenke, Schulte, and Schumacher, Atlas of Anatomy, 2nd edition, ©2014, Thieme Publishers, New York. Illustration by Karl Wesker/Markus Voll.)

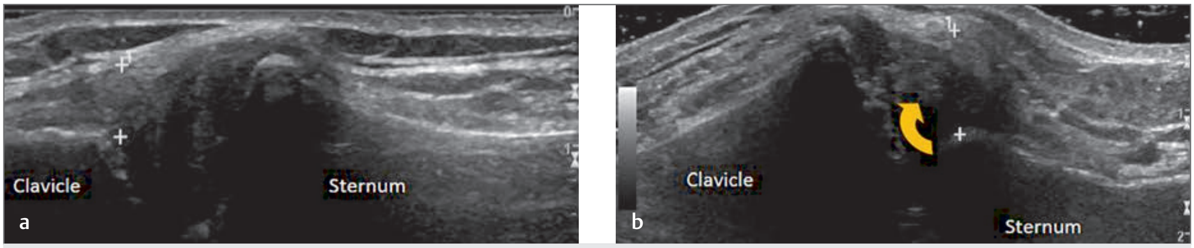

Fig. 2.49 (**a**) Longitudinal image of an asymptomatic sternoclavicular joint. There is no evidence of subluxation or hypertrophy of the capsule. A normal relationship is seen between the sternum and proximal clavicle (*white crosses*). (**b**) Longitudinal image of the symptomatic sternoclavicular joint in the same patient as above. The image demonstrates an anterior and superior subluxation of the medial end of the clavicle in relation to the sternum (*white crosses*). Some associated thickening of the capsule is also noted (*curved arrow*).

3 The Shoulder: Guided Injection Techniques

Abstract

This chapter outlines commonly used injection techniques around the shoulder. The aim is to detail the position and alignment of the probe and needle to allow accurate placement into the target tissue. In addition a brief clinical presentation is given for each condition as well as some of the anatomical considerations which should be noted. The drugs, dosages and volumes given are those used in the author's clinic.

Keywords: long head of biceps, subscapularis, subcoracoid, supraspinatus, infraspinatus, transverse ligament, coracoacromial ligament, subacromial bursa, glenohumeral joint, acromioclavicular joint, sternoclavicular joint, suprascapular notch

3.1 Glenohumeral Joint Injection—Acute or Chronic Capsulitis: "The Frozen Shoulder"

3.1.1 Cause

- Most commonly idiopathic.
- May be due to an underlying osteoarthritis or rheumatoid arthritis.
- Secondary to trauma or postsurgery.

3.1.2 Presentation

- Pain felt in the shoulder region with referral into the upper arm.
- Occasionally, pain may radiate as far as the hand.
- The shoulder presents in a classic capsular pattern of restriction with a painful loss of the following:
  - Most lateral rotation with a hard end feel.
  - Less abduction.
  - Least medial rotation.

3.1.3 Equipment

See ▶Table 3.1.

Table 3.1 Equipment needed for glenohumeral joint injection—acute or chronic capsulitis ("the frozen shoulder")

Syringe	Needle	Corticosteroid	Local anesthetic	Transducer
10 mL	21 gauge–2 inch or spinal	40-mg Depo-Medrone	10-mL 1% lidocaine (±20–40-mL saline)	Large linear footprint

3.1.4 Anatomical Considerations

The safest and easiest technique is to use a posterior approach. The clinician need not worry about any major blood vessels or nerves if this technique is used and the posterior curve of the humeral head gives a clear angle to direct the needle.

3.1.5 Procedure

- The patient sits facing the ultrasound machine with the arm to be injected resting across their stomach.
- Identify the spine of the scapula and place the transducer immediately below this in a parallel line.
- The needle is inserted at approximately 45 degrees to the transducer from a posterolateral to anteromedial direction.
- Using the posterior curve of the humeral head as a guide, direct the needle deep to the infraspinatus muscle and posterior labrum.
- The injection is given as a bolus and should flow freely.

3.1.6 The Injection

See ▶Fig. 3.1 and▶Fig. 3.2.

Fig. 3.1 Glenohumeral joint injection. The glenohumeral joint is best injected from a posterolateral approach. The probe is placed over the posterior aspect of the glenohumeral joint immediately below the spine of the scapula. The needle is inserted at approximately 45 degrees to the probe from a posterolateral to anteromedial direction. Using the posterior curve of the humeral head as a guide, direct the needle deep to the infraspinatus muscle and posterior labrum.

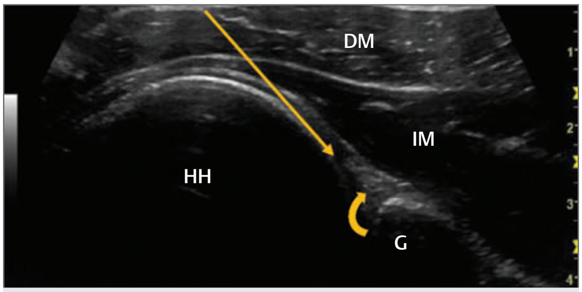

Fig. 3.2 Ultrasound image of the posterior aspect of the humeral head (HH) and glenoid (G). The infraspinatus muscle (IM) may be seen deep to the posterior deltoid muscle (DM). The posterior labrum (*curved arrow*) may be seen as an echogenic triangle extending from the glenoid. The needle should be directed so that it lies against the posterior aspect of the humeral head deep to the labrum and posterior capsule (*yellow arrow*).

3.1.7 Notes

In the acute stages the injection may be given up to three times at monthly intervals to facilitate a programme of stretching which should be prescribed without delay. If a more chronic shoulder presents with restriction of movement being more of a problem than pain a much higher volume may be given to cause a stretching (hydrodilatation) of the capsule. This may be of particular benefit in the diabetic frozen shoulder.

If a hydrodilatation effect is required, then the technique described above is utilized, but in addition to injection of corticosteroid and local anaesthetic up to 40 mL of normal saline is also injected. If this technique is adopted, it is useful to use a low-pressure tubing with one clinician directing the needle under guidance and a second clinician controlling the syringe. To facilitate the best possible outcome, a course of vigorous stretching must be immediately implemented.

3.2 Subacromial/Subdeltoid Bursal Injection

3.2.1 Cause

- Overuse/excessive use.
- Trauma.
- Idiopathic.

3.2.2 Presentation

- Pain felt in the region of the shoulder with referral into the upper arm to elbow. Occasionally, pain may radiate as far as the hand or into the scapular region.
- Pain may be felt in all directions if acute, but no capsular restriction should be noted.
- A painful arc may be present midrange flexion and abduction with positive Neer's sign and Hawkins–Kennedy test.

3.2.3 Equipment

See ▶Table 3.2.

Table 3.2 Equipment needed for subacromial/subdeltoid bursal injection

Syringe	Needle	Corticosteroid	Local anesthetic	Transducer
Acute 10 mL	21 gauge–2 inch	20-mg Depo-Medrone	Up to 5-mL 1% lidocaine	Large linear footprint
Chronic 10 mL	21 gauge–2 inch	20-mg Depo-Medrone	Up to 10-mL 1% lidocaine (±20-mL saline)	Large linear footprint

3.2.4 Anatomical Considerations

The subacromial bursa extends from below the acromion to lie over the anterolateral aspect of the humeral head. It may be variable in size and loculated particularly if the problem is chronic.

3.2.5 Procedure

- The patient sits facing the ultrasound machine with the arm in extension and their hand resting on their ipsilateral hip.
- The transducer is placed transversely over the underlying subacromial bursa and supraspinatus tendon immediately below the anterior edge of the acromion.
- The needle is inserted at approximately 45 degrees to the transducer from a posterolateral to anteromedial direction.
- The injection is given as a bolus and should flow freely with distension of the bursa noted.

3.2.6 The Injection

See ▶Fig. 3.3 and ▶Fig. 3.4.

3.2.7 Notes

Ultrasound allows dynamic imaging of the shoulder which is particularly useful in cases of subacromial pathology enabling real-time evaluation of impingement syndromes.

Some distension of the bursa may be noted with imaging and often these cases respond well to the lower total volume. However, in most cases of subacromial impingement, there is no evidence on imaging of a distended subacromial bursa. Rather the bursa will often appear thickened; in these cases, the higher volume is often more effective.

If an underlying rotator cuff tear is visualized, the decision to inject the bursa should be considered as part of a surgical

Fig. 3.3 Subacromial/subdeltoid bursal injection. The transducer is placed transversely over the underlying subacromial bursa and supraspinatus tendon immediately below the anterior edge of the acromion. The needle is inserted at approximately 45 degrees to the transducer from a posterolateral to anteromedial direction.

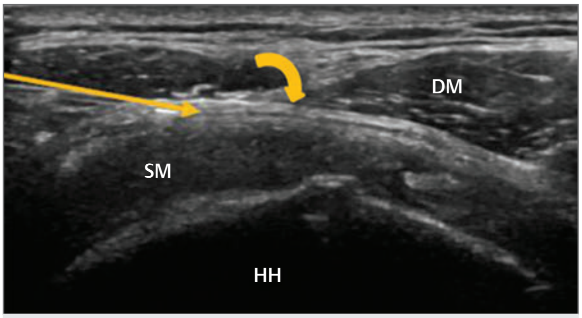

Fig. 3.4 Ultrasound image of the anterolateral aspect of the shoulder. This is essentially a transverse image of the supraspinatus muscle (SM) which may be seen to cover the humeral head (HH). Overlying the supraspinatus muscle and deep to the deltoid muscle (DM) the subacromial bursa (*curved arrow*) may be seen as an echogenic line. The injection is given as a bolus and should flow freely with distension of the bursa noted. Straight arrow indicates the direction of the needle.

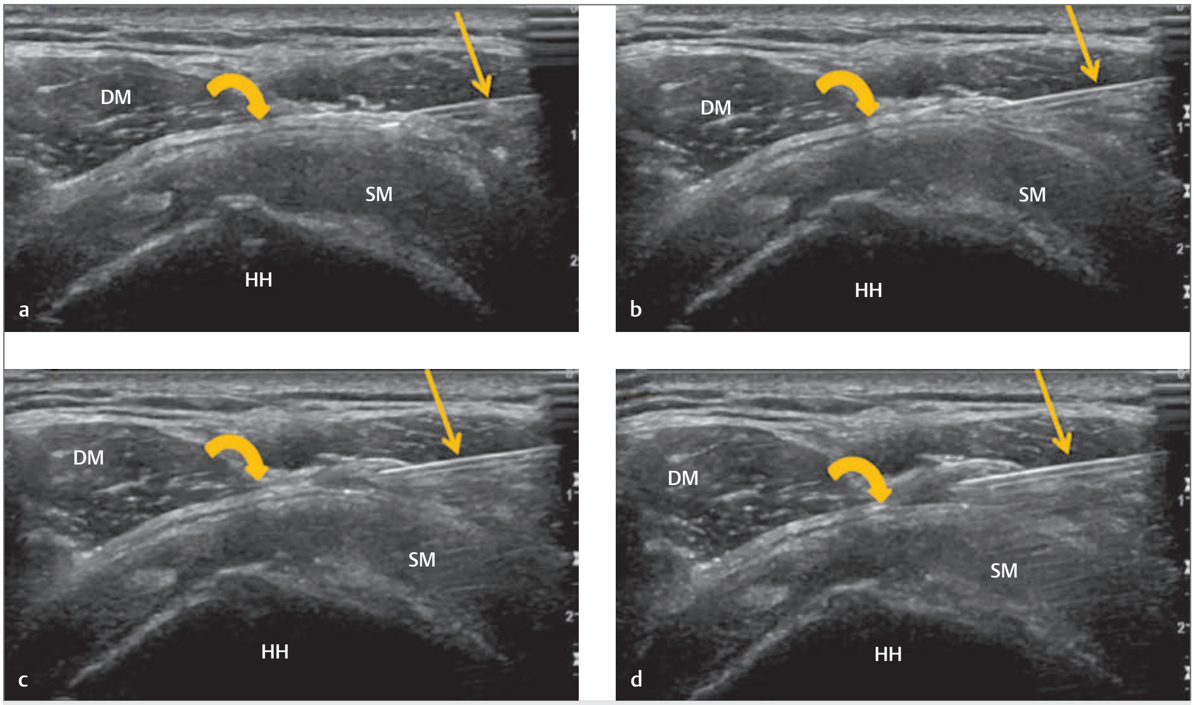

Fig. 3.5 (a–d) Ultrasound image of the anterolateral aspect of the shoulder. This transverse image demonstrates the supraspinatus muscle (SM) overlying the humeral head (HH) and deep to the deltoid muscle (DM). The subacromial bursa (*curved arrow*) may be seen as an echogenic line. A needle may be seen entering the bursa from the right side of the image (*straight arrow*). In these sequential images the bursa may be seen to distend with fluid as the injection is delivered.

review in regard to possible repair. This technique can provide significant and lasting relief in patients with calcification of the underlying supraspinatus tendon and should be considered first prior to more invasive techniques.

▶Fig. 3.5 demonstrates injection of the subacromial bursa. The needle can be seen approaching from the right side of the screen. The images are sequential and demonstrate how the bursa can be distended with injected fluid (▶Fig. 3.5a–d).

3.3 Acromioclavicular Joint Injection

3.3.1 Cause

- Overuse/excessive use—may present as an osteolysis.
- Trauma.
- Osteoarthritis.

3.3.2 Presentation

- Pain felt in the region of the acromioclavicular joint with little referral of symptoms.
- Pain is usually felt at extremes of movement particularly end range horizontal adduction and also combined end range extension and medial rotation.
- A high arc of pain may be present.

3.3.3 Equipment

See ▶Table 3.3.

3.3.4 Anatomical Considerations

The acromioclavicular joint line runs in the sagittal plane with the distal end of the clavicle being higher in relation to the acromium. The joint line runs at an oblique angle form posterolateral to anteromedial and contains a meniscal fibrocartilage.

Table 3.3 Equipment needed for acromioclavicular joint injection

Syringe	Needle	Corticosteroid	Local anesthetic	Transducer
2 mL	25 gauge–1 inch	20-mg Depo-Medrone	Up to 1-mL 1% lidocaine	Small hockey stick

3.3.5 Procedure

- The patient sits facing the ultrasound machine with the arm resting on the lap.
- The transducer is placed in the coronal plane over the joint.
- The needle is inserted at approximately 45 degrees to the transducer from a lateral direction toward the distal end of the clavicle into the joint.
- The injection is given as a bolus and should flow freely. If resistance is met, this may indicate that the needle tip is within the fibrocartilage meniscus and should be directed more vertically.

3.3.6 The Injection

See ▶Fig. 3.6 and ▶Fig. 3.7.

3.3.7 Notes

The acromioclavicular joint is a common site for osteoarthritis particularly in patients who have placed excessive load through the joint such as weight lifters. In these cases, it is worth trying a couple of injections which will often provide long-term relief of symptoms. Should injection not be successful, surgical opinion should be considered.

In addition to osteoarthritis of the acromioclavicular joint, excessive and prolonged loading may lead to an osteolysis which is well demonstrated on ultrasound imaging. This responds well to injection if the appropriate activity modification is also considered.

Fig. 3.6 Acromioclavicular injection. The probe is placed in the coronal plane over the joint. The needle is inserted at approximately 45 degrees to the transducer from a lateral direction toward the distal end of the clavicle into the joint. The injection is given as a bolus and should flow freely.

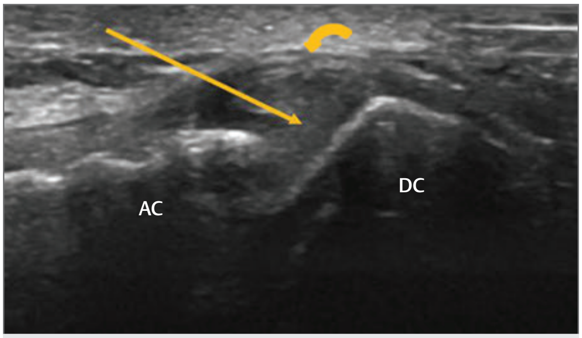

Fig. 3.7 Ultrasound image of the acromioclavicular joint. The distal end of the clavicle (DC) may be seen to sit in a more superior position relative to the acromion (AC). This facilitates injection from the lateral aspect of the joint toward the lateral face of the clavicle (*straight arrow*). The curved arrow indicates the joint capsule.

3.4 Sternoclavicular Joint Injection

3.4.1 Cause

- Overuse.
- Trauma.
- Inflammatory.

3.4.2 Presentation

- Pain is located over the sternoclavicular joint with little referral of symptoms.
- Pain toward end range, all shoulder movements in particular, horizontal adduction.
- The joint can often appear quite prominent due to subluxation.

3.4.3 Equipment

See ▶Table 3.4.

Table 3.4 Equipment needed for sternoclavicular joint injection

Syringe	Needle	Corticosteroid	Local anesthetic	Transducer
2 mL	25 gauge–1 inch	20-mg Depo-Medrone	Up to 1-mL 1% lidocaine	Small hockey stick

3.4.4 Anatomical Considerations

The sternoclavicular joint line runs at an oblique angle from superior and medial to inferior and lateral. The joint contains a small meniscal fibrocartilage. The proximal end of the clavicle sits higher than the sternum which aids injection if given from a medial to lateral direction.

3.4.5 Procedure

- The patient lies in supine with the arm resting across the abdomen.
- The transducer is placed in the transverse plane over the joint so that it sits along the line of the clavicle.
- The needle is inserted at approximately 45 degrees to the transducer from a medial direction laterally toward the proximal end of the clavicle into the joint.
- The injection is given as a bolus and should flow freely. If resistance is met, this may indicate that the needle tip is within the fibrocartilage meniscus and should be directed more vertically.

3.4.6 The Injection

See ▶Fig. 3.8 and ▶Fig. 3.9.

3.4.7 Notes

The sternoclavicular joint may present as an acute strain following a fall or more of a chronic problem related to degenerative change and inflammation. The injection is similar for both presentations although the outcome is generally better for more acute cases.

Fig. 3.8 Sternoclavicular injection. The transducer is placed in the transverse plane over the joint so that it sits along the line of the clavicle. The needle is inserted at approximately 45 degrees to the transducer from a medial direction laterally toward the proximal end of the clavicle into the joint.

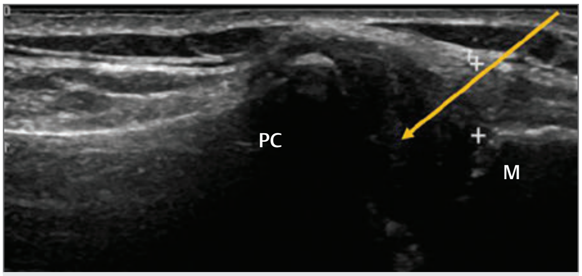

Fig. 3.9 Ultrasound image of the sternoclavicular joint. The proximal end of the clavicle (PC) sits more anteriorly relative to the manubrium (M) (indicated by *white crosses*). The needle should be directed to the proximal face of the clavicle (*straight arrow*).

3

3.5 Biceps Tendon Sheath Injection

3.5.1 Cause

- Overuse/excessive use.
- Inflammatory.

3.5.2 Presentation

- Pain is located over the long head of biceps at the anterior aspect of the shoulder. Often little referral of pain is described.
- Pain is often felt with impingement of the long head of biceps against the acromion with forward flexion and against the coracoid with horizontal adduction.
- Pain may also be elicited with resisted flexion of the elbow and supination of the forearm.

3.5.3 Equipment

See ▶Table 3.5.

3.5.4 Anatomical Considerations

Injection of the bicipital sheath is best considered using a short-axis approach. This allows excellent needle visualization. If approached from a lateral aspect, the clinician need to be troubled about anatomical structures.

Table 3.5 Equipment needed for biceps tendon sheath injection

Syringe	Needle	Corticosteroid	Local anesthetic	Transducer
10 mL	23 gauge–1 inch	20-mg Depo-Medrone	Up to 5-mL 1% lidocaine	Small hockey stick

3.5.5 Procedure

- The patient is seated with his or her arm resting on the lap.
- The transducer is placed in the transverse plane over the bicipital groove.
- The needle is inserted at approximately 45 degrees to the transducer from a lateral direction medially so that the tip pierces the transverse ligament and sits against the tendon. It may be useful to externally rotate the arm through a few degrees moving the lateral border of the groove in a posterior direction which facilitates a more direct approach for the needle.
- The injection is given as a bolus and should flow freely. If resistance is met, this may indicate that the needle tip is within the tendon and should be moved slightly.
- It is useful to move the probe through 90 degrees to visualize the bicipital sheath longitudinally as the injection is given to ensure free flow of fluid proximally and distally.

3.5.6 The Injection

See ▶Fig. 3.10 and ▶Fig. 3.11.

3.5.7 Notes

Pathology of the long head of biceps may present as a tenosynovitis or as a tendinopathy or as a combination of both conditions. The latter presentation is particularly likely in more chronic cases in the middle-aged patient.

If the presentation is one of a tenosynovitis, then fluid and synovitis may be seen around the tendon although the tendon itself appears intact. Such cases will often respond well to injection so long as the clinician is mindful of any precipitating activities which need to be addressed.

Fig. 3.10 Bicep tendon sheath injection. The probe is placed in the transverse plane over the bicipital groove. The needle is inserted at approximately 45 degrees to the probe from a lateral direction medially so that the tip pierces the transverse ligament and sits against the tendon. It may be useful to externally rotate the arm through a few degrees moving the lateral border of the groove in a posterior direction which facilitates a more direct approach for the needle.

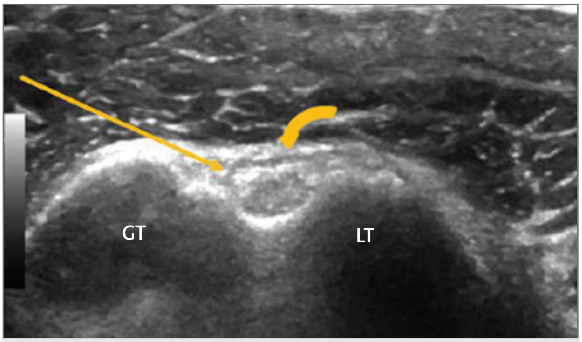

Fig. 3.11 Ultrasound image of the biceps tendon—transverse view. The bicep tendon (B) is seen as an echogenic oval structure lying deep to the transverse ligament (*curved arrow*). The needle is introduced into the sheath of the tendon from the lateral side (*straight arrow*). GT, greater tuberosity; LT, lesser tuberosity.

In regard to the presentation of tendinopathy, the tendon itself appears thickened and irregular with loss of a normal fibrillar pattern. Care must be adopted if injection is administered in such cases as the tendon is potentially already in a weakened state which injection may exacerbate. In addition, if an appropriate programme of rehabilitation is not considered in such a patient, an injection is unlikely to result in lasting benefit.

3.6 Suprascapular Nerve Block

3.6.1 Cause

- Intractable shoulder pain.

3.6.2 Presentation

A suprascapular nerve block may be considered in the patient who presents with pain in the shoulder not managed by oral medication or physiotherapy. The nerve block should be considered as a last resort typically in the patient with significant degenerative change or substantial rotator cuff rupture who is not suitable for or does not desire surgery.

3.6.3 Equipment

See ▶Table 3.6.

3.6.4 Anatomical Considerations

The suprascapular nerve arises from the upper trunk of the brachial plexus formed by the union of the fifth and sixth cervical nerves. It innervates the supraspinatus and infraspinatus muscles. Running laterally beneath the trapezius muscle, it enters the supraspinous fossa through the suprascapular notch below the superior transverse scapular ligament. It is to this point that the nerve block is directed. The nerve then enters the supraspinous fossa and gives off two branches: one to the supraspinatus muscle and another articular branch to the shoulder joint. In the infraspinous fossa, it again gives off two branches: one to the infraspinous muscle and the other to the shoulder joint. It should be noted that the suprascapular artery lies immediately above the transverse ligament and is not easily visualized when scanning. As with all injections aspiration should be attempted prior to injection to ensure that the needle point is not within the artery.

Table 3.6 Equipment needed for suprascapular nerve block

Syringe	Needle	Corticosteroid	Local anesthetic	Transducer
10 mL	21 gauge–2 inch	20-mg Depo-Medrone	Up to 5-mL 1% lidocaine	Linear transducer

3.6.5 Procedure

- The patient is seated with the arm resting on the lap.
- The transducer is placed in the coronal oblique plane over the supraspinous fossa.
- The needle is inserted at approximately 45 degrees immediately medial to the medial border of the acromion.
- The needle is positioned so that its tip lies just above the nerve in the suprascapular notch.
- The injection is given as a bolus and should flow freely.

3.6.6 The Injection

See ▶Fig. 3.12 and ▶Fig. 3.13.

Fig. 3.12 Suprascapular nerve block. The transducer is placed in the coronal oblique plane over the supraspinous fossa. The needle is inserted at approximately 45 degrees immediately medial to the medial border of the acromion. The needle is positioned so that its tip lies just above the nerve in the suprascapular notch.

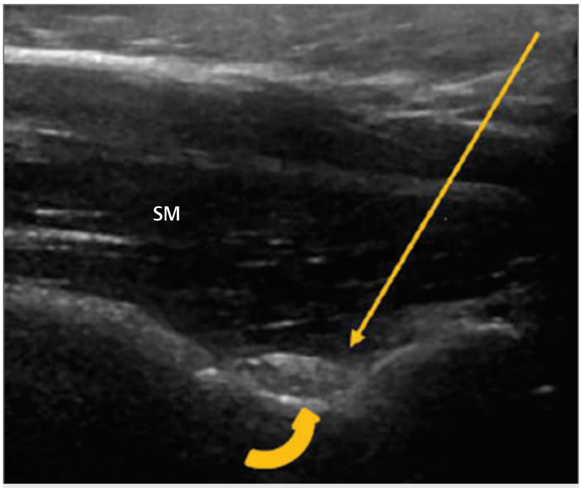

Fig. 3.13 Ultrasound image of the supraspinous fossa and supraspinatus muscle (SM). The suprascapular notch may be seen deep to the supraspinatus muscle. The suprascapular nerve appears as an echogenic oval structure within the suprascapular notch (*curved arrow*). The needle is directed toward the suprascapular nerve as indicated by the straight arrow. Straight arrow, direction of the needle.

3.6.7 Notes

A suprascapular nerve block is a safe and often efficacious treatment for the management of intractable shoulder pain in both osteoarthritis of the shoulder and/or severe rotator cuff pathology in patients who either are not suitable for or do not desire surgery. It may be repeated at regular intervals as required.

4 The Elbow: Diagnostic Imaging

Abstract
Ultrasound examination of the elbow allows a low-cost, non-invasive, and dynamic evaluation of the periarticular tendons and nerves as well as several joint ligaments. The commonest indication for elbow ultrasound is for pain around either the lateral or medial aspect of the joint ("tennis" and "golfers" elbow). However, ultrasound may also aid clinicians in the assessment of a wide variety of other disorders, including trauma (partial and complete tendon ruptures, ligament tears, and fractures), overuse problems (lateral and medial epicondylosis, triceps tendon enthesopathy), inflammatory diseases (osteoarthritis, rheumatoid arthritis, and bursitis), and neuropathies (ulnar or radial nerve entrapment neuropathies and nerve instability). Ultrasound is also capable of detecting very small joint effusions not identified clinically, synovial hypertrophy, and associated marginal joint erosions.

A high-frequency (7-15 MHz) linear probe with a relatively large footprint should be used for diagnostic imaging to allow sufficient anatomical resolution. The examination should include dynamic assessment where appropriate

Keywords: elbow joint, radiohumeral joint, ulnohumeral joint, distal biceps tendon, radial tuberosity, bicipitoradial bursa, extensor tendons, lateral epicondyle, flexor tendons, medial epicondyle, coronoid fossa, olecranon, olecranon fossa, triceps tendon

4.1 Diagnostic Imaging of the Elbow: Introduction

The elbow may be considered as consisting of four quadrants, anterior, medial, lateral, and posterior. Ultrasound would normally be focused on only one or two of these quadrants depending on the clinical diagnosis.

Imaging includes the following:

- Anterior
  - Brachialis muscle.
  - Brachial artery and vein.
  - Median nerve.
  - Anterior radiocapitellar joint.
  - Radial fossa.
  - Anterior humeroulnar joint.
  - Coronoid fossa.
  - Distal biceps tendon.
- Lateral
  - Lateral epicondyle and common extensor tendon.
  - Radial collateral ligament including dynamic varus stress as indicated.
  - Radiocapitellar joint.
- Medial
  - Medial epicondyle and common flexor tendon.
  - Ulnar collateral ligament including dynamic valgus stress as indicated.
  - Humeroulnar joint.
  - Ulnar nerve including dynamic scan for subluxation as indicated.
- Posterior
  - Triceps tendon.
  - Olecranon process and olecranon bursa.
  - Olecranon fossa and posterior joint.

4.1.1 Anterior

Transverse Scan

The patient is seated opposite the clinician with the arm resting on a table. The elbow should be placed in extension and full supination. A few degrees of flexion may be of use if an effusion is suspected as full extension will tend to force any fluid from the anterior aspect of the elbow resulting in a false-negative result. The probe is placed in the anatomical transverse plane over the anterior aspect of the elbow (▶Fig. 4.1, ▶Fig. 4.2, ▶Fig. 4.3).

Longitudinal Scan

As the elbow consists of two distinct articulations, two separate longitudinal views are required: one of the lateral radiocapitellar joint the other of the medial humeroulnar joint.

Fig. 4.1 Transverse scan of the anterior aspect of the elbow. The probe is placed in the anatomical transverse plane. The probe should be moved from a position a few centimeters above the joint distally until the shaft of the radius and ulna can be seen to ensure that the entire joint is evaluated.

4

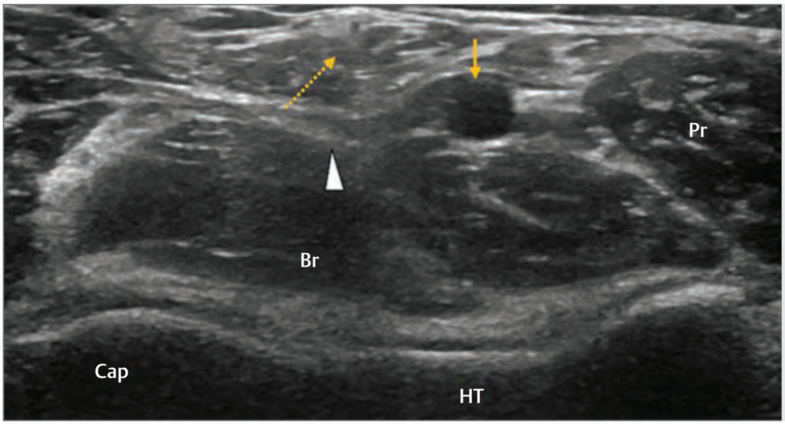

Fig. 4.2 Transverse image of the anterior aspect of the elbow joint. In this image the probe is placed over the distal aspect of the humerus to view the humeral trochlea and capitellum. Cap, capitellum; HT, humeral trochlea; Br, brachialis; Pr, pronator teres; white arrowhead, median nerve; yellow arrow, brachial artery; dashed yellow arrow, distal biceps tendon.

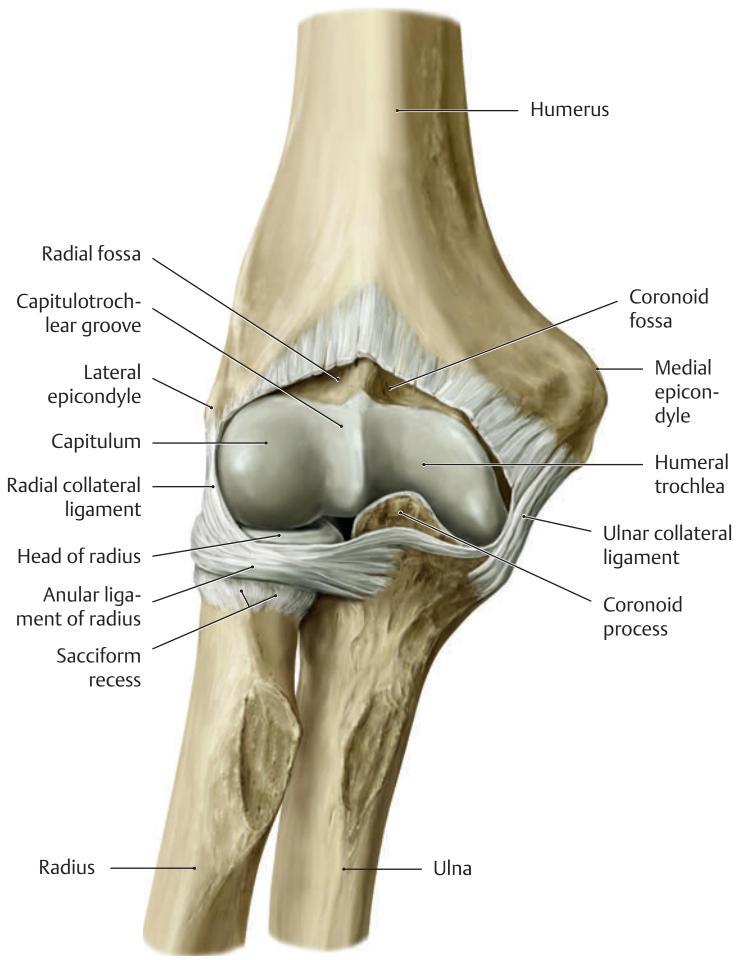

Fig. 4.3 Anterior coronal view of the right elbow joint. The capsule has been resected to demonstrate the bony architecture of the distal humerus and proximal radius and ulna. Imaging should include transverse views of the distal humerus and medial and lateral longitudinal views of the humeroulnar and radiocapitellar joints, respectively. (Reproduced from Schuenke, Schulte, and Schumacher, Atlas of Anatomy, 2nd edition, ©2014, Thieme Publishers, New York. Illustration by Karl Wesker/Markus Voll.)

Radiocapitellar Joint

The elbow should be in extension and full supination. The probe is placed in the sagittal plane over the lateral half of the anterior aspect of the antecubital fossa.

Humeroulnar Joint

The elbow is maintained in extension and full supination. The probe remains in the sagittal plane and is moved medially over the medial half of the anterior aspect of the antecubital fossa (▶ Fig. 4.4, ▶ Fig. 4.5, ▶ Fig. 4.6, ▶ Fig. 4.7, ▶ Fig. 4.8).

Fig. 4.4 Longitudinal scan of the lateral elbow joint encompassing the radiocapitellar joint. The probe is placed in the sagittal plane.

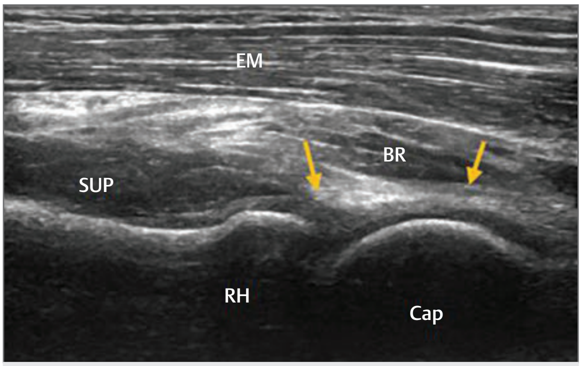

Fig. 4.5 Longitudinal image of the radiocapitellar joint demonstrating the radial head, capitellum, and overlying muscles. BR, brachialis; Cap, capitellum; EM, extensor muscles; RH, radial head; SUP, supinator; yellow arrows, anterior joint capsule.

Fig. 4.6 Longitudinal scan of the medial elbow encompassing the humeroulnar joint. The probe is positioned in the sagittal plane.

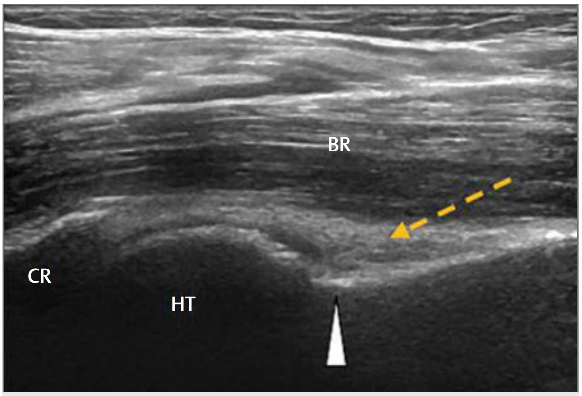

Fig. 4.7 Longitudinal image of the humeroulnar joint demonstrating the coronoid (CR), humeral trochlear (HT), and coronoid fossa. BR, brachialis; white arrowhead, coronoid fossa; yellow dashed arrow, anterior fat pad.

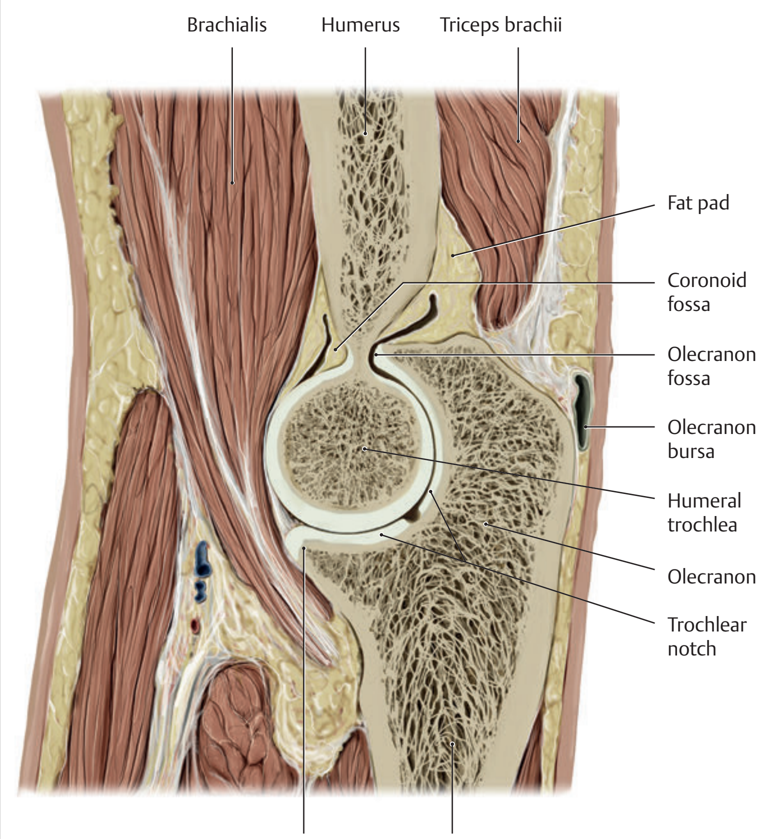

Fig. 4.8 Medial sagittal section of the elbow taken through the humeroulnar joint. Note the relative positions of the coronoid and olecranon fossae and fat pads. The superficial olecranon bursa overlying the triceps insertion cannot normally be seen on ultrasound if nonpathological. (Reproduced from Schuenke, Schulte, and Schumacher, Atlas of Anatomy, 2nd edition, ©2014, Thieme Publishers, New York. Illustration by Karl Wesker/Markus Voll.)

4.1.2 Distal Biceps Tendon

Longitudinal Scan

The distal biceps tendon is best examined longitudinally. Transverse imaging is of little practical value due to anisotropy.

The forearm should be placed in full extension and supination to bring the radial tuberosity into an anterior position. The probe is aligned in an oblique orientation and aimed laterally a few degrees toward the radius. In addition, the probe may be "toed-in" distally to allow better visualization of the biceps tendon. Even so the tendon is difficult to image particularly in patients with muscular forearms or who have pathology involving the tendon and are reluctant to allow optimal positioning due to pain inhibition (▶Fig. 4.9, ▶Fig. 4.10, ▶Fig. 4.11).

Fig. 4.9 Longitudinal scan of the distal biceps tendon. The probe is aligned obliquely a few degrees and angled laterally. A "toe-in" position can allow for better visualization of the tendon.

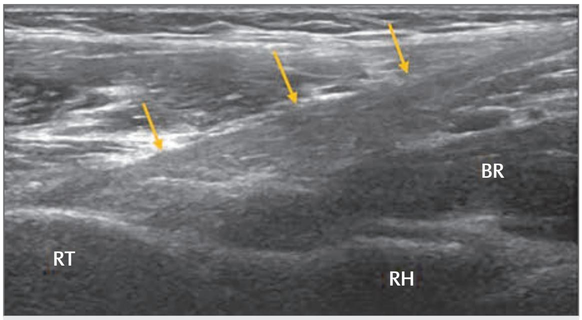

Fig. 4.10 Longitudinal image of the distal biceps tendon (*yellow arrows*). The tendon may be seen to run from proximal and superficial to distal and deep to insert onto the radial tuberosity (RT). BR, brachialis; RH, radial head.

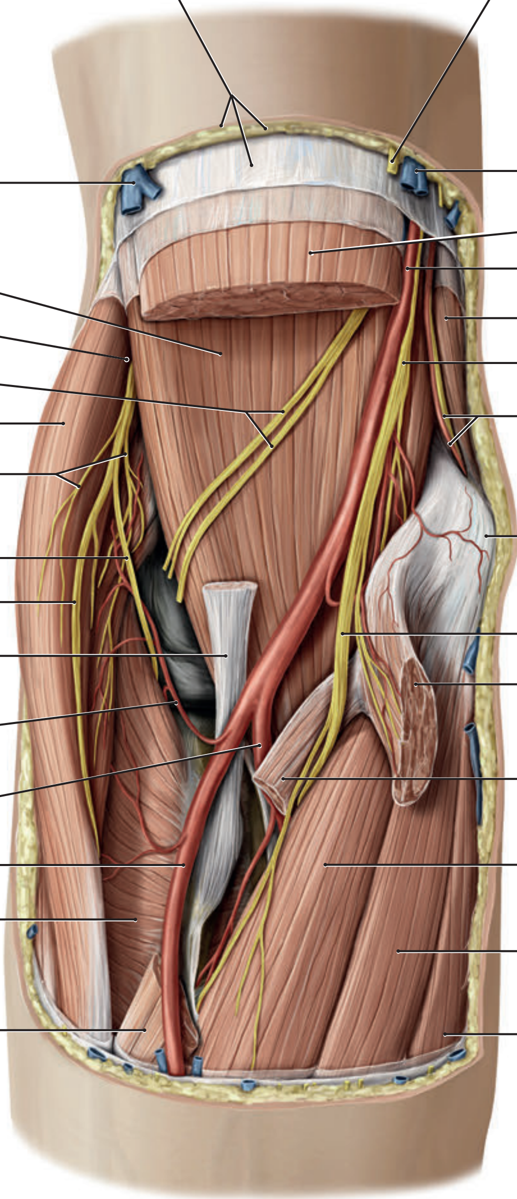

Fig. 4.11 Anterior coronal view of the right cubital fossa demonstrating the relationship and relative positions of the muscles, nerves, and distal biceps tendon. The boundaries of the fossa are formed superiorly by an imaginary horizontal line connecting the medial and lateral epicondyles of the humerus; medially by the lateral border of pronator teres muscle originating from the medial epicondyle of the humerus; laterally by the medial border of brachioradialis muscle originating from the lateral supracondylar ridge of the humerus; its apex is formed by the meeting point of the lateral and medial boundaries. The floor of the fossa is formed by the brachialis and supinator muscles. The cubital fossa contains four main vertical structures. From lateral to medial these are the radial nerve located between the brachioradialis and brachialis muscles; the biceps brachii tendon; the brachial artery (which may be seen to bifurcate near the apex of the fossa into the radial artery (superficial) and ulnar artery (deeper); and the median nerve. (Reproduced from Schuenke, Schulte, and Schumacher, Atlas of Anatomy, 2nd edition, ©2014, Thieme Publishers, New York. Illustration by Karl Wesker/Markus Voll.)

Distal Biceps Tendon: Pathology

See ▶ Fig. 4.12 and ▶ Fig. 4.13a,b.

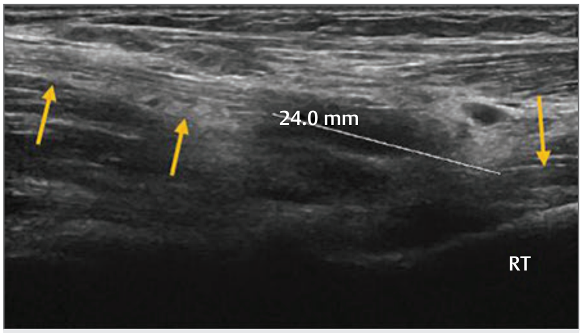

Fig. 4.12 Longitudinal image of the distal biceps tendon (*yellow arrows*). The proximal tendon to the left of the image appears of normal fibrillar pattern. Distally toward the right and bottom of the image some tendon fibers can be seen. However, there is a 24-mm gap within the tendon indicating a complete rupture. RT, radial tuberosity.

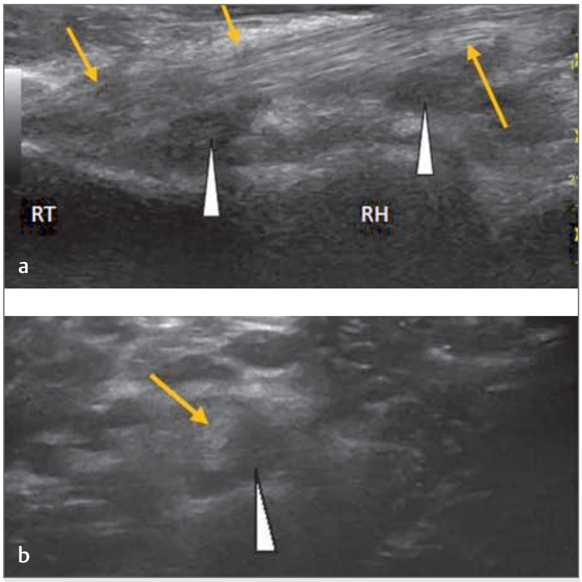

Fig. 4.13 (**a**) Longitudinal image of the distal biceps tendon. The tendon appears intact; however, there is evidence of a low echo collection deep to the tendon (*white arrowheads*). (**b**) Transverse image of the same tendon (*yellow arrow*) with evidence of a low echo swelling around the tendon (*white arrowhead*). The patient was a 32-year-old climber with insidious-onset elbow pain felt deep in the joint and aggravated with end range pronation. Findings are indicative of an effused bicipitoradial bursa in keeping with a diagnosis of a "climber's elbow." RH, radial head; RT, radial tuberosity; yellow arrow, distal biceps tendon; white arrowhead, fluid and thickening around the distal biceps tendon.

4.1.3 Lateral

Longitudinal Scan

The patient is seated facing the clinician with the arm resting on a table. The elbow is bent to 90-degree flexion and the forearm supinated. The probe is placed so that it rests with its proximal edge over the lateral epicondyle in the coronal plane. In the absence of pathology, the radial collateral ligament is difficult to distinguish from the overlying common extensor tendon (▶ Fig. 4.14, ▶ Fig. 4.15, ▶ Fig. 4.16, ▶ Fig. 4.17).

Fig. 4.14 Longitudinal scan of the lateral aspect of the elbow. The proximal edge of the probe is placed over the lateral epicondyle in the coronal plane.

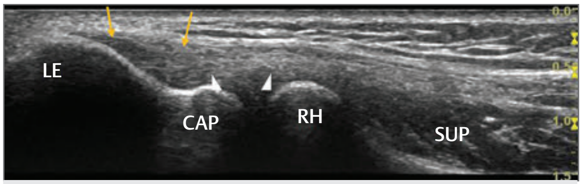

Fig. 4.15 Longitudinal image of the lateral aspect of the elbow demonstrating a normal appearance of the common extensor tendon (*yellow arrows*) and underlying radiocapitellar joint. Under normal conditions the radial collateral ligament (*white arrowheads*) is difficult to visualize separately from the overlying common extensor tendon. CAP, capitellum; LE, lateral epicondyle; RH, radial head; SUP, supinator.

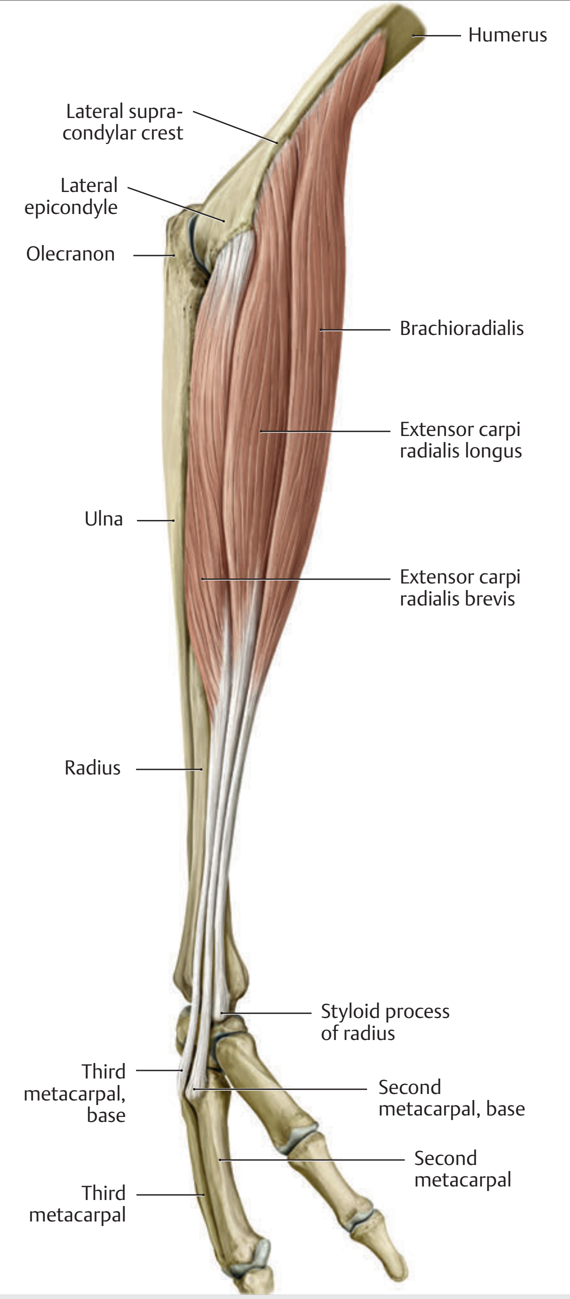

Fig. 4.16 Lateral sagittal view of the right elbow demonstrating the relationship and relative positions of the muscles attaching onto the lateral supracondylar ridge of the humerus and lateral epicondyle. The chief function of the brachioradialis is flexion of the forearm at the elbow. However, it is also capable of both pronation and supination depending on the position of the forearm. It takes origin from the upper portion of the lateral supracondylar ridge of the humerus above the extensor carpi radialis longus muscle. The common extensor tendon consisting of the anconeus, supinator, extensor carpi radialis brevis, extensor digitorum, extensor digiti minimi, and extensor carpi ulnaris takes origin from the lateral epicondyle. (Reproduced from Schuenke, Schulte, and Schumacher, Atlas of Anatomy, 2nd edition, ©2014, Thieme Publishers, New York. Illustration by Karl Wesker/Markus Voll.)

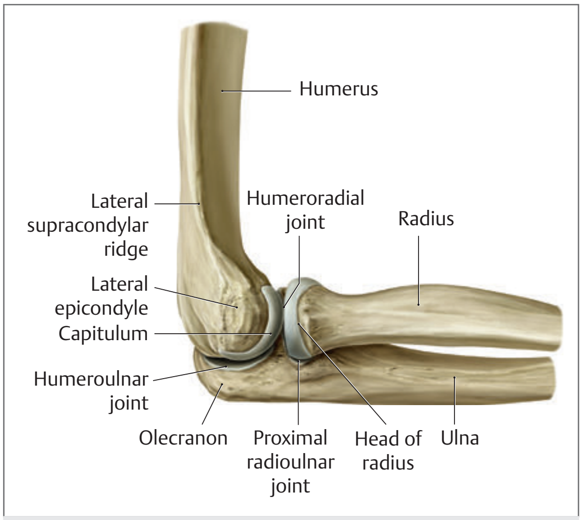

Fig. 4.17 Lateral sagittal view of the right elbow. The lateral epicondyle of the humerus is a small, tuberculated eminence, curved a little anteriorly. It gives attachment to the radial collateral ligament of the elbow joint and to a common tendon consisting of the anconeus, supinator, extensor carpi radialis brevis, extensor digitorum, extensor digiti minimi, and extensor carpi ulnaris. (Reproduced from Schuenke, Schulte, and Schumacher, Atlas of Anatomy, 2nd edition, ©2014, Thieme Publishers, New York. Illustration by Karl Wesker/Markus Voll.)

Lateral Elbow: Pathology

See ▶Fig. 4.18a–c and ▶Fig. 4.19.

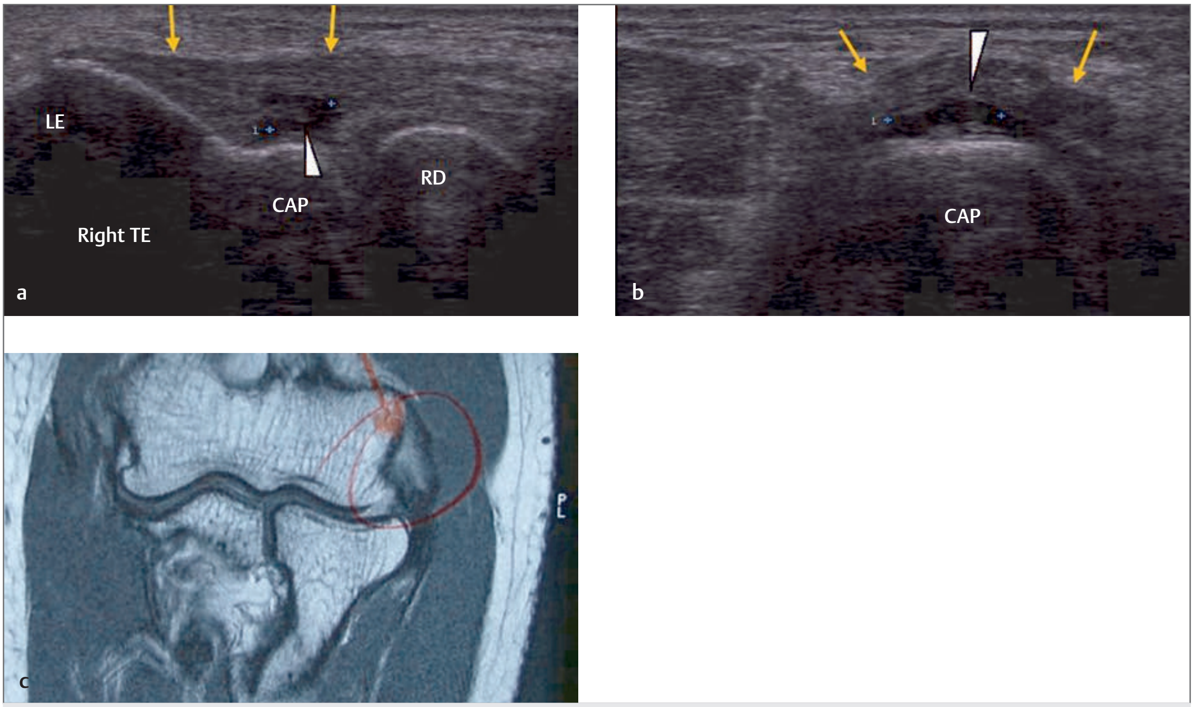

Fig. 4.18 (a) Longitudinal image of the lateral elbow demonstrating a hypoechoic region (*white arrowhead*) within the deep aspect of the common extensor tendon in keeping with a tear. The tear can be seen to for a "backward-C" shape between the two caliper markers. (b) Transverse image of the same patient as in part (a). The hypoechoic region (*white arrowhead*) deep within the tendon can be seen to extend almost the entire width of the tendon. (c) Magnetic resonance imaging (MRI) (T1 coronal) of the same elbow as outlined in parts (a) and (b). Although the MRI demonstrates increased signal within the common extensor tendon the US images are able to give more information in regard to an actual tear and its size. CAP, capitellum; LE, lateral epicondyle; RD, radial head; white arrowhead, tear; yellow arrows, common extensor tendon.

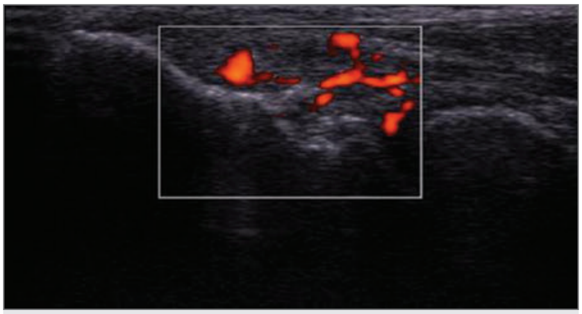

Fig. 4.19 Longitudinal image of the lateral aspect of the elbow demonstrating increased neovascularity throughout the common extensor tendon in keeping with a marked tendinopathy.

4.1.4 Medial

Longitudinal Scan

The patient is seated facing the clinician with the arm resting on a table. The elbow is bent to 90-degree flexion and the forearm supinated. The arm is externally rotated. The probe is placed so that it rests with its proximal edge over the medial epicondyle in the coronal plane (▶Fig. 4.20, ▶Fig. 4.21, ▶Fig. 4.22, ▶Fig. 4.23).

Fig. 4.20 Longitudinal scan of the medial aspect of the elbow joint. The proximal edge of the probe is placed over the medial epicondyle in the coronal plane with the probe resting over the common flexor tendon and humeroulnar joint.

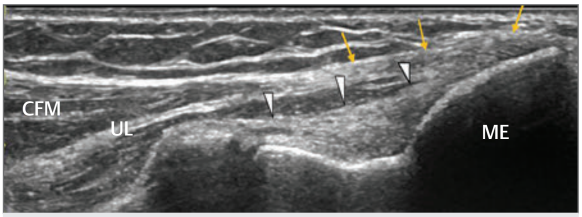

Fig. 4.21 Longitudinal image of the medial aspect of the elbow joint. The common flexor tendon (*yellow arrows*) can be seen overlying the ulnar collateral ligament (*white arrowheads*). CFM, common flexor muscle; ME, medial epicondyle; UL, ulnar.

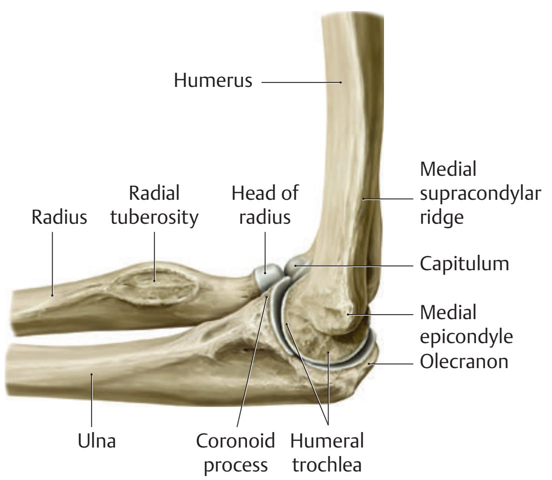

Fig. 4.22 Medial sagittal view of the right elbow joint. The medial epicondyle is larger and more prominent than the lateral epicondyle and is directed slightly more posteriorly in the anatomical position. The medial epicondyle gives attachment to the ulnar collateral ligament, the pronator teres and to a common tendon of origin (the common flexor tendon) of the flexor carpi radialis, flexor carpi ulnaris, flexor digitorum superficialis, and palmaris longus. (Reproduced from Schuenke, Schulte, and Schumacher, Atlas of Anatomy, 2nd edition, ©2014, Thieme Publishers, New York. Illustration by Karl Wesker/Markus Voll.)

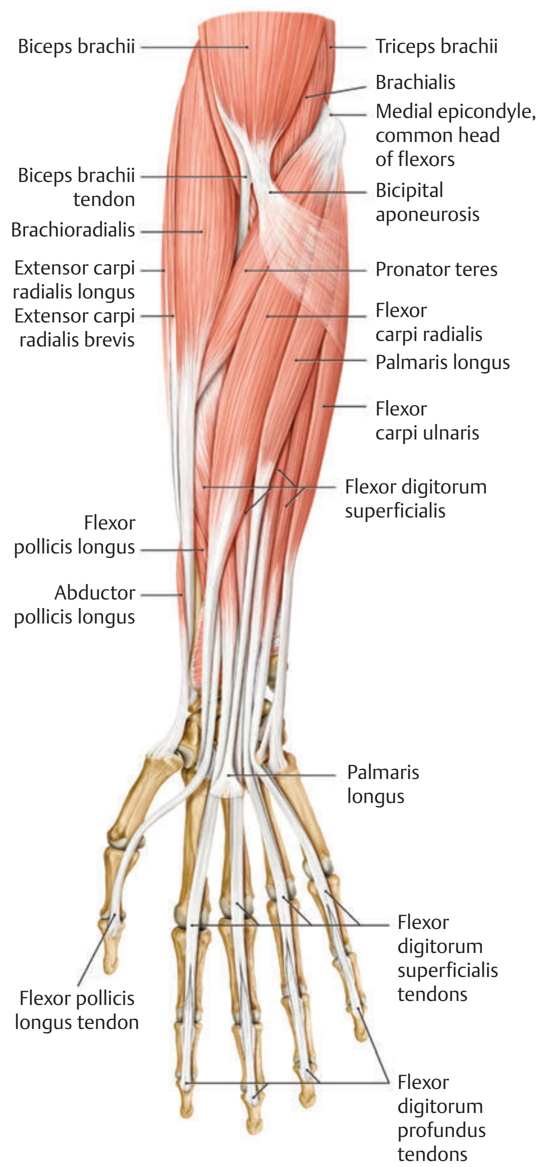

Fig. 4.23 Anterior coronal view of the right cubital region and forearm. Note the relative positon and course of the muscles of the forearm, and in particular, the flexor muscles of the anterior compartment consisting of pronator teres, flexor carpi radialis, palmaris longus, flexor carpi ulnaris, and more deeply flexor digitorum superficialis. (Reproduced from Gilroy and MacPherson, Atlas of Anatomy, 3rd edition, ©2016, Thieme Publishers, New York. Illustration by Karl Wesker/Markus Voll.)

Medial Elbow: Pathology

See ▶Fig. 4.24a,b.

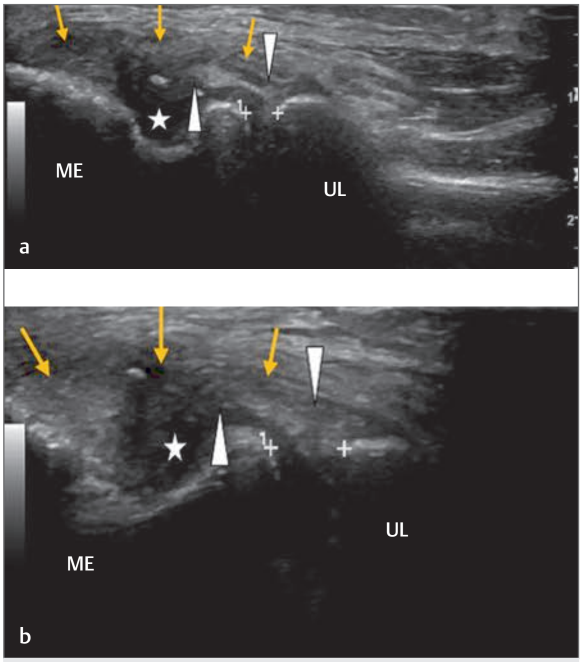

Fig. 4.24 (a) Longitudinal image of the medial aspect of the elbow. The common flexor tendon (*yellow arrows*) can be seen to be thickened and of poor echogenicity. The ulnar collateral ligament (*white arrowheads*) appears retracted distally with an anechoic region (*white star*) where it has torn proximally. In this image the elbow is at rest—note the gap between the calipers is within normal limits. (b) Longitudinal image of the same elbow as in part (a). In this image a valgus stress has been applied to the elbow. Note the increased gap between the calipers indicating instability. ME, medial epicondyle; UL, ulnar; white crosses, measurement calipers; white star, torn proximal ulnar collateral ligament.

4.1.5 Posterior

Longitudinal Scan

The patient is seated facing the clinician with the shoulder in 90-degree abduction and the elbow bent to 90-degree flexion. The hand rests on a table in front of the patient. The probe is placed so that it rests with its distal edge over the posterior aspect of the olecranon in line with the triceps tendon in the sagittal plane (▶Fig. 4.25, ▶Fig. 4.26, ▶Fig. 4.27).

Fig. 4.25 Longitudinal scan of the posterior aspect of the elbow. The probe is placed so that its distal edge is placed over the olecranon in line with the triceps tendon and posterior aspect of the elbow joint and olecranon fossa.

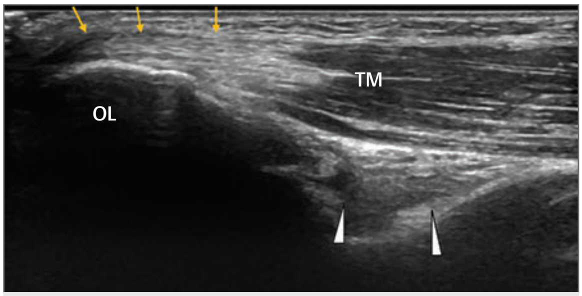

Fig. 4.26 Longitudinal image of the posterior aspect of the elbow joint. The triceps tendon (*yellow arrows*) and triceps muscle (TM) can be seen to overlay the olecranon fossa and olecranon fat pad (*white arrowheads*). OL, olecranon.

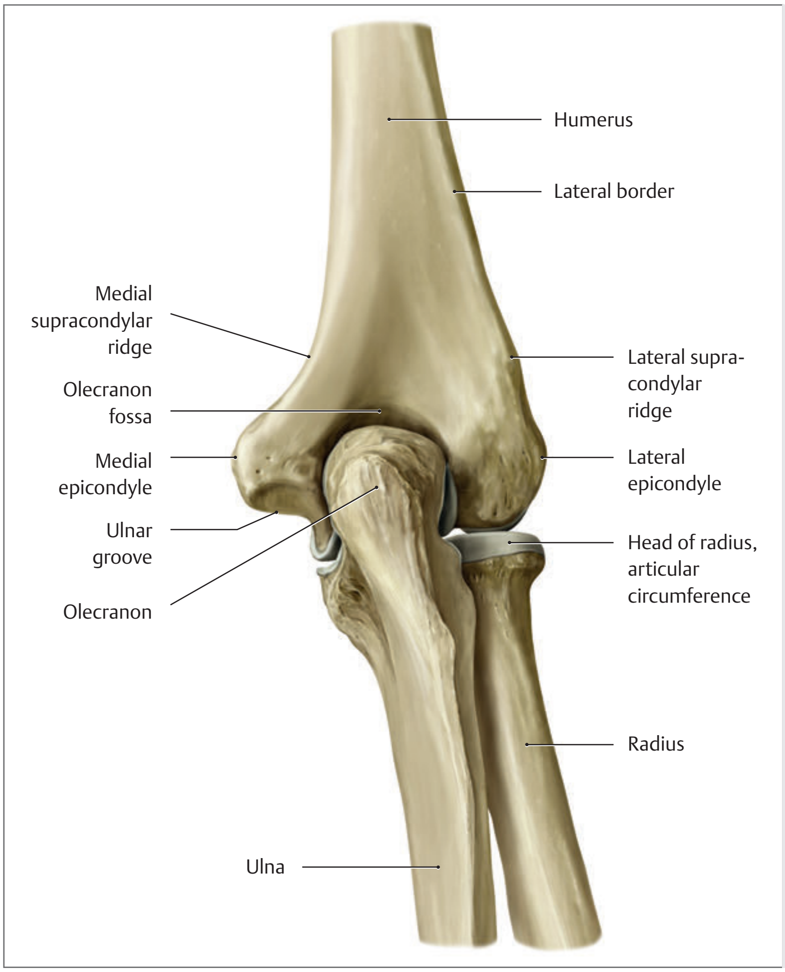

Fig. 4.27 Posterior coronal view of the right elbow. The olecranon (from the Greek olene meaning elbow and kranon meaning head) is a large, thick, curved bony eminence of the ulna which projects behind the elbow laying opposite to the cubital fossa. Extension of the elbow is limited by the olecranon engaging into the olecranon fossa which contains the olecranon fat pad. (Reproduced from Schuenke, Schulte, and Schumacher, Atlas of Anatomy, 2nd edition, ©2014, Thieme Publishers, New York. Illustration by Karl Wesker/Markus Voll.)

Transverse Scan

The patient is seated facing the clinician with the elbow bent to 90-degree flexion and the arm resting on a table.

The probe is placed so that it rests in the transverse plane over the posterior aspect of the olecranon fossa and triceps tendon (▶Fig. 4.28, ▶Fig. 4.29, ▶Fig. 4.30).

Fig. 4.28 Transverse scan of the posterior aspect of the elbow. The probe is placed in the transverse plane so that it rests over the olecranon fossa and triceps tendon.

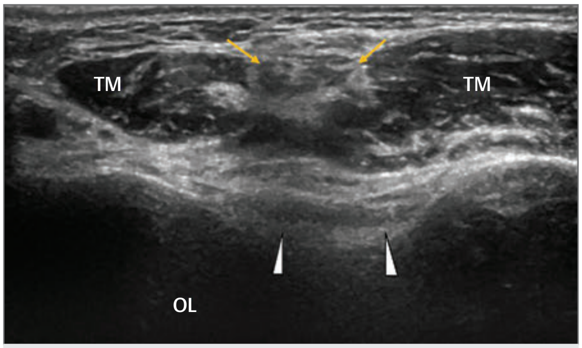

Fig. 4.29 Transverse image of the posterior aspect of the elbow. The triceps tendon (*yellow arrows*) and triceps muscle (TM) can be seen to overlay the olecranon fossa and olecranon fat pad (*white arrowheads*). OL, olecranon.

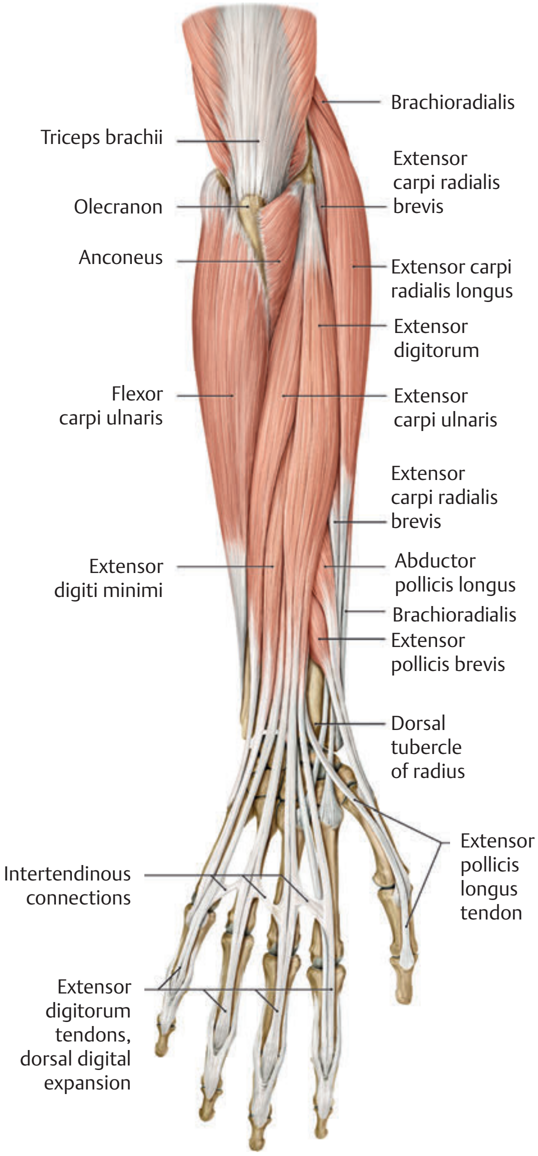

Fig. 4.30 Posterior coronal view of the right posterior elbow and forearm demonstrating the insertion of the triceps brachii and anconeus muscles onto the posterior aspect of the olecranon and the relationship of the muscles of the posterior compartment of the forearm. The long head of the triceps arises from the infraglenoid tubercle of the scapula and extends distally anterior to the teres minor and posterior to the teres major. The medial head arises distally from the groove of the radial nerve, from the dorsal surface of the humerus, and from the medial intermuscular septum. The distal part also arises from the lateral intermuscular septum. The medial head is mostly covered by the lateral and long heads, and is only visible distally on the humerus. The lateral head arises from the dorsal surface of the humerus, lateral and proximal to the groove of the radial nerve, and from the greater tubercle down to the region of the lateral intermuscular septum. The fibers from all three heads converge to a single tendon to insert onto the olecranon process and to the posterior wall of the capsule of the elbow joint. (Reproduced from Gilroy and MacPherson, Atlas of Anatomy, 3rd edition, ©2016, Thieme Publishers, New York. Illustration by Karl Wesker/Markus Voll.)

Posterior Elbow: Pathology

See ▶Fig. 4.31.

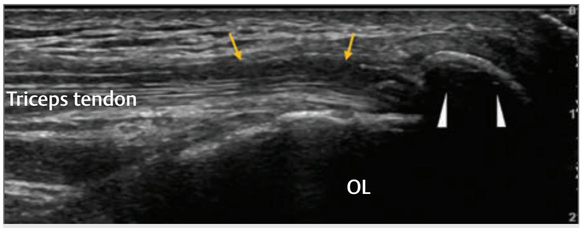

Fig. 4.31 Longitudinal image of the posterior aspect of the elbow. There appears to be a large bony exostosis with some calcification toward the distal insertion of the triceps tendon (*white arrowheads*). Some loss of normal tendon architecture is noted within the superficial aspect of the tendon (*yellow arrows*). These findings are in keeping with an insertional tendinopathy. OL, olecranon; white arrowheads, bony exostosis; yellow arrows, loss of normal tendon architecture.

5 The Elbow: Guided Injection Techniques

Abstract
This chapter outlines commonly used injection techniques around the elbow joint. The aim is to detail the position and alignment of the probe and needle to allow accurate placement into the target tissue. In addition, a brief clinical presentation is given for each condition as well as some of the anatomical considerations which should be noted. The drugs, dosages, and volumes given are those used in the author's clinic.

Keywords: elbow joint, radiohumeral joint, ulnohumeral joint, distal biceps tendon, radial tuberosity, bicipitoradial bursa, extensor tendons, lateral epicondyle, flexor tendons, medial epicondyle, coronoid fossa, olecranon, olecranon fossa, triceps tendon

5.1 Elbow Joint Injection

5.1.1 Cause

- Osteoarthritis.
- Occasionally acute or chronic overuse.

5.1.2 Presentation

- Pain is located within the elbow joint with referral into the muscles of the forearm.
- Depending on the severity of the underlying pathology, a varying degree of capsular restriction may present. The capsular pattern of the elbow is more limited flexion, less limited extension.

5.1.3 Equipment

See ▶Table 5.1.

Table 5.1 Equipment needed for elbow joint injection

Syringe	Needle	Corticosteroid	Local anesthetic	Transducer
10 mL	25 gauge –1 inch	20–40-mg Depo-Medrone	Up to 5-mL 1% lidocaine	Small hockey stick

5.1.4 Anatomical Considerations

The elbow joint consists of three separate articulations. The radiohumeral, radioulnar, and humeroulnar joints. The safest and easiest method is to use a posterolateral approach placing the needle between the head of the radius and the capitellum. Using this approach the clinician need to be troubled about no anatomical structures.

5.1.5 Procedure

- The patient is seated with the arm resting on a table in front of him or her and with the elbow in slight flexion.
- The transducer is placed in the longitudinal plane over the posterior aspect of the radiohumeral joint so that both the radial head and capitellum may be clearly visualized.
- Identify the gap between the radial head and capitellum with your finger.
- The needle is then inserted at approximately 45 degrees to the transducer in a distal to proximal direction so that the tip enters this gap between the superior surface of the radial head and capitellum.
- The injection is given as a bolus and should flow freely.

5.1.6 The Injection

See ▶Fig. 5.1 and ▶Fig. 5.2.

5.1.7 Notes

Osteoarthritis of the elbow is relatively rare unless there has been a significant preceding injury. This said in patients who do have symptomatic osteoarthritis, judicious use of corticosteroid or hyaluronan injection can provide significant relief of pain and improved function.

If a patient complains of locking or "catching"-like symptoms, injection should be avoided until further imaging is arranged to assess for the possibility of loose bodies. If present, a surgical opinion should be sought with a view to removal in order to avoid further possible joint damage.

Fig. 5.1 Elbow joint injection. The probe is placed in the longitudinal plane over the posterior aspect of the radiohumeral joint so that both the radial head and capitellum may be clearly visualized. Identify the gap between the radial head and capitellum with your finger. Flexing and extending the joint may aid its location. The needle is then inserted at approximately 45 degrees to the probe in a distal to proximal direction so that the tip enters this gap between the superior surface of the radial head and capitellum.

5.2 Common Extensor Tendon Injection—Tennis Elbow

5.2.1 Cause

- Acute or chronic overuse.

5.2.2 Presentation

- Pain is located over the lateral aspect of the elbow joint with occasional referral into the muscles of the forearm.
- A good range of elbow movements is usually maintained with pain being elicited with resisted wrist extension and on direct palpation of the lateral elbow.

5.2.3 Equipment

See ▶Table 5.2.

Table 5.2 Equipment needed for common extensor tendon injection—tennis elbow

Syringe	Needle	Corticosteroid	Local anesthetic	Transducer
5 mL	23 gauge –1 inch	20-mg Depo-Medrone	Up to 4-mL 1% lidocaine	Small hockey stick

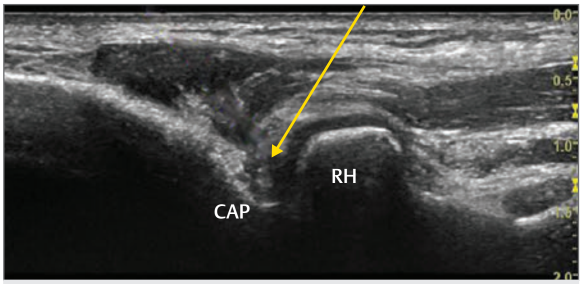

Fig. 5.2 Longitudinal image of the radiocapitellar joint. The radial head (RH) may be seen to the right of the image with the posterior aspect of the capitellum to the left (CAP). The arrow demonstrates the line of the needle. Straight arrow, direction of the needle.

5.2.4 Anatomical Considerations

Tennis elbow most commonly affects the common extensor tendon at its origin on the anterior facet of the lateral epicondyle of the humerus. The anterior facet faces anterolaterally.

Although the anterior facet of the epicondyle is the most common site, pain can also originate from the junction between the common extensor tendon and the extensor muscles more distally or at the origin of extensor carpi radialis longus more proximally on the lower third of the epicondylar ridge.

5.2.5 Procedure

- The patient is seated with the arm resting on a table in front of him or her and with the elbow at approximately 90 degrees of flexion.
- The transducer is placed in the longitudinal plane over the common extensor tendon at its origin on the lateral epicondyle.
- The needle is inserted at approximately 45 degrees to the transducer in a distal to proximal direction so that the tip enters the common extensor tendon passing through the tendon to be positioned resting against the anterolateral facet of the epicondyle deep to the tendon.
- Positioning the needle too vertically will risk the needle tip being placed within the substance of the radial collateral ligament or within the elbow joint itself.
- The bulk of the injection is delivered deep to the common extensor tendon followed by fenestration of the tendon itself.

5.2.6 The Injection

See ▶Fig. 5.3 and ▶Fig. 5.4.

5.2.7 Notes

Ultrasound is the investigation of choice for many tendons and provides the clinician with valuable information as to the state of the common extensor tendon. In addition to the degree of change seen on B-mode imaging, the use of Power Doppler provides detailed information on the presence of neovascularity within the tendon.

Fig. 5.3 Injection of the common extensor tendon of the elbow. The probe is placed in the longitudinal plane over the common extensor tendon at its origin on the lateral epicondyle. The needle is inserted at approximately 45 degrees to the probe in a distal to proximal direction so that the tip enters the common extensor tendon passing through the tendon to be positioned resting against the anterolateral facet of the epicondyle deep to the tendon. The injection should be given using a fenestration technique.

It should be noted if no changes are seen within the common extensor tendon on ultrasound, the diagnosis of tennis elbow should be questioned. A thorough examination of the cervical spine should be included to eliminate the possibility of referral from the neck. More distally, a diagnosis of entrapment of the posterior interosseous nerve within the arcade of Frohse should be excluded. As with most injection techniques the patient must be advised on an appropriate programme of rehabilitation including eccentric loading and activity modification if possible.

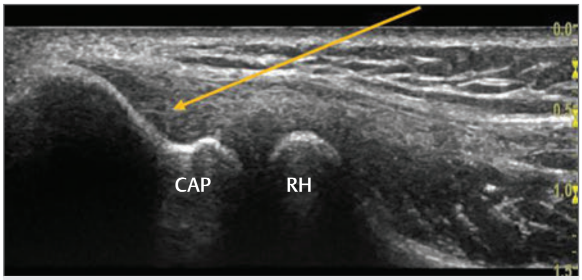

Fig. 5.4 Longitudinal image of the lateral elbow and radiocapitellar joint. The radial head (RH) may be seen to the right of the image with the capitellum to the left (CAP). The arrow demonstrates the line of the needle which should be directed toward the lateral epicondyle.

5.3 Common Flexor Tendon Injection—"Golfer's Elbow"

5.3.1 Cause

- Acute or chronic overuse.

5.3.2 Presentation

- Pain is located at the medial aspect of the elbow.
- Pain may be reproduced with resisted wrist flexion and gripping movements.

5.3.3 Equipment

See ▶Table 5.3.

Table 5.3 Equipment needed for common flexor tendon injection—"golfer's elbow"

Syringe	Needle	Corticosteroid	Local anesthetic	Transducer
5 mL	23 gauge –1 inch	20-mg Depo-Medrone	Up to 2-mL 1% lidocaine	Small hockey stick

5.3.4 Anatomical Considerations

Golfer's elbow is a very common cause of medial elbow pain. The condition may present as a relatively acute problem or be related to more long-term tendinopathic change within the common flexor tendon.

The common flexor tendon at the elbow has its origin on the anterior facet of the medial epicondyle. Injection should not be given too deeply or the medial collateral ligament may be injected rather than the tendon.

5.3.5 Procedure

- The patient is seated with the arm resting on a table in front and with the elbow at approximately 90 degrees of flexion and the shoulder in a few degrees of lateral rotation.

- The clinician is positioned alongside the patient so that he or she is able to support the patient's arm against the body.
- The transducer is placed in the longitudinal plane over the medial epicondyle so that the common flexor origin may be clearly visualized.
- Identify the common flexor tendon.
- The needle is inserted at approximately 45 degrees to the transducer in a distal to proximal direction so that the tip enters the common flexor tendon passing through the tendon to be positioned resting against the medial epicondyle.
- The bulk of the injection is delivered deep to the common flexor tendon followed by fenestration of the tendon itself.

Fig. 5.5 Injection of the common flexor tendon of the elbow. The probe is placed in the longitudinal plane over the medial epicondyle so that the common flexor origin may be clearly visualized. Identify the common flexor tendon. The needle is inserted at approximately 45 degrees to the probe in a distal to proximal direction so that the tip enters the common flexor tendon passing through the tendon to be positioned resting against the medial epicondyle. The injection should be given using a fenestration technique.

5.4 Radiobicipital Bursa/Biceps Insertional Tendinopathy Injection

5.4.1 Cause

- Overuse, particularly with repetitive flexion activities of the elbow with the forearm in a pronated position.

5.4.2 Presentation

- Pain is located deep within the anterior aspect of the elbow.
- Pain may be reproduced with resisted elbow flexion. This is usually worse with the forearm positioned in pronation. Full pronation and elbow extension may be particularly painful if the bursa is affected.

5.3.6 The Injection

See ▶Fig. 5.5 and ▶Fig. 5.6.

5.3.7 Notes

The clinician should be aware of the ulnar nerve positioned posteriorly to the medial epicondyle in the cubital tunnel. Injection with a higher volume may lead to some temporary numbness in the distribution of this nerve distally to the elbow.

As with most injection techniques the patient must be advised on an appropriate program of rehabilitation including eccentric loading and activity modification if possible.

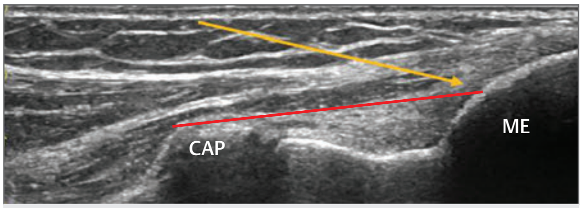

Fig. 5.6 Longitudinal image of the medial elbow and common flexor tendon. The medial epicondyle (ME) may be seen to the right of the image. The red line indicates the superficial surface of the anterior bundle of the ulnar collateral ligament. The yellow arrow demonstrates the line of the needle which should be directed toward the medial epicondyle. CAP, capitellum.

5.4.3 Equipment

See ▶Table 5.4.

5.4.4 Anatomical Considerations

Insertional tendinopathy of the biceps is not a common presentation but can become problematic in patients who repetitively flex the elbow against resistance with the forearm in a pronated position. This would be the case in the climber or weightlifter when associated with pain at the end point of the clean prior to jerk.

Table 5.4 Equipment needed for radiobicipital bursa/biceps insertional tendinopathy injection

Syringe	Needle	Corticosteroid	Local anesthetic	Transducer
5 mL	23 gauge –1 inch	20-mg Depo-Medrone	Up to 2-mL 1% lidocaine	Small hockey stick

The patient may present with either a biceps insertional tendinopathy or a radiobicipital bursa or a combination of both pathologies.

Imaging and injection using an anterior approach are difficult as the biceps lies deep to the vascular structures. A much easier and safer method is to place the forearm in full pronation and approach from the posterior aspect of the forearm.

5.4.5 Procedure

- The patient is seated with the arm resting on a table in front and with the elbow at approximately 90 degrees of flexion and the forearm in full pronation.
- In this position the radial tuberosity is rotated to face posteriorly.
- The transducer is placed in the longitudinal plane over the biceps tendon at its insertion onto the radial tuberosity.
- The needle is inserted at approximately 45 degrees to the transducer from an anteromedial to posterolateral direction.
- If a radiobicipital bursa is identified, injection may be given as a bolus into the bursa. If the pathology appears to be more related to a biceps tendinopathy, the injection may be given around the tendon followed by fenestration of the tendon insertion itself.

5.4.6 The Injection

See ▶Fig. 5.7 and ▶Fig. 5.8.

5.4.7 Notes

The patient should be advised to avoid any loading of the elbow in flexion particularly with a pronated forearm for at least 2 weeks following the injection. In addition, careful consideration needs to be given to technique to avoid recurrence.

Fig. 5.7 Injection of the radiobicipital bursa/distal biceps tendon. The probe is placed in the longitudinal plane over the biceps tendon at its insertion onto the radial tuberosity. The needle is inserted at approximately 45 degrees to the probe from an anteromedial to posterolateral direction. If a radiobicipital bursa is identified, injection may be given as a bolus into the bursa. If the pathology appears to be more related to a biceps tendinopathy, the injection may be given around the tendon followed by fenestration of the tendon insertion itself.

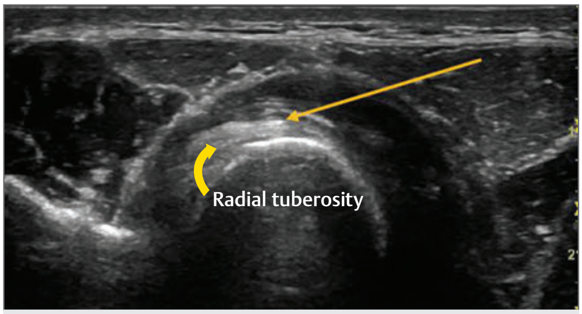

Fig. 5.8 Longitudinal image of the distal biceps tendon (*curved arrow*) at its insertion onto the radial tuberosity. The *yellow arrow* demonstrates the line of the needle which should be directed toward the superficial surface of the distal biceps tendon.

5.5 Olecranon Bursa Injection

5.5.1 Cause

- Direct trauma such as a fall or blow to the olecranon.
- Overuse.
- Septic bursitis.
- Gout.

5.5.2 Presentation

Swelling over the posterior aspect of the olecranon. In the case of a reactive bursitis due to excessive friction, this may not be painful.

If the swelling is painful and inflamed, the clinician should be mindful of a possible septic bursitis or a bursitis secondary to gout. A direct fall onto the olecranon may result in a hemorrhagic bursitis.

If there is any possibility of infection, aspiration should be carried out with the aspirate being sent for analysis prior to injection being considered. Analysis of aspirate may also help identify urate crystals associated with gout.

5.5.3 Equipment

See ▶Table 5.5.

Table 5.5 Equipment needed for olecranon bursa injection

Syringe	Needle	Corticosteroid	Local anesthetic	Transducer
5 mL	23 gauge –1 inch	20-mg Depo-Medrone	Up to 2-mL 1% lidocaine	Small hockey stick

5.5.4 Anatomical Considerations

5

The olecranon bursa lies over the posterior aspect of the olecranon and triceps insertion. In its normal state it is not visible with ultrasound. As the bursa lies superficially, there are no other anatomical structures that need be avoided.

5.5.5 Procedure

- The patient is seated with the arm resting on a table in front and with the elbow at approximately 90 degrees of flexion.
- The transducer is placed in the longitudinal plane over the olecranon bursa.
- The needle is inserted at approximately 45 degrees to the transducer from an inferior to superior direction.
- Aspiration should always be carried out first. If there is any possibility from the clinical history and examination or from the appearance of the aspirate of infection, no injection should be given.
- If there are no concerns in regard to infection, the injection is given as a bolus.

5.5.6 The Injection

See ▶Fig. 5.9 and ▶Fig. 5.10.

5.5.7 Notes

With a mechanical and reactive bursitis the patient is advised on relative rest for a couple of weeks and activity modification if required. Further management will be dependent on the cause and results of any analysis of the aspirate.

Fig. 5.9 Injection of an olecranon bursa. The probe is placed in the longitudinal plane over the olecranon. The needle is inserted at approximately 45 degrees to the probe from an inferior to superior direction. Aspiration should always be carried out first. If there is any possibility from the clinical history and examination or from the appearance of the aspirate of infection, no injection should be given.

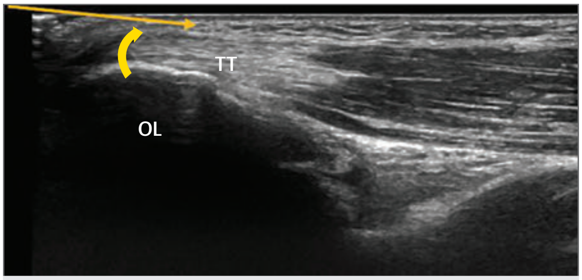

Fig. 5.10 Longitudinal image of the posterior elbow. The olecranon bursa lies superficial to the triceps tendon (TT) and olecranon (OL). In its normal state the olecranon bursa cannot be seen. The *curved arrow* indicates where the bursa lies. Straight arrow, line of injection.

6 The Wrist and Hand: Diagnostic Imaging

Abstract
An ultrasound examination of the wrist and hand is one of the most common ultrasound examinations conducted in patients with rheumatological disease and is able to detect early signs of pathology. Such signs will depend on the advancement of the disease. In osteoarthritis, ultrasound has been shown to be more sensitive than clinical examination in detection of joint inflammation in patients with erosive OA. In patients with rheumatoid arthritis, ultrasound is able to detect significant synovitis not determined by clinical examination—'subclinical' synovitis. An ultrasound examination of the wrist and hand should be conducted using a linear transducer of a high frequency (12-18 MHz). While a larger footprint probe allows better overall anatomical resolution, a smaller 'hockey stick' probe should be utilized for smaller structures.

Keywords: proximal radiocarpal joint, midcarpal joints, carpometacarpal joints, metacarpophalangeal joints, proximal and distal interphalangeal joints, ligament, dorsal extensor compartments and tendons, carpal tunnel, flexor tendons and pulley system

6.1 Diagnostic Imaging of the Wrist and Hand: Introduction

Examination of the wrist and hand will be dependent on the specific structure and pathology suspected from a thorough clinical examination. Based on this examination it would be normal to scan one or two specific structures. In addition to static scanning dynamic imaging should be included particularly when imaging tendons and ligaments to fully assess the patency of these structures.

Imaging includes the following:

- Wrist joint—volar
  - Flexor retinaculum.
  - Median nerve.
  - Flexor pollicis longus tendon.
  - Flexor digitorum profundus and superficialis tendons.
  - Flexor carpi radialis longus tendon and radial artery.
  - Guyon's canal and the ulnar nerve and artery.
  - Flexor carpi ulnaris tendon.
- Wrist joint—dorsal
  - The six dorsal compartments and extensor retinaculum.
  - Proximal radiocarpal and midcarpal joints.
  - Scapholunate joint and ligament.
- Fingers and thumb
  - Metacarpophalangeal, proximal interphalangeal, and distal interphalangeal joints.
  - Pulley system (A1–A5).
  - First carpometacarpal joint of the thumb.
  - Ulnar collateral ligament of the thumb.

6.1.1 Wrist Joint—Volar

Carpal Tunnel: Transverse Scan

The patient is seated facing the clinician with the forearm supinated and hand facing upward resting on a table. The probe is placed so that it rests transversely at the level of the distal palmer crease in the axial plane over the flexor tendons and wrist joint (▶Fig. 6.1, ▶Fig. 6.2, ▶Fig. 6.3, ▶Fig. 6.4).

Fig. 6.1 Transverse scan of the volar aspect of the wrist and carpal tunnel. The probe is placed at the level of the distal palmer crease. The radial aspect of the probe should be placed so that it overlays the scaphoid tubercle and the ulnar aspect of the probe should overlay the pisiform.

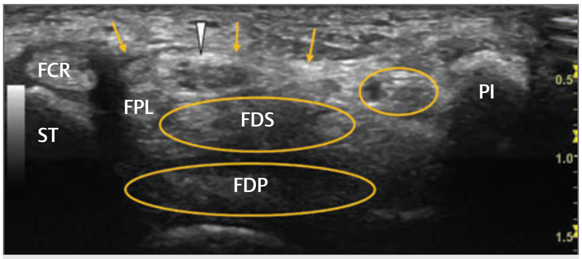

Fig. 6.2 Transverse image of the carpal tunnel and its contents. From the radial aspect can be seen the scaphoid tubercle (ST) with the overlying tendon of flexor carpi radialis (FCR). Immediately medial to this can be seen the tendon of flexor pollicis longus (FPL). Next to this the median nerve (*white arrowhead*) can be seen immediately deep to the flexor retinaculum (*yellow arrows*). To the ulnar side the pisiform (PI) can be seen with Guyon' canal (*yellow ellipse*). The tendons of flexor digitorum superficialis (FDS) and flexor digitorum profundus (FDP) can be seen deep below the median nerve and Guyon's canal.

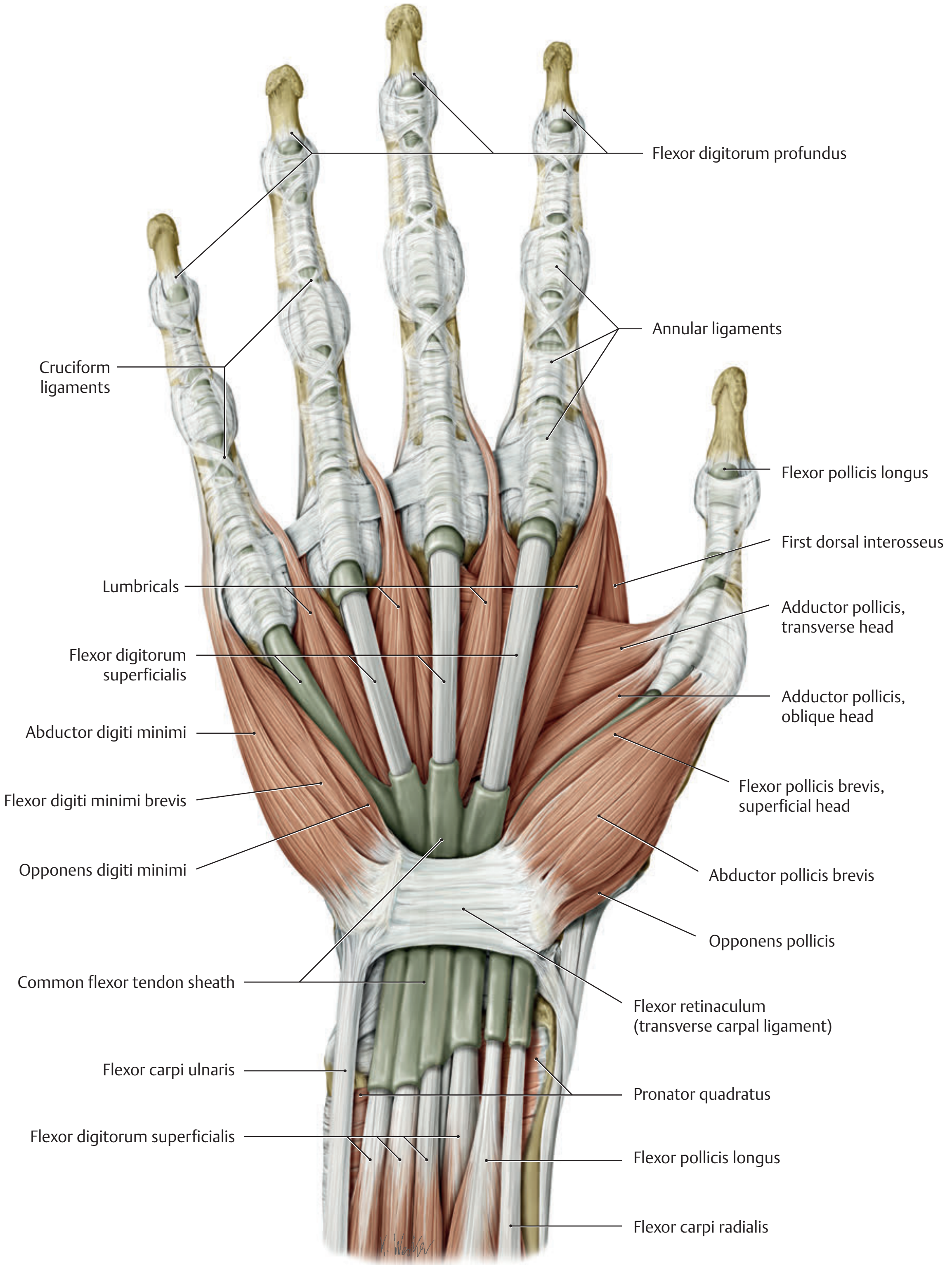

Fig. 6.3 Coronal view of the carpal tunnel and hand demonstrating the carpal and digital tendon sheaths on the palmar surface of the right hand. (Reproduced from Schuenke, Schulte, and Schumacher, Atlas of Anatomy, 2nd edition, ©2014, Thieme Publishers, New York. Illustration by Karl Wesker/Markus Voll.)

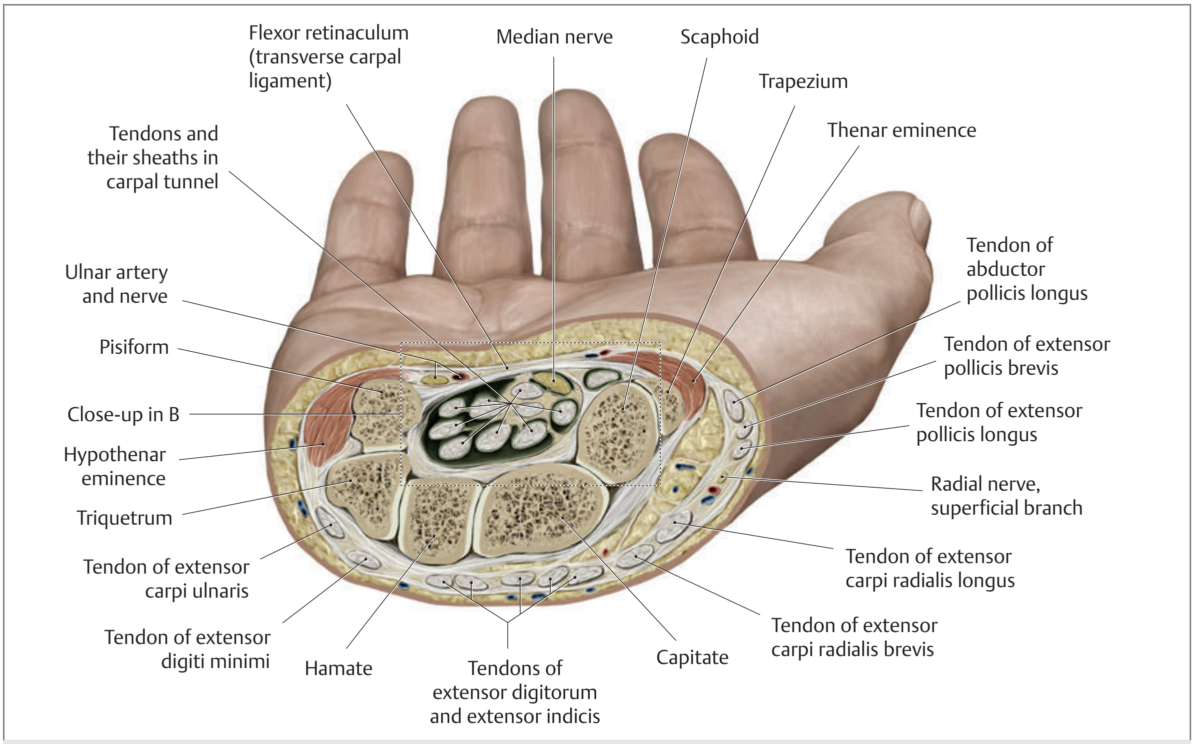

Fig. 6.4 Cross-section of the right wrist at the level of the carpal tunnel. The carpus, the bony elements of the wrist, forms an arch which is convex on the dorsal side of the hand and concave on the palmar side. The groove on the palmar side, the sulcus carpi, is covered by the flexor retinaculum, a sheath of tough connective tissue forming the carpal tunnel. The flexor retinaculum is attached radially to the scaphoid tubercle and the ridge of trapezium, and on the ulnar side to the pisiform and hook of hamate. The tendons of the flexor digitorum superficialis and profundus pass through a common ulnar sheath, while the tendon of the flexor pollicis longus passes through a separate radial sheath. Superficial to the carpal tunnel and the flexor retinaculum, the ulnar artery and ulnar nerve pass through Guyon's canal. (Reproduced from Schuenke, Schulte, and Schumacher, Atlas of Anatomy, 2nd edition, ©2014, Thieme Publishers, New York. Illustration by Karl Wesker/Markus Voll.)

Guyon's Canal: Transverse Scan

The patient is seated facing the clinician with the forearm supinated and hand facing upward resting on a table. The probe is placed so that it rests transversely at the level of the distal palmer crease in the axial plane over the flexor tendons and wrist joint. The probe may be aligned more medially to ensure suitable visualization of Guyon's canal at the ulnar aspect of the carpal tunnel (▶Fig. 6.5, ▶Fig. 6.6, ▶Fig. 6.7).

Fig. 6.5 Transverse scan of the volar aspect of the wrist and carpal tunnel. The probe is placed at the level of the distal palmer crease. The ulnar aspect of the probe should be placed so that it overlays the pisiform. Guyon's canal is situated immediately lateral to the pisiform.

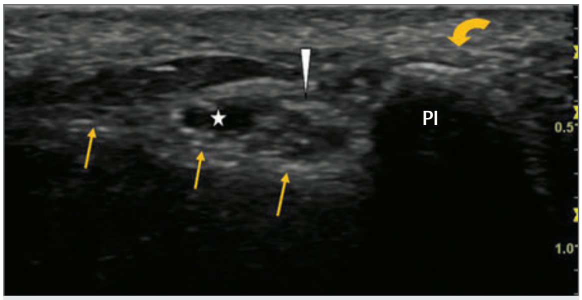

Fig. 6.6 Transverse image of the medial side of the carpal tunnel and Guyon's canal. The pisiform (PI) should be used as a landmark with Guyon's canal immediately lateral to this. At this level the ulnar nerve (*white arrowhead*) appears as an oval structure transversely. Immediately lateral to this the ulnar artery may be seen (*white star*). If the probe is moved distally toward the hook of hamate, the ulnar nerve may be seen to split into a superficial sensory and deeper motor branch. The insertion of the tendon of flexor carpi ulnaris can be seen superficial to the pisiform onto which it joins (*curved arrow*). Yellow arrows, flexor retinaculum.

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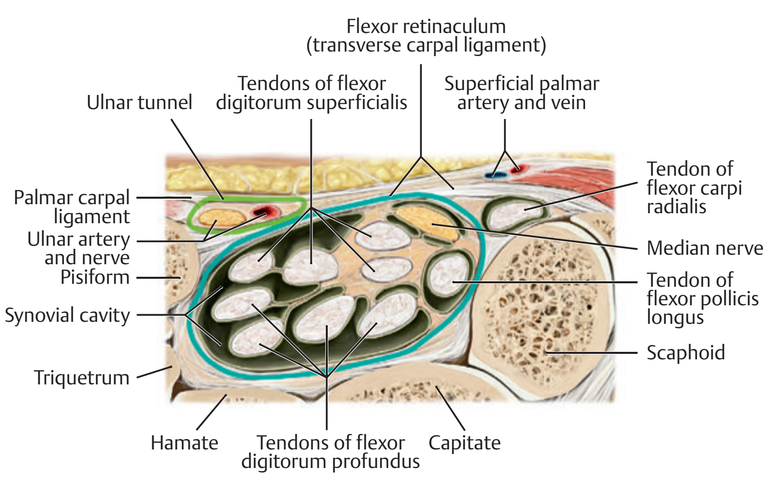

Fig. 6.7 Cross-section of the right wrist at the level of the carpal tunnel. In this enlarged view the relationship and relative positions of the flexor tendons and neurovascular structures may be seen. (Reproduced from Schuenke, Schulte, and Schumacher, Atlas of Anatomy, 2nd edition, ©2014, Thieme Publishers, New York. Illustration by Karl Wesker/Markus Voll.)

Wrist—Pathology: Carpal Tunnel Syndrome

The median nerve should be assessed at the level of the carpal tunnel at the distal wrist crease, again immediately proximal to the carpal tunnel at the level of the pronator quadratus muscle and again at the level of the midforearm. In the normal patient, the cross-sectional area of the nerve should be approximately 9 mm^2 throughout its entire length. In patients with carpal tunnel syndrome this cross-sectional area can significantly increase at the level of the carpal tunnel with an associated flattening of the nerve (▶Fig. 6.8a–c).

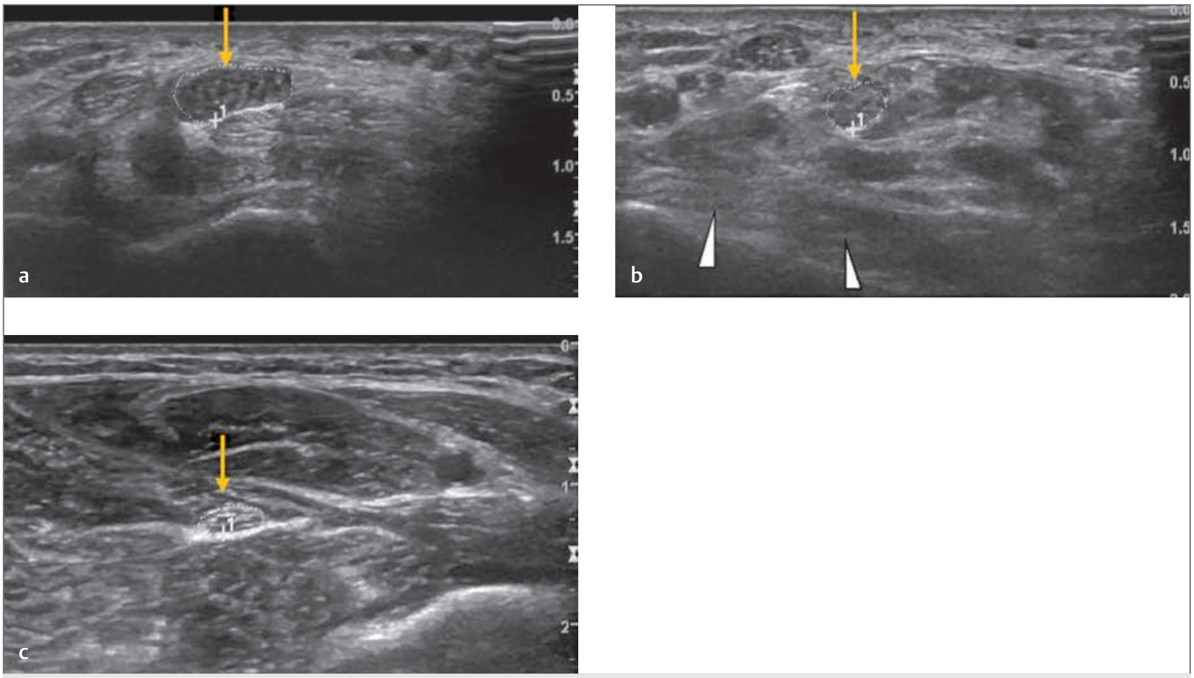

Fig. 6.8 (**a**) Transverse image of the median nerve at the carpal tunnel (*yellow arrow*). The nerve appears enlarged and flattened. The cross-sectional area measures 25 mm^2. (**b**) Transverse image of the median nerve (*yellow arrow*) at the level of the pronator quadratus muscle (*white arrowheads*). The nerve appears rounded rather than flattened. The cross-sectional area is reduced to 10 mm^2. (**c**) Transverse image of the median nerve at the level of the midforearm (*yellow arrow*). The nerve appears rounded rather than flattened. The cross-sectional area is reduced to 7 mm^2.

Wrist—Pathology: Carpal Tunnel Syndrome

See ▶Fig. 6.9, ▶Fig. 6.10, and ▶Fig. 6.11.

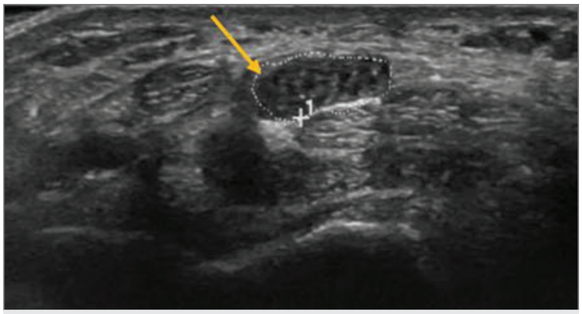

Fig. 6.9 Transverse image of the median nerve at the wrist (*yellow arrow*) demonstrating marked thickening of the nerve and associated flattening.

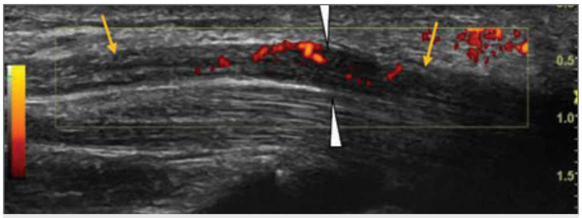

Fig. 6.10 Longitudinal image of the median nerve (*yellow arrows*) at the level of the carpal tunnel. There appears to be a mild swelling of the nerve as it enters the tunnel (*white arrowhead*). Doppler imaging demonstrates a mild intraneural vascularity suggestive of carpal tunnel syndrome.

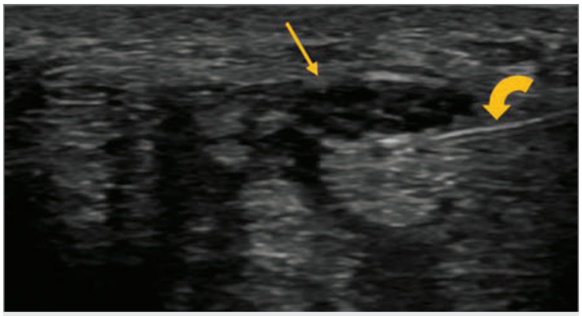

Fig. 6.11 Transverse image of the median nerve at the level of the carpal tunnel (*yellow arrow*). The nerve appears both thickened and flattened. In this image a needle (*curved arrow*) may be seen entering the carpal tunnel from the right side of the screen to be placed immediately deep to the nerve.

6.1.2 Wrist Joint—Dorsal

Dorsal Wrist—Overview of the Six Dorsal Compartments

The patient is seated facing the clinician with the forearm resting on a table. The probe is placed so that it rests transversely over the dorsal compartment to be assessed. The clinician should identify each tendon within its specific compartment from dorsal compartment one through six transversely and then longitudinally. The patient should be asked to actively move the wrist and fingers appropriate to each compartment to allow the clinician to further dynamically assess the tendons (▶Fig. 6.12, ▶Fig. 6.13, ▶Fig. 6.14).

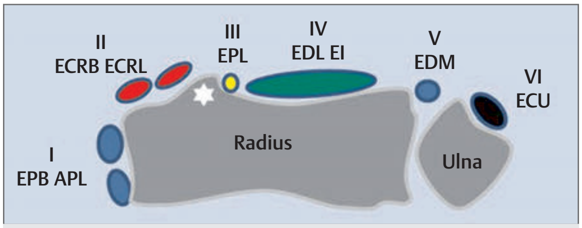

Fig. 6.12 Schematic representation of the dorsal compartments of the wrist. There are six separate compartments formed by the extensor retinaculum. Assessment of all six compartments would be unlikely with the clinician being directed by a thorough clinical examination of the patient. I, extensor pollicis brevis (EPB) and abductor pollicis longus (APL); II, extensor carpi radialis brevis (ECRB) and extensor carpi radialis longus (ECRL); III, extensor pollicis longus (EPL); IV, extensor digitorum longus (EDL) and extensor indicis (EI); V, extensor digiti minimi (EDM); VI, extensor carpi ulnaris (ECU); white star, Lister's tubercle.

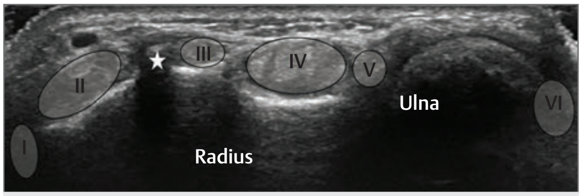

Fig. 6.13 Transverse image of the dorsal wrist compartments. From left to right: Compartment I extensor pollicis brevis and abductor pollicis longus; compartment II extensor carpi radialis brevis and extensor carpi radialis longus; compartment III extensor pollicis longus; compartment IV extensor digitorum longus and extensor indicis; compartment V extensor digiti minimi; compartment VI extensor carpi ulnaris. Note: compartment I and VI cannot be clearly seen in this image as they are positioned around the radial and ulnar aspect of the wrist, respectively, and need to be imaged separately. White star, Lister's tubercle.

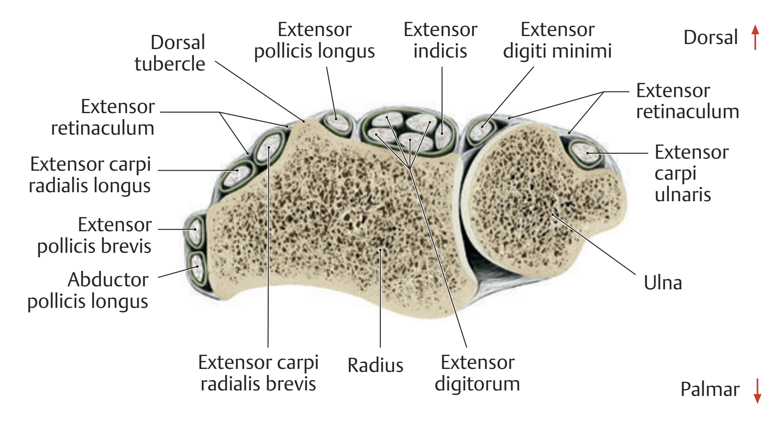

Fig. 6.14 Transverse section of the distal radius and ulna demonstrating the dorsal compartment and their respective tendons. Compartment I, extensor pollicis brevis and abductor pollicis longus; compartment II, extensor carpi radialis brevis and extensor carpi radialis longus; compartment III, extensor pollicis longus; compartment IV, extensor digitorum longus and extensor indicis; compartment V, extensor digiti minimi; compartment VI, extensor carpi ulnaris. (Reproduced from Schuenke, Schulte, and Schumacher, Atlas of Anatomy, 2nd edition, ©2014, Thieme Publishers, New York. Illustration by Karl Wesker/Markus Voll.)

Dorsal Compartment I—Abductor Pollicis Longus and Extensor Pollicis Brevis

The patient's forearm is positioned so that it is halfway between supination and pronation with the thumb facing upward. The probe is placed transversely over the first dorsal compartment at the level of the radial styloid. A smaller hockey stick probe may be useful when examining the individual dorsal compartments. As for all the dorsal compartments the tendons should first be identified and examined using a transverse view and then further evaluated in longitudinal view (▶ Fig. 6.15, ▶ Fig. 6.16, ▶ Fig. 6.17, ▶ Fig. 6.18, ▶ Fig. 6.19).

Fig. 6.15 Transverse scan of the first dorsal compartment of the wrist. The probe should be placed over the radial styloid to visualize the tendons of abductor pollicis longus and extensor pollicis brevis.

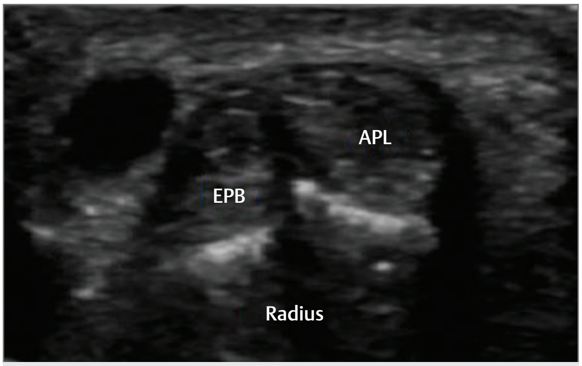

Fig. 6.16 Transverse image of the first dorsal compartment of the wrist demonstrating the more volar tendon of abductor pollicis longus (APL) and the dorsal tendon of extensor pollicis brevis (EPB).

Fig. 6.17 Longitudinal scan of the first dorsal compartment of the wrist. The probe should be placed over the radial styloid to visualize the tendons of abductor pollicis longus and extensor pollicis brevis.

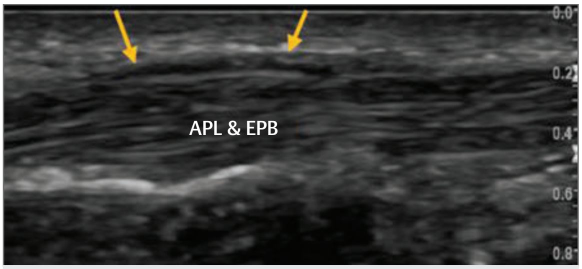

Fig. 6.18 Longitudinal image of the first dorsal compartment of the wrist. The tendons of abductor pollicis longus (APL) and extensor pollicis brevis (EPB) cannot be easily distinguished in longitudinal view. The extensor retinaculum (*yellow arrows*) can be seen overlaying the tendons.

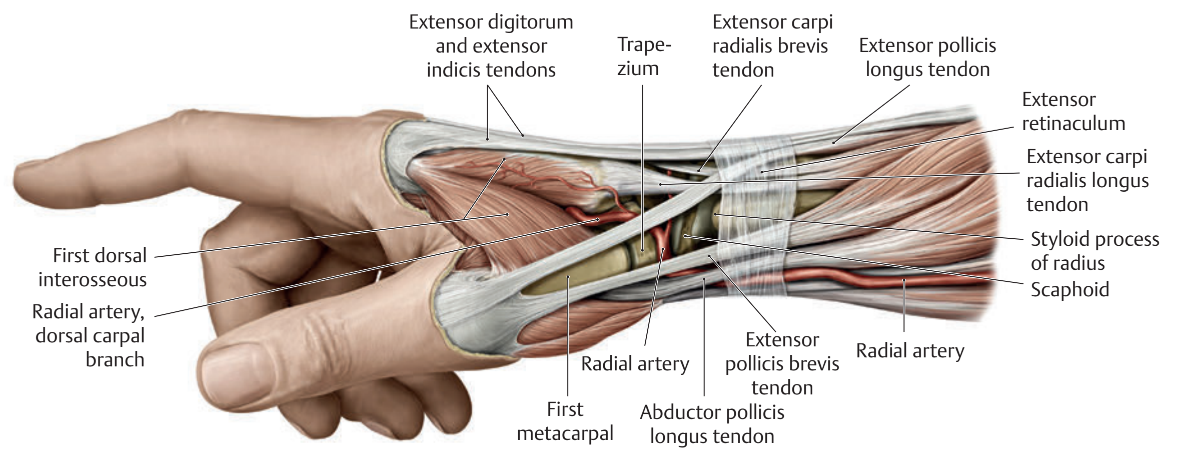

Fig. 6.19 Sagittal view of the radial aspect of the wrist demonstrating the first, second, and third dorsal compartments. The first dorsal compartment contains the tendons of abductor pollicis longus and extensor pollicis brevis. The abductor pollicis longus tendon is positioned anteriorly to the tendon of extensor pollicis brevis and appears larger on ultrasound imaging. The second dorsal compartment contains the tendons of extensor carpi radialis brevis and longus. The third compartment contains the tendon of extensor pollicis longus. Immediately distal to the extensor retinaculum, the tendon of extensor pollicis longus may be seen to cross the tendons of the second compartment (extensor carpi radialis brevis and longus) at a point known as the distal intersection of the wrist. (Reproduced from Schuenke, Schulte, and Schumacher, Atlas of Anatomy, 2nd edition, ©2014, Thieme Publishers, New York. Illustration by Karl Wesker/Markus Voll.)

Dorsal Compartment II—Extensor Carpi Radialis Longus and Extensor Carpi Radialis Brevis

Dorsal Compartment III—Extensor Pollicis Longus

The patient's forearm is positioned in pronation. The probe is placed transversely over the second and third dorsal compartments at the level of Lister's tubercle. As for all the dorsal compartments the tendons should first be identified and examined using a transverse view and then further evaluated in a longitudinal view.

The Distal Intersection

See ▶ Fig. 6.20, ▶ Fig. 6.21, ▶ Fig. 6.22a–c.

Fig. 6.20 Transverse scan of the second and third dorsal compartments. The probe is placed transversely over the wrist at the level of Lister's tubercle.

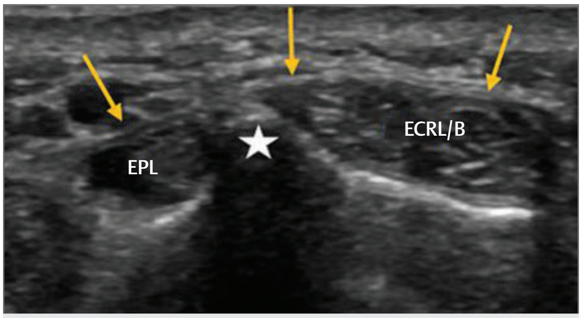

Fig. 6.21 Transverse image of the second and third dorsal compartments. The tendon of extensor pollicis longus (EPL) can be seen to the left of Lister's tubercle (*white star*). The tendons of extensor carpi radialis longus and brevis (ECRL/B) can be seen to the right. Yellow arrows, extensor retinaculum.

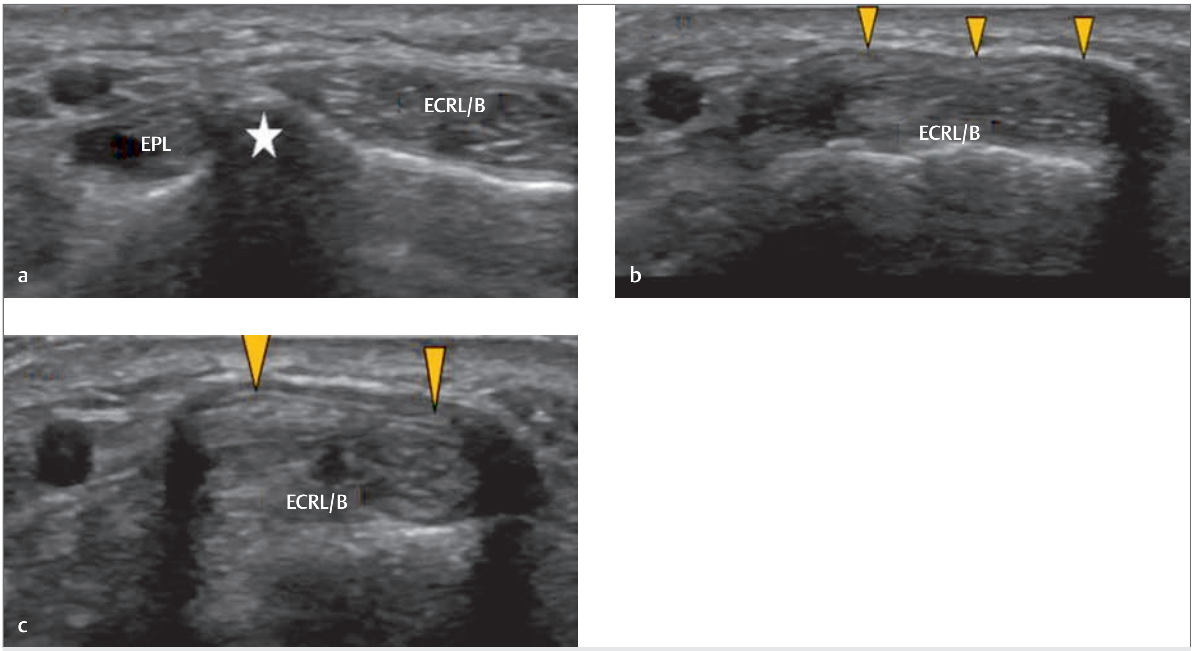

Fig. 6.22 (**a–c**) Distal intersection. Keep the probe in a transverse line and move distally to below Lister's tubercle (*white star*). The tendon of extensor pollicis longus (EPL and *yellow arrowhead*) can be seen to turn radially and run superficially over the tendons of extensor carpi radialis longus and brevis (ECRL/B).

Dorsal Compartment IV—Extensor Digitorum Longus and Extensor Indicis

Dorsal Compartment V—Extensor Digiti Minimi

The patient's forearm is positioned in pronation. The probe is placed transversely over the fourth and fifth dorsal compartments at the level of and to the ulnar side of Lister's tubercle. As for all the dorsal compartments the tendons should first be identified and examined using a transverse view and then further evaluated in longitudinal view (▶Fig. 6.23, ▶Fig. 6.24).

Fig. 6.23 Transverse scan of the IV and V dorsal compartments. The probe is placed transversely over the wrist at the level of and ulnar to Lister' tubercle.

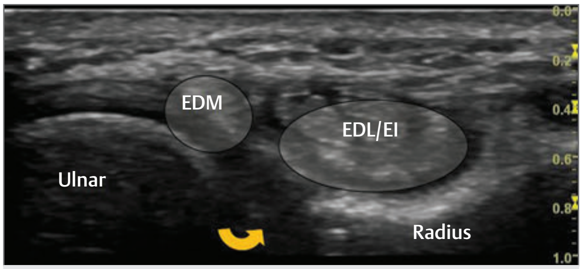

Fig. 6.24 Transverse image of the fourth and fifth dorsal compartments of the wrist. The fourth compartment contains the tendons of extensor digitorum longus and extensor indicis (EDL/EI) and overlies the medial aspect of the distal radius. The fifth compartment contains the tendon of extensor digiti minimi (EDM) which can be seen to overlie the distal radioulnar joint (*curved arrow*).

Dorsal Compartment VI—Extensor Carpi Ulnaris

The patient's forearm is positioned in pronation. The probe is placed transversely over the sixth dorsal-compartment situated along the ulnar border of the wrist at the level of the ulnar styloid. As for all the dorsal compartments the tendons should first be identified and examined using a transverse view and then further evaluated in longitudinal view. Dynamic scanning is of particular use to evaluate for tendon subluxation (▶ Fig. 6.25, ▶ Fig. 6.26).

Fig. 6.25 Transverse scan of the sixth dorsal compartment. The probe is positioned transversely over the compartment at the level of the ulnar styloid.

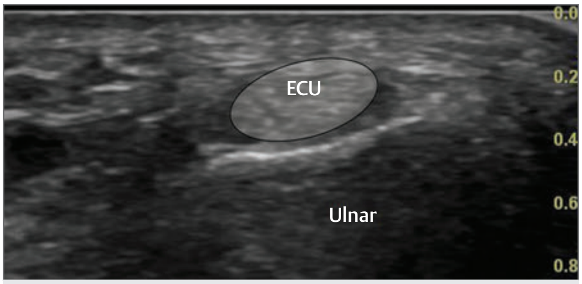

Fig. 6.26 Transverse image of the sixth dorsal compartment and the tendon of extensor carpi ulnaris (ECU) at the level of the ulnar styloid.

Dorsal Compartments of the Wrist: Pathology

Imaging , ▶ Fig. 6.27a–d demonstrates a chronic de Quervain's tenosynovitis. See also ▶ Fig. 6.28a,b.

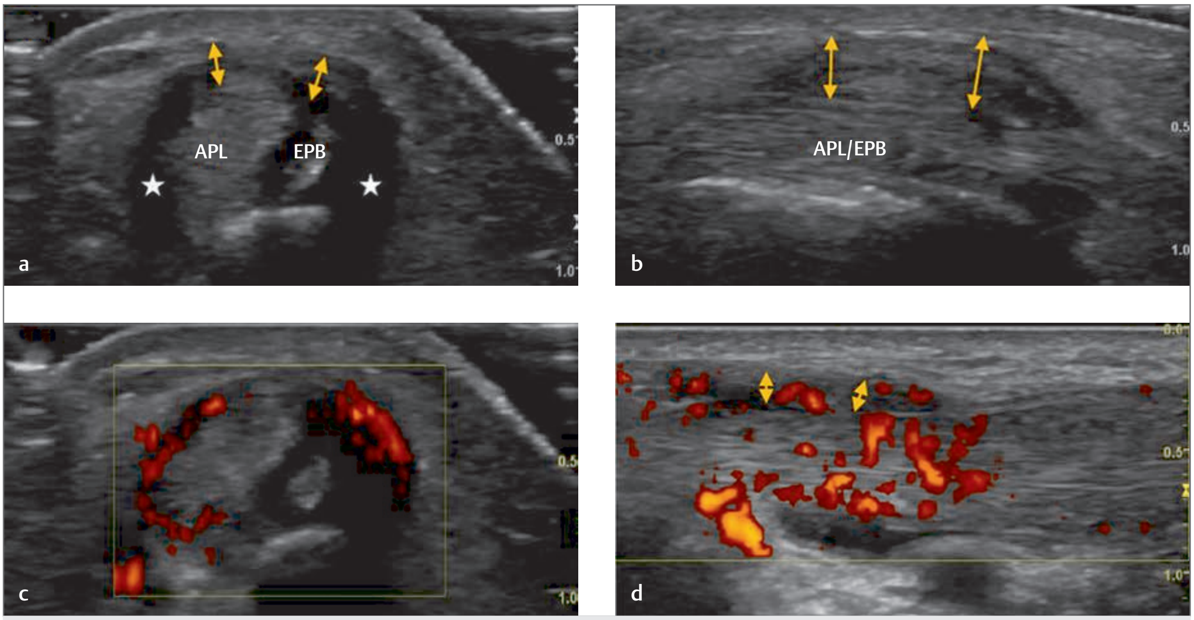

Fig. 6.27 (**a**) Transverse image of the first dorsal compartment. The tendons of abductor pollicis longus (APL) and extensor pollicis brevis (EPB) appear intact. However, fluid is noted around the tendons (*white stars*) and the extensor retinaculum appears thickened (*double-headed yellow arrows*). (**b**) Longitudinal image demonstrating the marked thickening of the extensor retinaculum more clearly (*double-headed yellow arrows*). (**c**) In addition to fluid within the first dorsal compartment and thickening of the retinaculum, Power Doppler demonstrates a significant tenosynovitis around the tendons within the tendon sheath. (**d**) Longitudinal image with Power Doppler demonstrating tenosynovitis within the tendon sheath at the level of the extensor retinaculum (*double-headed yellow arrows*).

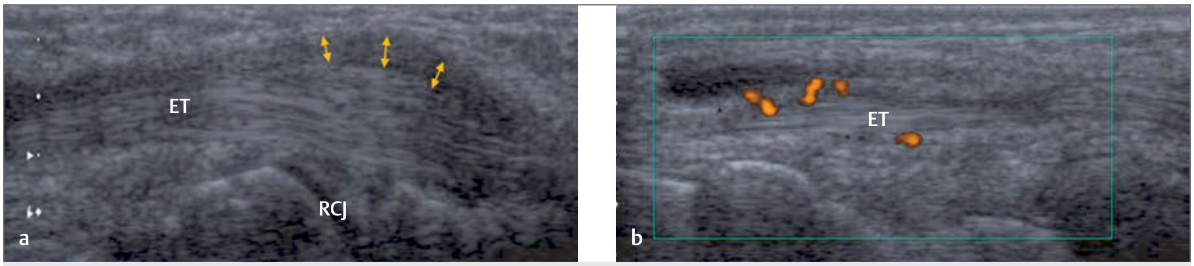

Fig. 6.28 (**a,b**) Longitudinal images of the fourth dorsal compartment at the level of the radiocarpal joint (RCJ). The extensor tendons (ET) themselves appear intact. However, there appears to be marked thickening of the extensor retinaculum (*double-headed yellow arrows*). In addition, Power Doppler imaging demonstrates evidence of an associated tenosynovitis.

Dorsal Wrist: Proximal Radiocarpal and Midcarpal Joints

The patient's forearm is positioned in pronation resting on a table in front of the clinician. The probe is placed in the sagittal plane longitudinally over the dorsum of the wrist joint to allow imagining of the radiocarpal and midcarpal joints. The use of a large footprint linear probe allows visualization of both joints (▶Fig. 6.29).

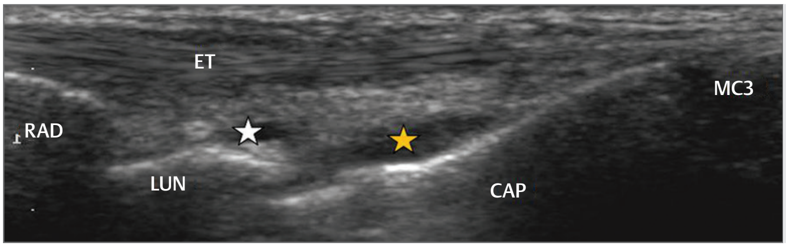

Fig. 6.29 Longitudinal image of the radiocarpal and midcarpal joints. The joint recesses may be seen as low echo foci overlaying the bones (*white and yellow stars*). The tendons of the fourth dorsal compartment may be seen overlaying the joints (ET). CAP, capitate; LUN, lunate; MC3, base of third metacarpal; RAD, radius.

Scapholunate Joint

To scan the scapholunate joint the probe is moved through 90 degrees so that it is positioned transversely over the dorsum of the wrist joint. Lister's tubercle may be used as a landmark with the scapholunate joint laying immediately distal to this (▶Fig. 6.30, ▶Fig. 6.31, ▶Fig. 6.32).

Fig. 6.30 Transverse scan of the dorsum of the wrist and the scapholunate joint. The integrity of the scapholunate ligament may be further assessed by placing the hand in ulnar deviation.

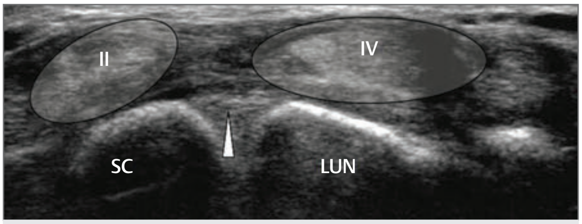

Fig. 6.31 Transverse image of the scapholunate joint and ligament (*white arrowhead*). LUN, lunate; SC, scaphoid.

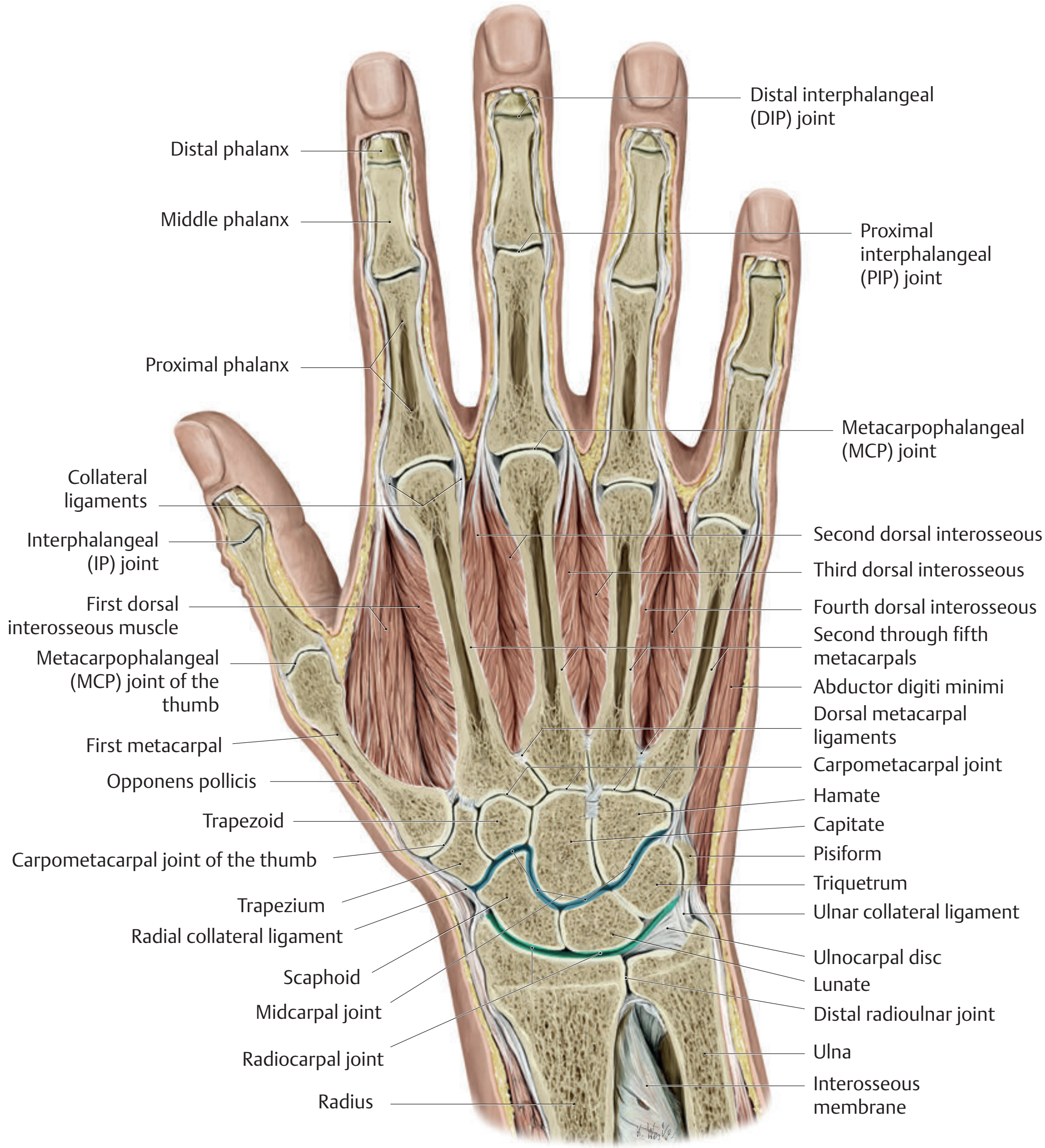

Fig. 6.32 Coronal section of the wrist and hand. The radiocarpal joint is formed by the radius, triangular fibrocartilage, and three bones in the proximal carpal row: the scaphoid, lunate, and triquetrum. The proximal joint surface is a single biconcave curvature. The distal radius is triangular in shape and flares distally. The distal lateral extension of the radius is the radial styloid. The distal articular surface of the radius is composed of two concave facets, one for articulation with the scaphoid and one for the lunate. The medial aspect of the distal radius (ulnar notch) is concave for its articulation with the ulna. The triangular fibrocartilage is present at the distal end of the ulna and lies between the distal ulna and the triquetrum and lunate. The disc is important for proper arthrokinematics of the distal radioulnar joint. The disc cannot be assessed with ultrasound imaging. (Reproduced from Schuenke, Schulte, and Schumacher, Atlas of Anatomy, 2nd edition, ©2014, Thieme Publishers, New York. Illustration by Karl Wesker/Markus Voll.)

6.1.3 Fingers and Thumb

The Fingers: Metacarpophalangeal, Proximal Interphalangeal, and Distal Interphalangeal Joints

The patient's forearm is positioned in supination with the hand resting on a table in front of the clinician. The probe is placed in the sagittal plane longitudinally over the volar aspect of the joint to be assessed either the metacarpophalangeal, the proximal interphalangeal, or the distal interphalangeal joints. The use of a small footprint linear probe (hockey stick) allows better visualization of these small joints.

The scan and image shown in figures demonstrate assessment of the volar aspect of the metacarpophalangeal joint. The approach for the proximal and distal interphalangeal joints is the same; only the probe is positioned more distally for each. The dorsal aspect of each joint should also be examined if indicated. In addition, both the radial and ulnar collateral ligaments may be assessed at the proximal and distal interphalangeal joints. This is not possible at the metacarpophalangeal joints other than the radial collateral ligament of the index finger and the ulnar collateral ligament of the little finger (▶Fig. 6.33, ▶Fig. 6.34, ▶Fig. 6.35).

Fig. 6.33 Longitudinal scan of the volar aspect of the metacarpophalangeal joint of the middle finger. The use of a smaller footprint probe such as the hockey stick probe shown here is ideal for the smaller joints, ligaments, and tendons of the fingers and thumbs.

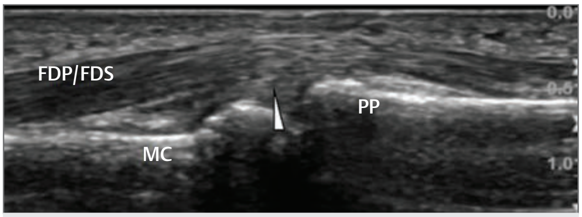

Fig. 6.34 Longitudinal image of the volar aspect of the metacarpophalangeal joint of the middle finger. The flexor tendons may be seen running superficially over the joint (FDP/FDS). Immediately below the flexor tendons the volar plate (*white arrowhead*) may be seen as an echoic structure reinforcing the anterior capsule of the joint. FDP/FDS, flexor digitorum profundus and superficialis; MC, metacarpal; PP, proximal phalanx.

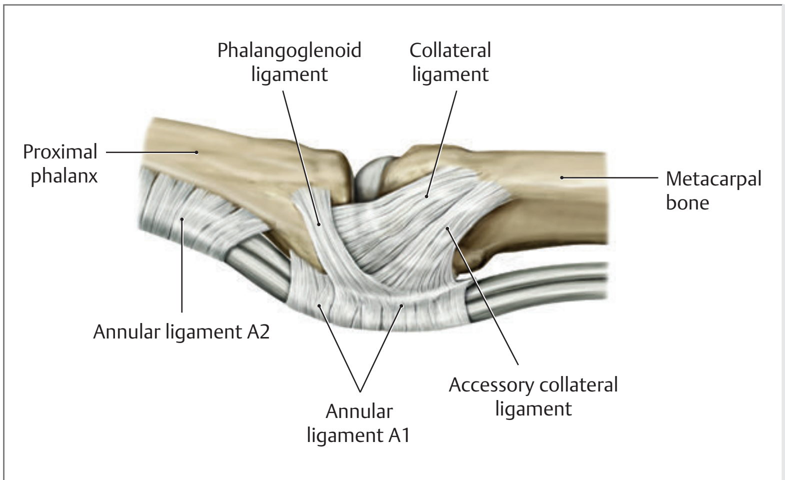

Fig. 6.35 Sagittal view of the metacarpophalangeal (MCP) joint of the index finger. The collateral, accessory collateral, and phalangoglenoid ligaments cannot be clearly identified as individual structures on ultrasound imaging. The first annular pulley (A1) begins in the volar plate of the MCP joint and extends to the base of the proximal phalanx. The second annular pulley (A2) rises from the volar aspect of the proximal portion of the proximal phalanx and extends to the distal third of the proximal phalanx. (Reproduced from Schuenke, Schulte, and Schumacher, Atlas of Anatomy, 2nd edition, ©2014, Thieme Publishers, New York. Illustration by Karl Wesker/Markus Voll.)

The Fingers: Flexor Tendons and Pulley System—A1–A5

Longitudinal Scan

The patient's forearm is positioned in supination with the hand resting on a table in front of the clinician. The probe is placed in the sagittal plane longitudinally over the volar aspect of the finger at the level to be assessed. Although the use of a small footprint linear probe allows better visualization of the small structures to be assessed, a large footprint probe allows a superior overview (▶Fig. 6.36, ▶Fig. 6.37, ▶Fig. 6.38, ▶Fig. 6.39).

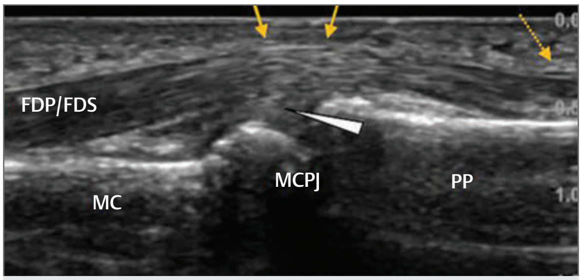

Fig. 6.37 Longitudinal image of the volar aspect of the metacarpophalangeal joint (MCPJ). The tendons of flexor digitorum profundus and superficialis (FDP/FDS) can be seen superficially to the joint. The A1 pulley is located anteriorly to these tendons at the level of the metacarpophalangeal joint (*yellow arrows*) is seen as a thin anechoic band. The A2 pulley is located at the midpoint of the proximal phalanx (PP) (*dashed arrow*).

Fig. 6.36 Longitudinal scan of the volar aspect of the ring finger. In this view the probe lies over the proximal and middle phalanx. In this position the A2, A3, and A4 pulleys can be visualized.

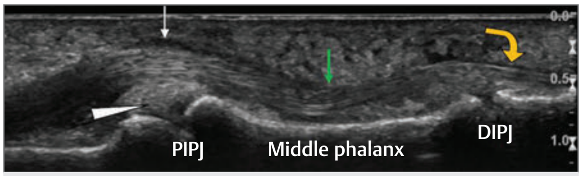

Fig. 6.38 Longitudinal scan of the volar aspect of the proximal interphalangeal joint (PIPJ) and distal interphalangeal joint (DIPJ). The A3 pulley is located at the level of the PIPJ (*white arrow*). The A4 pulley at the level of the mid-middle phalanx (*green arrow*) and the A5 pulley at the level of the DIPJ (*curved arrow*). White arrowhead, volar plate at the proximal interphalangeal joint.

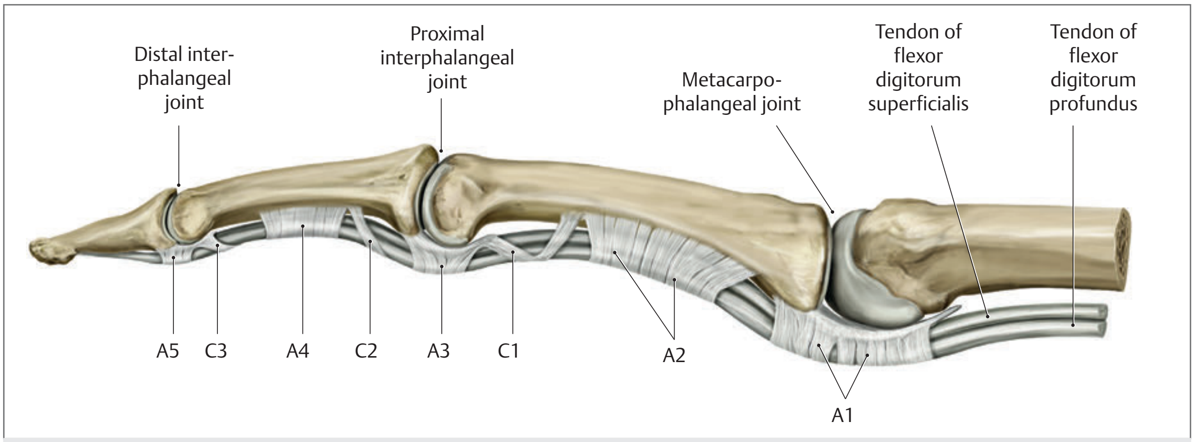

Fig. 6.39 Sagittal view of the index finger demonstrating the tendons of flexor digitorum profundus and superficialis and the relationship of the tendons with the annular and cruciate pulley system. The annular and cruciate ligaments serve to govern the flexor mechanism of the hand and wrist, providing critical constraints to the flexor tendons to prevent bowstringing upon contraction and excursion of extrinsic flexor musculotendinous units. The first annular ligament (A1 pulley), near the head of the metacarpal bone, lies in the flexor groove in the deep transverse metacarpal ligament. As a general rule, the A1, A3, and A5 ligaments in the fingers are "joint pulleys" that originate from the volar plate on the volar aspect of the metacarpophalangeal, proximal interphalangeal, and distal interphalangeal joints, respectively. The A2 and A4 ligaments arise from the periosteum on the proximal half of the proximal phalanx and the midportion of the middle phalanx, respectively. In the thumb, there are two annular ligaments and a single oblique ligament. The cruciate ligaments cannot be clearly visualized on ultrasound imaging. (Reproduced from Schuenke, Schulte, and Schumacher, Atlas of Anatomy, 2nd edition, ©2014, Thieme Publishers, New York. Illustration by Karl Wesker/Markus Voll.)

The Fingers: Flexor Tendons and Pulley System—A1–A5

Transverse Scan

The patient's forearm is positioned in supination with the hand resting on a table in front of the clinician. The probe is placed in the axial plane transversely over the volar aspect of the finger at the level to be assessed. The pulleys may be seen at the following levels:

- A1 pulley 0.5 cm proximal and distal to the metacarpophalangeal joint.
- A2 pulley midshaft of the proximal phalanx.
- A3 pulley level of the proximal interphalangeal joint
- A4 pulley midshaft of the middle phalanx.
- A5 pulley level of the distal interphalangeal joint.

The use of a small footprint linear probe allows better visualization of these small structures. However, it may still not be possible to clearly visualize the A3, A4, and A5 pulleys (▶Fig. 6.40, ▶Fig. 6.41).

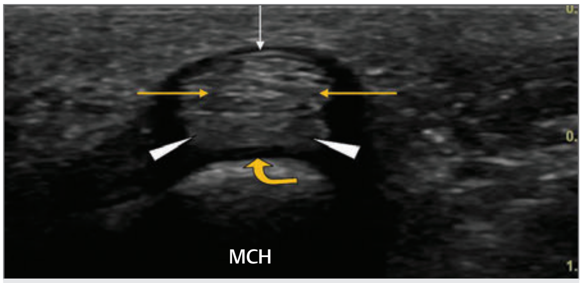

Fig. 6.40 Transverse image of the volar aspect of an index finger at the level of the metacarpal head (MCH). The articular cartilage of the metacarpal head can be seen as a anechoic layer over the head (*curved arrow*). The volar plate (*white arrowheads*) can be seen as a hyperechoic structure immediately anterior to the metacarpal head. Superficial to this the tendons of flexor digitorum profundus and superficialis can be seen (*yellow arrows*). Anterior to the flexor tendons a thin hyperechoic band can be seen indicating the A1 pulley (*white arrow*).

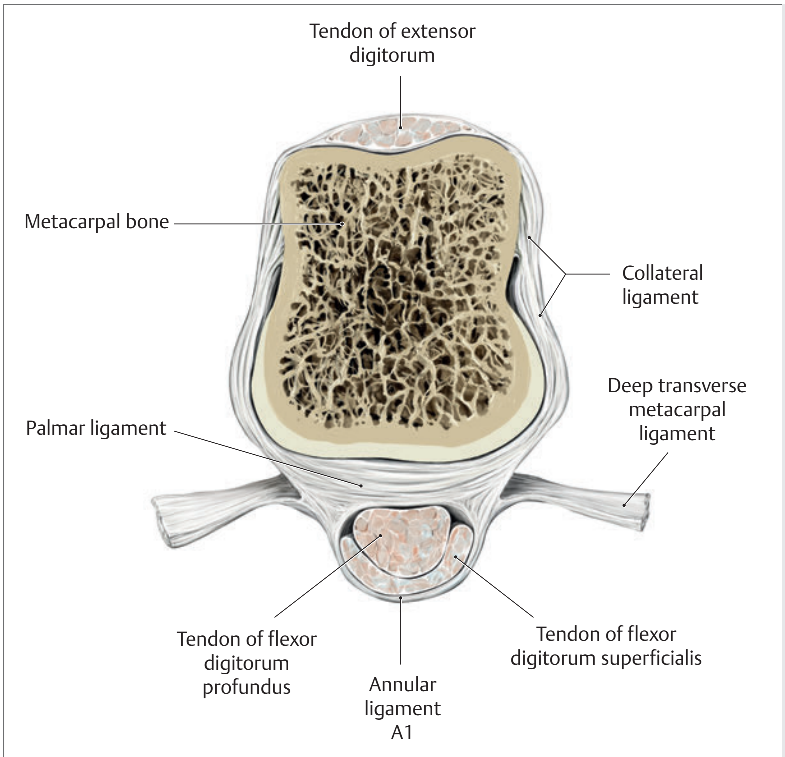

Fig. 6.41 Transverse section of the third metacarpal taken at the level of the distal metacarpal immediately proximal to the metacarpophalangeal joint. The illustration demonstrates the tendons of flexor digitorum profundus and superficialis and the surrounding flexor sheath which at this level is thickened to form the A1 annular ligament. Immediately deep to the tendons the palmar ligament (volar plate) may be seen. The tendon of extensor digitorum may be seen over the dorsal aspect of the metacarpal. (Reproduced from Schuenke, Schulte, and Schumacher, Atlas of Anatomy, 2nd edition, ©2014, Thieme Publishers, New York. Illustration by Karl Wesker/Markus Voll.)

The Thumb: First Carpometacarpal Joint

The patient's forearm is positioned in neutral with the hand resting on a table in front of the clinician. The patient is asked to clench his or her flexed thumb in the hand helping to gap the joint while at the same time stabilizing the thumb allowing better visualization of the joint.

The probe is placed in the coronal plane longitudinally over the dorsal aspect of the carpometacarpal joint. A small footprint linear probe allows much better visualization of the joint.

In addition to imaging the carpometacarpal joint from the dorsal aspect, the joint may also be imaged from its volar side through the thenar eminence (▶Fig. 6.42, ▶Fig. 6.43, ▶Fig. 6.44).

Fig. 6.42 Longitudinal scan of the dorsal aspect of the first carpometacarpal joint of the thumb. The joint may be located by passively flexing and extending the first metacarpal while palpating for the joint line. The patient is asked to clench the flexed thumb in their hand to help open and stabilize the joint.

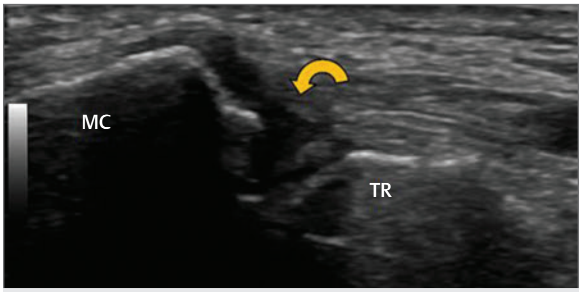

Fig. 6.43 Longitudinal image of the dorsal aspect of the first carpometacarpal joint (*curved yellow arrow*). The base of the first metacarpal (MC) should normally stand prominent in relation to the proximal trapezium (TR).

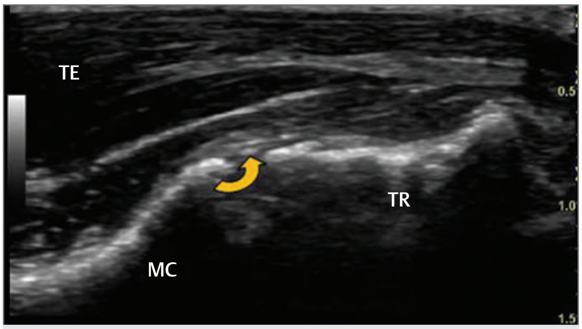

Fig. 6.44 Longitudinal image of the volar aspect of the first carpometacarpal joint (*curved yellow arrow*). The thenar eminence (TE) can be seen overlaying the joint. MC, base of the first metacarpal; TR, trapezium.

The Thumb: Ulnar Collateral Ligament

The patient's forearm is positioned in pronation with the hand resting on a table in front of the clinician. The thumb is positioned in extension. The probe is placed in an oblique sagittal plane longitudinally over the ulnar collateral ligament at the metacarpophalangeal joint of the thumb. The use of a small footprint linear probe allows better visualization of the ligament. Assessment of the ligament should include a careful study of the ligament's patency through dynamic scanning (▶Fig. 6.45, ▶Fig. 6.46).

Fig. 6.45 Longitudinal scan of the ulnar collateral ligament of the thumb at the metacarpophalangeal joint. The ligament is approximately 4–8 mm wide and 12–14 mm long. Assessment should include a dynamic study of the ligament's patency. This can be achieved with the help of a second clinician applying a valgus force through the joint. This should be carefully applied to avoid further damage to the ligament.

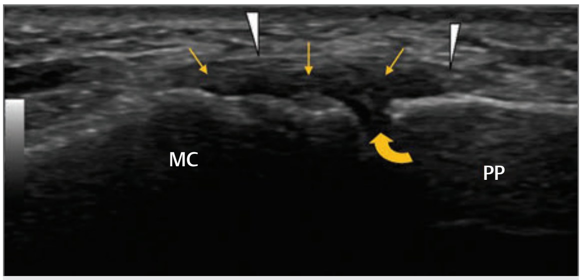

Fig. 6.46 Longitudinal image of the ulnar collateral ligament of the thumb at the metacarpophalangeal joint (*curved arrow*). The ulnar collateral ligament appears as a low echo structure arching across the joint (*yellow arrows*). In the normal state as demonstrated above the ligament should appear relatively flat. A thin anechoic line can be seen over the top of the ulnar collateral ligament representing the adductor aponeurosis (*white arrowheads*). MC, metacarpal; PP, proximal phalanx.

Finger and Thumb: Pathology

See ▶Fig. 6.47, ▶Fig. 6.48, ▶Fig. 6.49a,b; ▶Fig. 6.50a,b; ▶Fig. 6.51a,b; ▶Fig. 6.52, ▶Fig. 6.53, ▶Fig. 6.54, ▶Fig. 6.55, ▶Fig. 6.56, ▶Fig. 6.57).

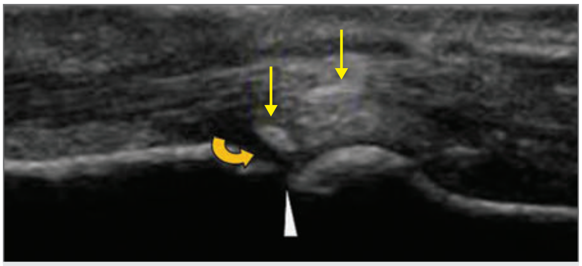

Fig. 6.47 Longitudinal image of the volar aspect of the metacarpophalangeal joint (*arrow head*). The volar plate appears thickened (*yellow arrows*) and it appears to be avulsed from the base of the phalanx (*curved arrow*).

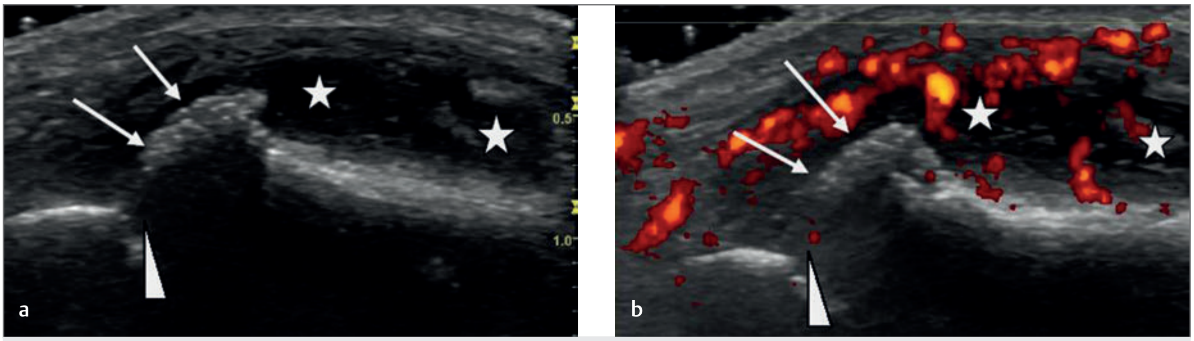

Fig. 6.48 (**a**) Longitudinal image of the metacarpophalangeal joint of the thumb (*arrowhead*). The head of the metacarpal appears prominent in relation to the phalanx indicative of subluxation (*white arrows*). In addition, there appears to be a significant effusion and synovial thickening (*white stars*). The patient had a chronic and active rheumatoid arthritis. (**b**) This is the same image as in part (a) except that Power Doppler imaging has been used to demonstrate that the thickened synovium is actively inflamed with a marked synovitis. White arrows, prominent metacarpal; white stars, effused joint with synovial thickening and an active synovitis as demonstrated with Power Doppler imaging.

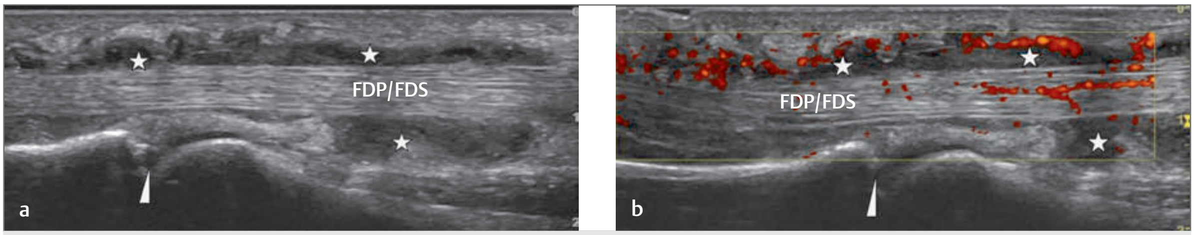

Fig. 6.49 (**a**) Longitudinal image of the volar aspect of the metacarpophalangeal joint (*white arrowhead*) of a left middle finger demonstrating intact tendons of flexor digitorum profundus and flexor digitorum superficialis (FDP/FDS). However, a marked effusion and synovitis can be seen with in the flexor sheath (*white stars*). The underlying metacarpophalangeal joint appears intact. (**b**) The use of Power Doppler imaging demonstrates that this effusion and synovial thickening is associated with an active synovitis (*white stars*). These findings are in keeping with a chronic flexor sheath tenosynovitis. White stars, effused joint with synovial thickening and an active synovitis as demonstrated with Power Doppler imaging.

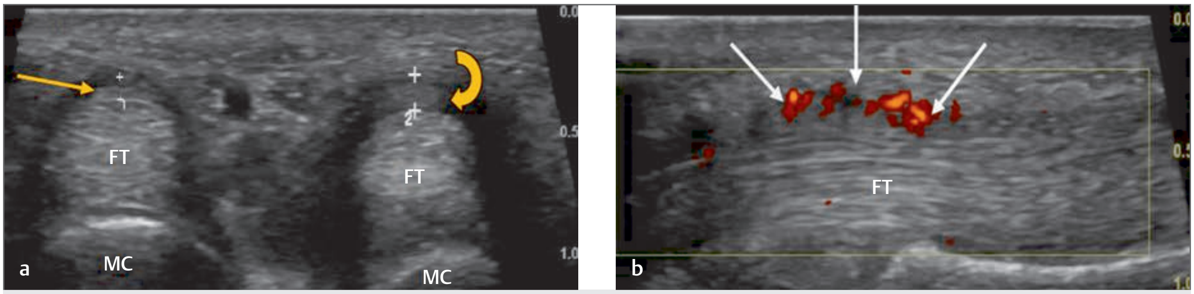

Fig. 6.50 (**a**) Transverse image of the volar aspect of the index (right) and middle finger (left) at the level of the metacarpal head (MC). The A1 pulley can be seen laying above the flexor tendons (FT) between the calipers. Thickening of the pulley may be seen at the index finger (right) (*curved arrow*). The A1 pulley at the middle finger (left) is of normal appearance (*yellow arrow*). Findings in keeping with a trigger finger. (**b**) Longitudinal image of the volar aspect of the index finger at the level of the metacarpophalangeal joint. In addition to the thickening of the A1 pulley demonstrated in part (a), there is also an associated synovitis (*white arrows*).

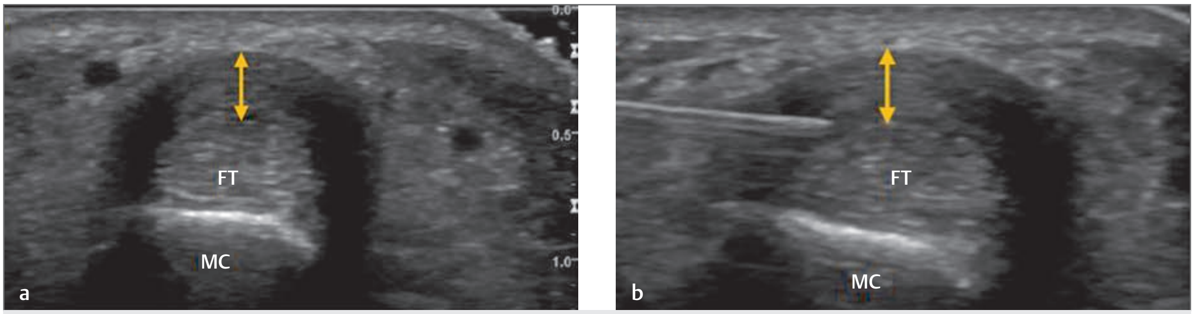

Fig. 6.51 (**a**) Transverse image of the volar aspect of a ring finger at the level of the metacarpal head demonstrating marked thickening of the A1 pulley (*double-headed arrow*). (**b**) Transverse image of the volar aspect of an index finger at the level of the metacarpal head demonstrating thickening of the A1 pulley (*double-headed arrow*). A needle can be seen being placed between the flexor tendons and A1 pulley prior to injection. This image demonstrates the accuracy that is possible with ultrasound guided injection. FT, flexor tendons; MC, metacarpal head.

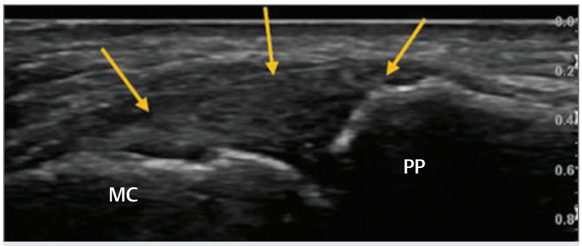

Fig. 6.52 Longitudinal image of the ulnar collateral ligament of the metacarpophalangeal joint of the thumb. The ulnar collateral ligament appears thickened (*yellow arrows*). However, there is no evidence of acute rupture or avulsion. Findings are in keeping with a grade I tear of the ulnar collateral ligament. MC, metacarpal; PP, proximal phalanx.

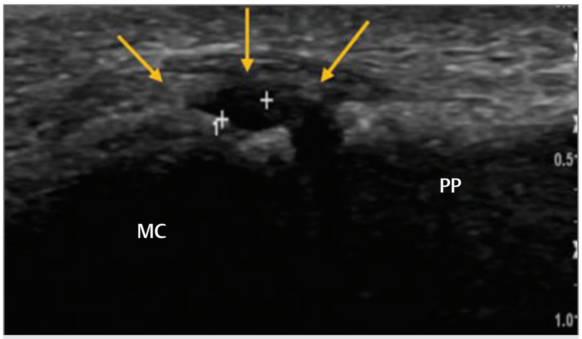

Fig. 6.53 Longitudinal image of the ulnar collateral ligament of the metacarpophalangeal joint of the thumb. A small anechoic foci can be seen within the deeper portion of the ligament over its origin on the metacarpal (between crosses). The more superficial fibers appear intact (*yellow arrows*). These findings are in keeping with an articular side partial tear (grade II) of the ulnar collateral ligament. Crosses, articular side tear within the deeper portion of the ulnar collateral ligament; MC, metacarpal; PP, proximal phalanx; yellow arrows, ulnar collateral ligament.

6

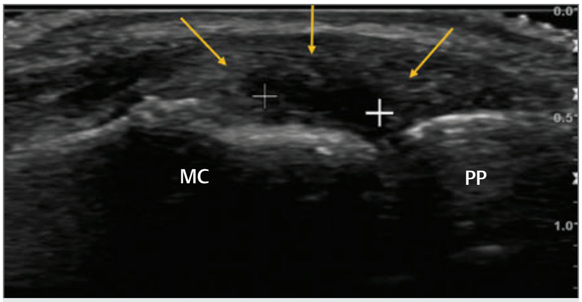

Fig. 6.54 Longitudinal image of the ulnar collateral ligament of the metacarpophalangeal joint of the thumb. The ligament demonstrates marked thickening with anechoic foci within its articular side. Findings are in keeping with a partial articular side tear of the ulnar collateral ligament with associated thickening. There is no evidence of a Stener lesion. The ligament appeared patent with stressing. Crosses, articular side tear within the deeper portion of the ulnar collateral ligament; MC, metacarpal; PP, proximal phalanx; yellow arrows, ulnar collateral ligament.

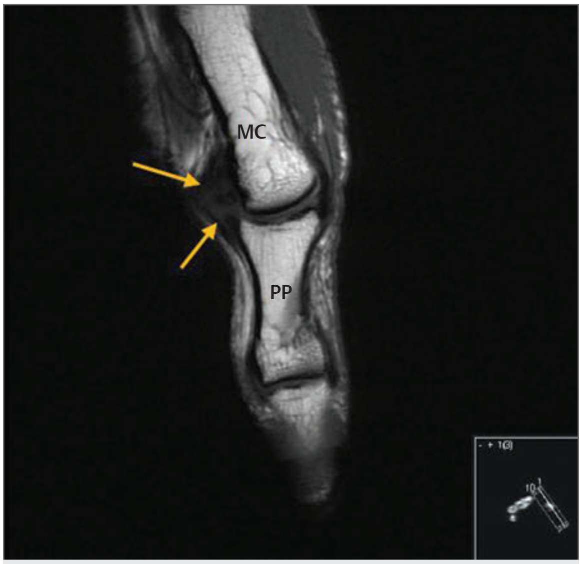

Fig. 6.55 Thumb-MRI coronal T1 images of the ulnar collateral ligament demonstrated in ▶Fig. 6.54. There appears to be a subluxation of the proximal phalanx at the metacarpophalangeal joint. In addition, there is a rupture of the ulnar collateral ligament in its midsubstance. It may be seen that the information obtained with the ultrasound in ▶Fig. 6.55 is just as accurate as the MRI scan. In addition, the ultrasound scan may be undertaken in an office setting and include dynamic imaging. MC, metacarpal; PP, proximal phalanx; yellow arrows, ulnar collateral ligament.

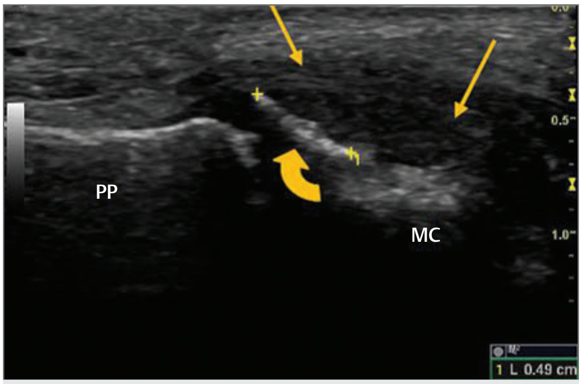

Fig. 6.56 Longitudinal image of the ulnar collateral ligament of the thumb. The ligament appears thickened but patent (*yellow arrows*). In addition, there appears to be an avulsion fracture from the base of the proximal phalanx (PP) measuring approximately 4.9 mm (*curved arrow*). These findings are in keeping with an avulsion fracture of the insertion of the ulnar collateral ligament. MC, metacarpal.

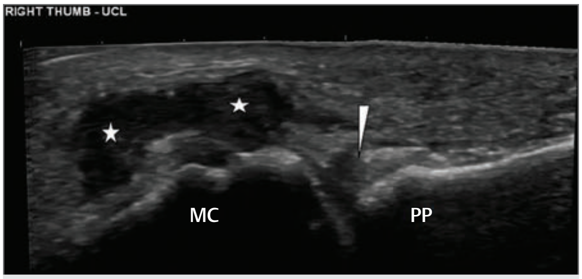

Fig. 6.57 Longitudinal image of the ulnar collateral ligament at the metacarpophalangeal joint of the thumb. Ultrasound demonstrates a large anechoic lesion overlying the ulnar aspect of the metacarpal head (*white stars*). The normal architecture of the ulnar collateral ligament cannot be seen (*white arrowhead*). When a valgus force was placed across the joint, there was an increased gapping of the joint. Findings are in keeping with a complete rupture of the ulnar collateral ligament and associated Stener lesion. MC, metacarpal; PP, proximal phalanx; white arrowhead, absence of normal architecture of the ulnar collateral ligament; white stars, Stener lesion.

7 The Wrist and Hand: Guided Injection Techniques

Abstract
This chapter outlines commonly used injection techniques at the wrist and hand. The aim is to detail the position and alignment of the probe and needle to allow accurate placement into the target tissue. In addition a brief clinical presentation is given for each condition as well as some of the anatomical considerations which should be noted. The drugs, dosages, and volumes given are those used in the author's clinic.

Keywords: proximal radiocarpal joint, midcarpal joints, carpometacarpal joints, metacarpophalangeal joints, proximal and distal interphalangeal joints, scapholunate ligament, dorsal extensor compartments and tendons, carpal tunnel, flexor tendons and pulley system

7.1 Wrist Joint Injection—Radiocarpal Joint

7.1.1 Cause

- Osteoarthritis.
- Rheumatoid arthritis.
- Overuse.

7.1.2 Presentation

- Pain is located within the wrist joint.
- The capsular restriction of the wrist results in an equal limitation of both passive flexion and extension.

7.1.3 Equipment

See ▶Table 7.1.

Table 7.1 Equipment needed for wrist joint injection—radiocarpal joint

Syringe	Needle	Corticosteroid	Local anesthetic	Transducer
5 mL	23 gauge – 1 inch	20-mg Depo-Medrone	2-mL 1% lidocaine	Small hockey stick

7.1.4 Anatomical Considerations

The radiocarpal joint is formed by the distal radius, triangular fibrocartilage, and the three bones of the proximal carpal row: the scaphoid, lunate, and triquetrum. Although the wrist joint as a whole is not continuous having various internal septa dividing it into separate compartments, a variable degree of communication can exist with the radiocarpal, intercarpal, midcarpal, and carpometacarpal joints often intercommunicating through a common synovial cavity.

This intercommunication can work to the advantage of the patient with generalized arthritic change as one injection into the midradiocarpal joint is able to perfuse throughout the wrist.

7.1.5 Procedure

- The patient is seated facing the clinician with the forearm and hand resting on a table palm facing down.
- The transducer is placed in the longitudinal plane over the midpoint of the dorsal aspect of the wrist joint. In this position, it should be possible to visualize the distal radius, lunate, and capitate.
- The needle is inserted at approximately 45 degrees to the transducer from a distal to proximal direction. The needle should lie along and parallel to the posterior surface of the lunate.
- The injection is given as a bolus into the radiocarpal joint.

7.1.6 The Injection

See ▶Fig. 7.1 and ▶Fig. 7.2.

7.1.7 Notes

The patient may be advised on a period of relative rest for 2 weeks during which time a splint is worn to protect the joint. Following this a programme of rehabilitation aimed at mobilizing and strengthening the wrist should be implemented.

Fig. 7.1 Wrist joint injection. The probe is placed in the longitudinal plane over the midpoint of the dorsal aspect of the wrist joint. In this position it should be possible to visualize the distal radius, lunate, and capitate. The needle is inserted at approximately 45 degrees to the probe from a distal to proximal direction. The needle should lie along and parallel to the posterior surface of the lunate. If the midcarpal joint is the aim, then the needle is aimed slightly more distally toward the midcarpal recess between the capitate and lunate.

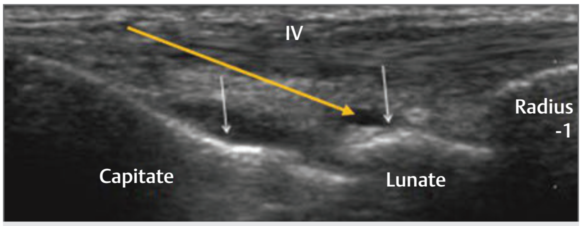

Fig. 7.2 Longitudinal image of the dorsal aspect of the wrist demonstrating the proximal radiocarpal joint to the right of the image between the distal radius and lunate. The midcarpal joint may be seen to the center of the image between lunate and capitate. The respective joint recesses are indicated by the white arrows. The tendons of the fourth dorsal compartment (IV) may be seen overlying both joints. The yellow arrow demonstrates the line of the needle to inject the proximal radiocarpal joint. White arrows, dorsal joint recesses of the proximal and midcarpal joints; yellow arrow, direction of the needle.

7.2 Carpometacarpal Joint of the Thumb Injection

7.2.1 Cause

- Osteoarthritis.

7.2.2 Presentation

- Pain is located at the base of the thumb and thenar eminence.
- The capsular restriction of the thumb is a painful passive restriction of both extension and abduction with the thumb gradually becoming fixed into an adducted position. In cases of advanced degeneration of the joint a loss of normal thenar muscle mass may also be noted.

7.2.3 Equipment

See ▶Table 7.2.

Table 7.2 Equipment needed for carpometacarpal joint of the thumb injection

Syringe	Needle	Corticosteroid	Local anesthetic	Transducer
2 mL	25 gauge –1 inch	10-mg Depo-Medrone	1-ml 1% lidocaine	Small hockey stick

7.2.4 Anatomical Considerations

The carpometacarpal joint of the thumb is formed by the articulation of the head of the first metacarpal and the trapezium proximally. The radial artery lies immediately proximal to the joint and should not be at risk.

7.2.5 Procedure

- The patient is seated facing the clinician with the forearm and hand resting on a table with the thumb facing upward.
- The thumb is flexed into the palm allowing the carpometacarpal joint to open laterally.
- The transducer is placed in the longitudinal plane over the carpometacarpal in line with the thumb.
- The needle is inserted at approximately 45 degrees to the transducer from a proximal to distal direction.
- The injection is given as a bolus into the carpometacarpal joint.
- If difficulty is experienced with correct needle placement, the clinician may passively flex and extend the metacarpal applying a gentle distraction force to the joint.

7.2.6 The Injection

See ▶Fig. 7.3 and ▶Fig. 7.4.

7.2.7 Notes

The patient may be advised on a period of relative rest for 2 weeks during which time a splint is worn to protect the joint. Following this a programme of rehabilitation aimed at mobilizing and strengthening the wrist and thenar muscles should be implemented.

Osteoarthritis of the carpometacarpal joint is a common presentation in older patients particularly in those who have had very manual occupations or taken part in sports involving high loading of the joint. Local injection followed by a programme of strengthening exercise can provide significant and long-term relief.

In mild to moderate cases of osteoarthritis in patients who are still very active injection of hyaluronan may provide a long-term relief of symptoms.

Fig. 7.3 Injection of the carpometacarpal joint of the thumb. The probe is placed in the longitudinal plane over the carpometacarpal in line with the thumb. The needle is inserted at approximately 45 degrees to the transducer from a proximal to distal direction. The injection is given as a bolus into the carpometacarpal joint.

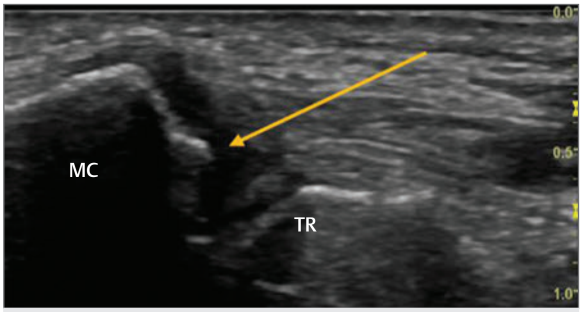

Fig. 7.4 Longitudinal image of the carpometacarpal joint of the thumb. The trapezium (TR) may be seen to the right of the image and the base of the first metacarpal (MC) to the left. The base of the metacarpal normally sits in a more superior position relative to the trapezium. This facilitates injection from a proximal to distal direction outlined by the yellow arrow. Yellow arrow, direction of the needle.

7.3 First Dorsal Compartment Injection—de Quervain's Tenosynovitis

7.3.1 Cause

- Overuse.

7.3.2 Presentation

- Pain is located at the base of the thumb and along the radial border of the wrist.
- Pain may be reproduced with resisted thumb extension and abduction.
- Pain may also be reproduced with Finkelstein's test which is performed by passively flexing the patient's thumb while the wrist is placed into ulnar deviation.

7.3.3 Equipment

See ▶Table 7.3.

7.3.4 Anatomical Considerations

The first dorsal compartment is located along the radial border of the wrist and consists of the tendons of abductor pollicis longus and extensor pollicis brevis which share a common tendon sheath. The tendon of abductor pollicis longus is situated more anteriorly and may be seen on ultrasound to consist of a number of different strands as it progresses distally.

The radial artery can be seen passing deep to the compartment at its more distal aspect. Overlaying the sheath the extensor retinaculum may be visualized.

Table 7.3 Equipment needed for first dorsal compartment injection—de Quervain's tenosynovitis

Syringe	Needle	Corticosteroid	Local anesthetic	Transducer
5 mL (10 mL[a])	25 gauge –1 inch	10-mg Depo-Medrone	2-mL (6-mL[a]) 1% lidocaine	Small hockey stick

[a]A higher volume should be considered in more chronic cases.

7.3.5 Procedure

- The patient is seated facing the clinician with the forearm and hand resting on a table and the thumb facing upward.
- Injection may be facilitated if the wrist is placed in a few degrees of ulnar deviation and the thumb is flexed into the palm.
- The transducer is placed over the first dorsal compartment in the longitudinal plane.
- The needle is inserted at approximately 45 degrees to the transducer from a distal to proximal direction. The needle should be placed immediately deep to the extensor retinaculum so that it lies resting against the tendons themselves.
- The injection is given as a bolus into the first compartment and should flow freely.
- If difficulty is experienced with injecting, then pressure is maintained on the syringe and the needle point moved slowly until flow is seen in the sheath.

7.3.6 The Injection

See ▶Fig. 7.5 and ▶Fig. 7.6.

7.3.7 Notes

Care should be taken that the injection is delivered into the tendon sheath and not seen to pool in the superficial tissues. The patient should be advised on relative rest for 2 weeks following the injection and thought given to activity modification.

In acute cases, ultrasound may demonstrate marked synovitis around within the tendon sheath. In these cases a relatively lower total volume should be used. In more chronic cases ultrasound may demonstrate marked thickening of the extensor retinaculum with "catching" of the tendons with passive ulnar and radial deviation of the wrist. In these cases a higher total volume of up to 5 or 6 mL should be considered. The total dosage of steroid should remain the same.

Fig. 7.5 Injection of the first dorsal compartment. The probe is placed over the first dorsal compartment in the longitudinal plane. The needle is inserted at approximately 45 degrees to the probe from a distal to proximal direction. The needle should be placed immediately deep to the extensor retinaculum so that it lies resting against the tendons themselves. A higher volume should be considered in more chronic cases.

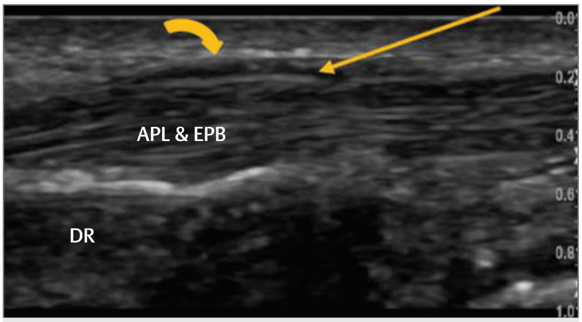

Fig. 7.6 Longitudinal image of the first dorsal compartment of the wrist. The first dorsal compartment consists of the tendons abductor pollicis longus (APL) and extensor pollicis brevis (EPB). The distal radius (DR) may be seen deep to the tendons. The extensor retinaculum should appear as a low echo band lying superficial to the tendons (*curved arrow*). The straight arrow indicates the direction of the needle which should lie deep to the extensor retinaculum.

7.4 A1 Pulley Injection—Trigger Finger or Thumb

7.4.1 Cause

- May be related to overuse but commonly idiopathic.

7.4.2 Presentation

- Painful clicking of the finger or thumb with an intermittent locking in a flexed position.
- Tenderness is felt at the volar aspect of the corresponding metacarpophalangeal joint.

7.4.3 Equipment

See ▶Table 7.4.

Table 7.4 Equipment needed for A1 pulley injection—trigger finger or thumb

Syringe	Needle	Corticosteroid	Local anesthetic	Transducer
2 mL (5 mL[a])	25 gauge –1 inch	10-mg Depo-Medrone	0.5-mL (2-mL[a]) 1% lidocaine	Small hockey stick

[a]A higher volume should be considered in more chronic cases.

7.4.4 Anatomical Considerations

Trigger finger is caused when the tendons of flexor digitorum superficialis and flexor digitorum profundus become caught as they pass beneath the A1 pulley at the level of the metacarpophalangeal joint.

Catching may be due to a localized swelling of the flexor tendon or a thickened A1 pulley. The A1 pulley extends approximately 0.5 cm proximal and distal to the metacarpophalangeal joint. On ultrasound it is visualized as a low echo, elliptical thickening of the flexor sheath.

7.4.5 Procedure

- The patient is seated facing the clinician with the forearm and hand resting on a table and palm facing upward.
- The transducer is placed over the A1 pulley at the level of the metacarpophalangeal joint in the longitudinal plane.
- The needle is inserted at approximately 45 degrees to the transducer from a proximal to a distal direction. The needle should be placed immediately deep to the A1 pulley so that it lies resting against the flexor tendons themselves.
- The injection is given as a bolus into the flexor sheath and should flow freely.
- Alternatively, a transverse or short-axis approach may be adopted. In this case the transducer is placed transversely over the A1 pulley in the transverse plane. The needle is inserted at 45 degrees to the transducer from either medially or laterally. The needle should be positioned immediately deep to the A1 pulley and the injection given as a bolus (see below).

7.4.6 The Injection

See ▶Fig. 7.7, ▶Fig. 7.8, ▶Fig. 7.9, and ▶Fig. 7.10.

Fig. 7.7 A1 Pulley injection. The probe is placed over the A1 pulley at the level of the metacarpophalangeal joint in the longitudinal plane. The needle is inserted at approximately 45 degrees to the probe from a proximal to a distal direction. The needle should be placed immediately deep to the A1 pulley so that it lies resting against the flexor tendons themselves.

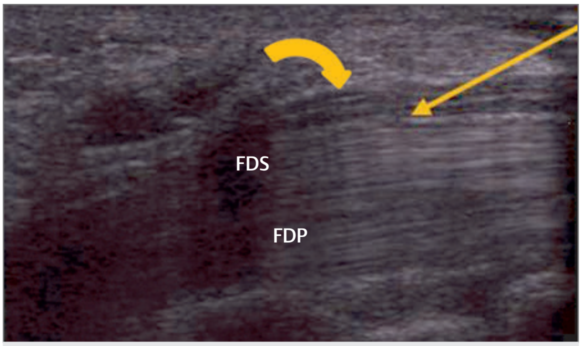

Fig. 7.8 Longitudinal image of the flexor tendons at the level of the metacarpophalangeal joint. The tendon of flexor digitorum superficialis (FDS) may be seen to overlay the tendon of flexor digitorum profundus (FDP). The A1 pulley appears as a thickened low echo band superficial to the flexor tendons in this symptomatic finger (*curved arrow*). The straight arrow indicates the direction of the needle which should lie deep to the A1 pulley. Straight yellow arrow, direction of the needle.

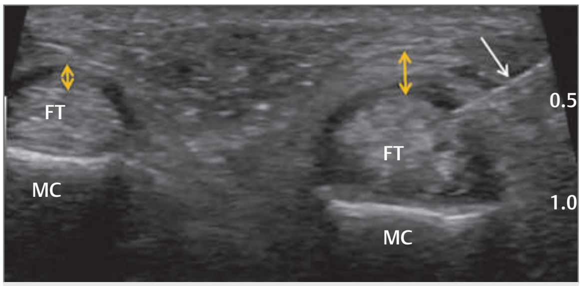

Fig. 7.9 Alternative transverse or short-axis approach. Transverse image of the flexor tendons (FT) at the level of the distal metacarpal (MC). The double-headed arrows demonstrates a significantly thickened A1 pulley at the finger on the right of the image while of normal thickness at finger toward the left side. The white arrow indicates the needle entering the flexor sheath at the level of the A1 pulley.

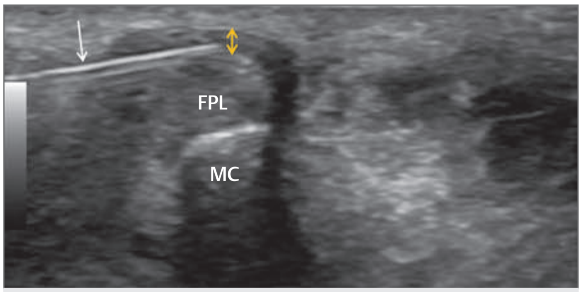

Fig. 7.10 Injection for trigger thumb. Alternative transverse or short-axis approach. Transverse image of the tendon of flexor pollicis longus (FPL) at the level of the distal metacarpal (MC). The double-headed arrow demonstrates a thickened A1 pulley. The white arrow indicates the needle entering the flexor sheath at the level of the A1 pulley.

7.4.7 Notes

The patient is advised to avoid gripping and carrying activities for 48 hours.

Injection for trigger finger can be extremely effective if carried out at an early stage. If the condition has become chronic, ultrasound often demonstrates significant thickening of the A1 pulley. If this is the case, a higher-volume injection is often more effective.

Many patients with trigger finger will go on to develop similar problems in other fingers over time.

7.5 Ganglion Cyst: Guided Aspiration

(A ganglion cyst may occur anywhere and is described here as it is a common presentation at the wrist. The principle described below applies to any ganglion cyst).

7.5.1 Cause

- May be related to overuse.
- More commonly idiopathic.

7.5.2 Presentation

- Commonly a nontender firm swelling associated with a joint capsule or tendon sheath. The patient may describe some pain if the cyst impinges against other structures or impedes movement.

7.5.3 Equipment

See ▶Table 7.5.

7.5.4 Anatomical Considerations

Thought to surrounding anatomical structures needs to be given in view of the location of the ganglion cyst. Doppler imaging should be used to locate relevant vascular structures.

Table 7.5 Equipment needed for ganglion cyst: guided aspiration

Syringe	Needle	Corticosteroid	Local anesthetic	Transducer
5 mL	16 gauge[a]	N/A	2-mL 1% lidocaine	Small hockey stick

[a] The gauge of the needle will be dependent on the size and location of the cyst. However, as most cystic structures contain gelatinous material, a 16-gauge needle may be required. A higher volume should be considered in more chronic cases.

7.5.5 Procedure

- The patient is seated facing the clinician with the forearm and hand resting on a table and palm facing downward.
- The transducer is placed over the cyst.
- The needle is inserted at approximately 45 degrees to the transducer so that it enters the body of the cyst.
- Aspiration may be facilitated if injection of local anesthetic is first given.
- Needle gauge will be dependent on the size and position of the cyst. However, as most cystic structures contain gelatinous material a 16-gauge needle may be required.

7.5.6 Guided Aspiration

See ▶Fig. 7.11, and ▶Fig. 7.12.

Fig. 7.11 Aspiration of ganglion cyst. The probe is placed over the cyst. The needle is inserted at approximately 45 degrees to the probe so that it enters the body of the cyst. Aspiration may be facilitated if injection of local anesthetic is first given. Needle gauge will be dependent on the size and position of the cyst. However, as most cystic structures contain gelatinous material a 16-gauge needle may be required.

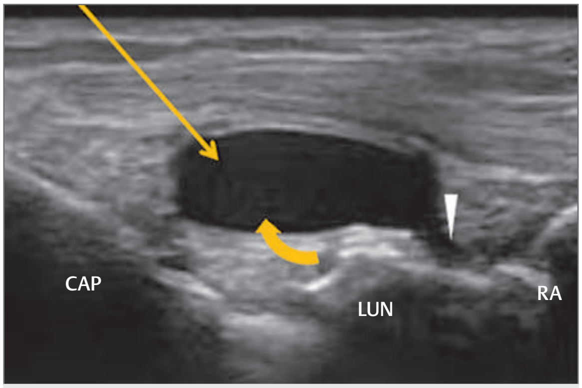

Fig. 7.12 Longitudinal image of the dorsal aspect of the wrist joint. A well-defined anechoic swelling (*curved arrow*) may be seen lying superficially over the dorsal aspect of the lunate (LUN). The swelling may be seen to have origin from the proximal radiocarpal joint (*arrowhead*). The swelling exhibits posterior enhancement. The appearances are in keeping with a dorsal wrist ganglion. The needle direction is given by the straight yellow arrow. Arrowhead, ganglion origin; CAP, capitate; curved arrow, ganglion; RA, distal radius; straight arrow, direction of the needle.

7.6 Carpal Tunnel Syndrome: Guided Injection

7.6.1 Cause

- Commonly related to pregnancy. May also be related to rheumatoid arthritis or hypothyroidism.
- There may be a history of previous trauma such as wrist fracture.
- Commonly may present as idiopathic.

7.6.2 Presentation

Paresthesia in the distribution of the median nerve. The patient typically describes symptoms as being worse at night causing sleep disturbance. In more advanced cases, the patient may also describe loss of normal dexterity with difficulty with fine movements of the fingers and thumb.

Clinically, there may be a positive Tinel's sign on percussion over the median nerve at the carpal tunnel. In addition, Phalen's test may be positive with the patient describing a reproduction of symptoms with full wrist flexion for 30 seconds.

7.6.3 Equipment

See ▶Table 7.6.

7.6.4 Anatomical Considerations

The carpal tunnel is formed by the carpal bones of the wrist posteriorly and the flexor retinaculum anteriorly. The flexor retinaculum attaches to four sites, the pisiform and hook of hamate medially and the scaphoid tubercle and trapezium laterally. It is approximately the width of the thumb and lies so that its proximal edge is at the distal wrist crease. The median nerve lies superficially within the carpal tunnel at approximately its midpoint below the tendon of palmaris longus (if present) and medial to the tendon of flexor carpi radialis.

Table 7.6 Equipment needed for carpal tunnel syndrome: guided injection

Syringe	Needle	Corticosteroid	Local anesthetic
1 mL	25 gauge –1 inch	20-mg Depo-Medrone	Nil

7.6.5 Procedure

- The patient is seated facing the clinician with the forearm and hand resting on a table and palm facing upward.
- The transducer is placed over the carpal tunnel so that its proximal edge lies at the distal wrist crease in the transverse plane.
- The median nerve is identified in transverse section and the needle is inserted at approximately 45 degrees at a right angle to the transducer from a proximal direction so that it lies alongside the nerve at its radial or ulnar side.
- The probe may be turned through 90 degrees to visualize the needle longitudinally once the needle has been correctly position next to the nerve.
- The injection is given as a bolus into the carpal tunnel and should flow freely.
- Alternatively, a transverse approach may be used. The transducer is again placed over the median nerve at the carpal tunnel in the transverse plane. The needle is inserted at 45 degrees to the transducer from either the ulnar or radial aspect so that it lies immediately below the median nerve. Injection is again given as a bolus (see below).

7.6.6 The Injection

See ▶Fig. 7.13, ▶Fig. 7.14, and ▶Fig. 7.15.

Fig. 7.13 Carpal tunnel injection. The probe is placed over the carpal tunnel so that its proximal edge lies at the distal wrist crease in the transverse plane. The median nerve is identified in transverse section and the needle is inserted at approximately 45 degrees at a right angle to the transducer from a proximal direction so that it lies alongside the nerve at its radial or ulnar side. In this alignment the needle point will appear as a small echogenic dot alongside the nerve. The probe may be turned through 90 degrees to visualize the needle longitudinally once the needle has been correctly positioned next to the nerve.

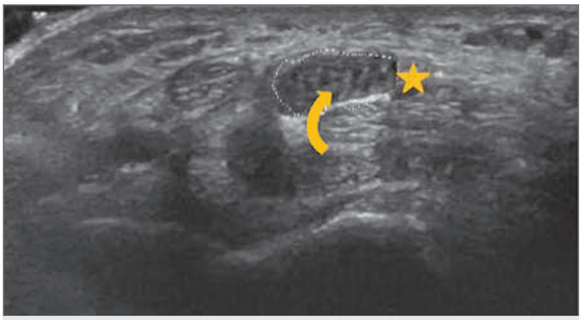

Fig. 7.14 Transverse image of the median nerve within the carpal tunnel. In the approach outlined in ▶Fig. 7.13, the probe is used to identify the median nerve (*curved arrow*) in transverse section and the needle placed immediately alongside the nerve. With this approach the needle will only appear as a small dot alongside the nerve (*yellow star*).

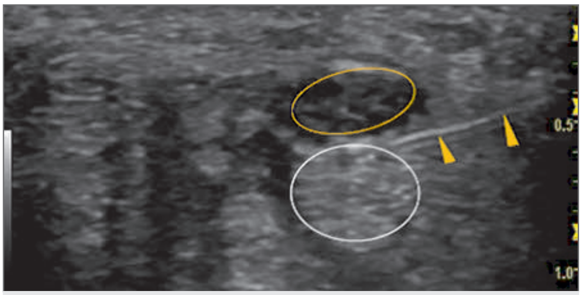

Fig. 7.15 Median nerve (*yellow circle*) in transverse section. The needle (*yellow arrowheads*) may be seen approaching from the right side of the image to lie immediately below the median nerve and superficial to a flexor tendon (*white circle*).

7.6.7 Notes

The injection is only given with corticosteroid. Local anesthetic is avoided as increased volume is likely to put more pressure on the nerve and should be kept to a minimum. If the condition is of less than 6 months' duration, injection may be effective. However, the more chronic the nature of the condition, the less likely it is that an injection will be effective and a surgical opinion should be considered.

8 The Hip: Diagnostic Imaging

Abstract
Ultrasound examination has always had a relatively limited role in the assessment of hip pathology due to restrictions with regard to the deeper joints such as the shoulder and hip from which little detail of internal structure may be determined. However, despite these limitations much hip pathology is well detected provided that the clinician is familiar with the normal anatomy of the hip. Examination includes assessment of the soft tissues, tendons, ligaments, and muscles, and also of the bone and joint where there is acoustic access allowing adequate visualization.

Ultrasound is of particular use in the evaluation of the periarticular soft tissues and in the detection of both intra and periarticular synovial effusions and collections, and if required provides an easy and non traumatic guidance for needle aspiration for diagnostic purposes or therapeutic intervention. Given the complex anatomy around the hip joint, the examiner should make accurate differential diagnoses based on careful history taking and objective findings in order to focus on the relative appropriate structures of the hip prior to scanning. The hip is usually divided into four quadrants during scanning, the anterior, medial, lateral, and posterior aspects and accurate clinical information allows the examiner to focus on particular quadrants. It would not be a normal practice to examine all four quadrants in all patients.

An ultrasound examination of the hip should be conducted with a large footprint linear probe of a medium to low frequency (9-12 MHz). In the larger patient, a low frequency curvilinear probe may be of benefit.

Keywords: hip joint, labrum, psoas bursa, trochanteric bursa, iliopsoas, rectus femoris, sartorius, tensor fascia latae, gluteus maximus, gluteus medius, gluteus minimus, ischium, hamstrings, adductors

8.1 Diagnostic Imaging of the Hip: Introduction

Examination of the hip will be dependent on the specific structure and pathology suspected from a thorough clinical examination. Based on this examination it would be normal to scan one or two specific structures. In addition to static scanning dynamic imaging should be included particularly when imaging tendons and ligaments to fully assess the patency of these structures. It should be noted that examination of the hip can be problematic particularly in the muscular or obese patient given the anatomical position of the joint. The use of relatively low-frequency ultrasound should be used where necessary to maximize image quality.

Imaging includes the following:

- Anterior—supine
  - Hip joint including the femoral head, neck, capsule, and anterior synovial recess.
  - Anterior labrum.
  - Iliopsoas muscle, tendon, and bursa.
  - Anterior inferior iliac spine (AIIS) and the tendon and muscle of rectus femoris.
  - Anterior superior iliac spine (ASIS) and the tendons and muscles of sartorius and tensor fascia lata.
  - Lateral femoral cutaneous nerve and inguinal ligament.
- Medial region—supine in frog-leg position
  - Adductor tendons and muscles.
- Lateral—side lying
  - Gluteus maximus, tensor fascia lata, and the fascia lata.
  - Gluteus medius muscle and tendon.
  - Gluteus minimus muscle and tendon.
  - Greater trochanter and bursa (if pathological).
- Posterior—prone lying
  - Hamstring muscles and tendon.
  - Ischial tuberosity and bursa (if pathological).
- Midline—supine lying
  - Symphysis pubis.

8.1.1 Anterior

Anterior Hip Joint: Longitudinal Scan

The hip joint may only be effectively visualized from its anterior aspect which also allows imaging of the anterior femoral recess and the iliopsoas tendon and bursa (if pathological).

The patient is positioned in supine. A small pillow placed under the knee allows the hip to rest in a few degrees flexion which can facilitate scanning. To visualize the anterior aspect of the hip joint and the anterior femoral recess, a large footprint probe is required. In addition, given the depth of the joint particularly in the larger patient, a low-frequency probe should be used (▶Fig. 8.1, ▶Fig. 8.2, ▶Fig. 8.3).

Fig. 8.1 Longitudinal scan of the anterior aspect of the hip joint. The probe is placed over the joint in the sagittal oblique plane. A large footprint probe should be utilized. A low frequency may be required particularly in the larger patient.

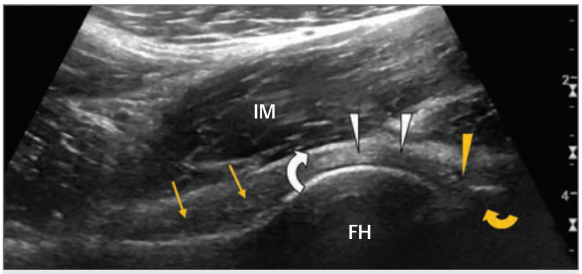

Fig. 8.2 Longitudinal image of the anterior aspect of the hip joint. In this example, a linear probe has been used in sector mode to better visualize both the hip joint and the anterior femoral recess. The psoas bursa cannot be seen in its normal state. If pathological, it will appear as a low echo foci overlaying the anterior capsule (*curved white arrow*). The anterosuperior labrum appears as an echogenic triangle at the acetabulum (*yellow arrowhead*). Curved white arrow, location of psoas bursa; curved yellow arrow, anterior margin of acetabulum; FH, femoral head; IM, iliopsoas muscle; white arrowheads, anterior capsule of hip joint and iliofemoral ligament.

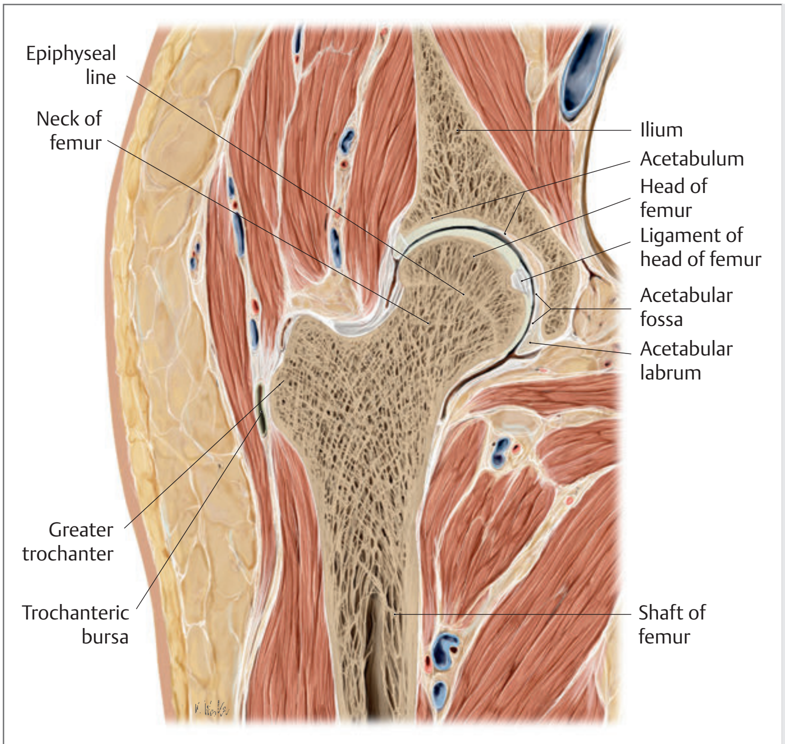

Fig. 8.3 Coronal section of the right hip. Note how far the anterosuperior capsule extends down the femoral neck to form the anterior femoral recess. The illustration demonstrates a trochanteric bursa immediately lateral to the greater trochanter. In reality, however, it has been shown that a considerable variation in both the number and position of bursae around the lateral hip can exist. Bursae may be present beneath the gluteus maximus muscle and the fascia lata overlaying the gluteus medius tendon and deep to the gluteus minimus tendon. In the normal nonpathological state the bursae are not normally seen with ultrasound imaging. (Reproduced from Gilroy and MacPherson, Atlas of Anatomy, 3rd edition, ©2016, Thieme Publishers, New York. Illustration by Karl Wesker/Markus Voll.)

Anterior Inferior Iliac Spine: Longitudinal Scan

The patient is positioned in supine. A small pillow placed under the knee allows the hip to rest in a few degrees flexion which may facilitate scanning. The probe is placed over the AIIS in the sagittal plane to image both the AIIS and the tendon of rectus femoris. The use of a large footprint probe allows for better visualization of this area. In the larger patient, a low-frequency curvilinear probe should be used (▶Fig. 8.4, ▶Fig. 8.5).

Fig. 8.4 Longitudinal scan of the anterior aspect of the hip joint to image the anterior inferior iliac spine (AIIS) and tendon of rectus femoris. The probe is placed over the joint in the sagittal plane. A large footprint probe should be utilized. A low frequency may be required particularly in the larger patient.

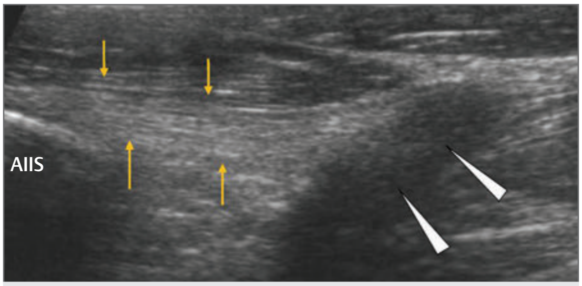

Fig. 8.5 Ultrasound image of the anterior aspect of the hip and the anterior inferior iliac spine (AIIS). The tendon of rectus femoris has two separate attachments, a direct head from the AIIS (*yellow arrows*) and a deeper attachment from the anterior superior acetabulum (*white arrowheads*). This deeper indirect attachment can be seen on imaging as a low echo region due to anisotropy because of the fiber orientation in relation to the probe. White arrowheads, rectus femoris tendon (indirect tendon); yellow arrows, rectus femoris tendon (direct tendon).

Anterior Inferior Iliac Spine: Transverse Scan

The transducer is placed over the AIIS in the transverse plane to image the origin of the direct tendon of rectus femoris. The transducer is then moved in a caudal direction maintaining alignment in the transverse plane to image first the musculotendinous junction of the rectus femoris and then the muscle belly itself which can be found positioned between tensor fasciae lata, sartorius, and iliopsoas. More distally the muscle of rectus femoris may be seen to overlay the vastus intermedius muscle belly (► Fig. 8.6, ► Fig. 8.7, ► Fig. 8.8, ► Fig. 8.9).

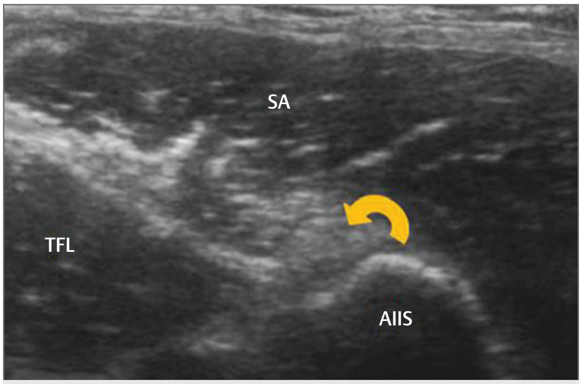

Fig. 8.6 Ultrasound image of the anterior aspect of the hip and anterior inferior iliac spine (AIIS). The tendon of rectus femoris can be seen as echogenic foci anterior to the AIIS (*curved yellow arrow*). Laterally to the tendon and the AIIS, the muscle of tensor fasciae lata (TFL) can be seen. Sartorius (SA) can be seen overlaying the AIIS and rectus femoris tendon.

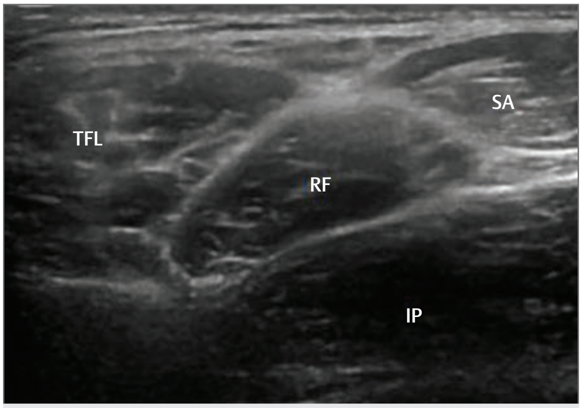

Fig. 8.7 Ultrasound image of the upper third of the thigh distal to the AIIS demonstrating the muscle belly of rectus femoris (RF) situated between the muscles of tensor fasciae latae (TFL) laterally and sartorius (SA) medially. The muscle belly of iliopsoas (IP) can be seen deep to the rectus femoris.

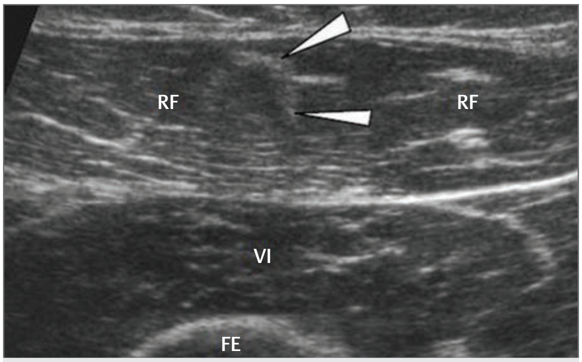

Fig. 8.8 Ultrasound image of the anterior aspect of the midthigh. The rectus femoris (RF) muscle can be seen to overlay the muscle of vastus intermedius (VI). The central aponeurosis of rectus femoris (*arrowheads*) is a direct extension of the indirect tendon. The femur (FE) may be seen deep to the muscle of vastus intermedius.

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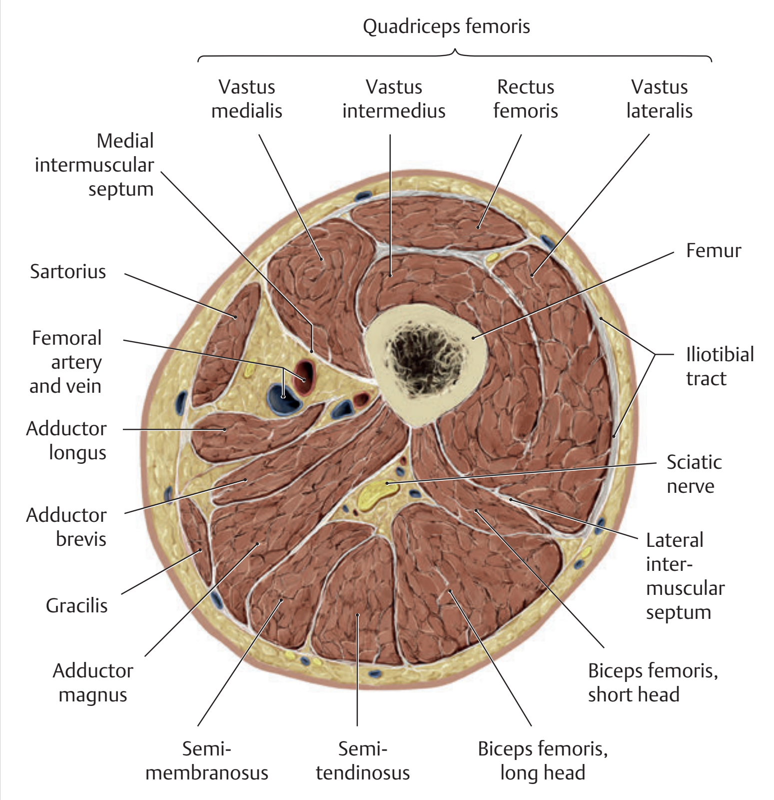

Fig. 8.9 Transverse section of the midthigh. In cross-section, the thigh is divided up into three distinct compartments separated by fascia using the femur as an axis. Each of these compartments has its own blood and nerve supply and contains a different group of muscles. The anterior compartment muscles of the thigh include pectineus, sartorius, and the four muscles that comprise the quadriceps muscles—rectus femoris, vastus medialis, vastus intermedius, and vastus lateralis. The posterior compartment muscles of the thigh are the hamstring muscles, which include semimembranosus, semitendinosus, and biceps femoris. The medial compartment muscles are adductor magnus, adductor longus, adductor brevis, and adductor gracilis. Note the relationship of the quadriceps, hamstrings, and medial thigh muscles, in particular, the extent to which the quadriceps vastus intermedius and lateralis wrap around the lateral thigh deep to the iliotibial tract. (Reproduced from Schuenke, Schulte, and Schumacher, Atlas of Anatomy, 2nd edition, ©2014, Thieme Publishers, New York. Illustration by Karl Wesker/Markus Voll.)

Anterior Superior Iliac Spine: Transverse Scan

The patient is positioned in supine and the probe is placed over the ASIS in the transverse plane to image the tendons of sartorius medially and tensor fasciae lata laterally. Each tendon may be followed distally to view the musculotendinous junction and more distally the muscle belly itself. The muscle of rectus femoris may be seen to lie between the muscles of sartorius and tensor fasciae lata in the upper part of the thigh (▶Fig. 8.10).

Anterior Superior Iliac Spine: Longitudinal Scan

The probe is turned through 90 degrees so that it lies in the sagittal plane with its proximal edge against the ASIS. With the probe directed a few degrees medially, the tendon of sartorius can be seen and when directed laterally, the tendon of tensor fasciae latae can be viewed (▶Fig. 8.11).

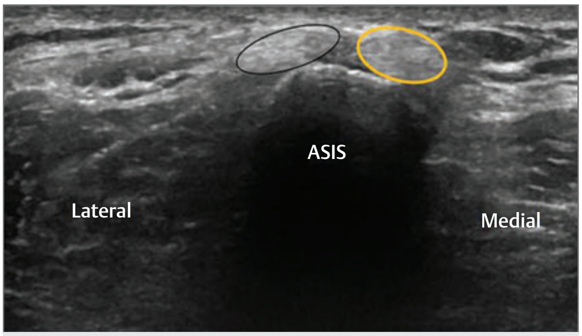

Fig. 8.10 Ultrasound image of the anterior superior iliac spine (ASIS). The probe is placed transversely over the ASIS in the transverse plane. The tendons of sartorius and tensor fascia lata share a common attachment at the ASIS. If the probe is moved distally, the two tendons can be seen to separate with sartorius directed medially (*yellow oval*) and tensor fascia lata directed laterally (*black oval*).

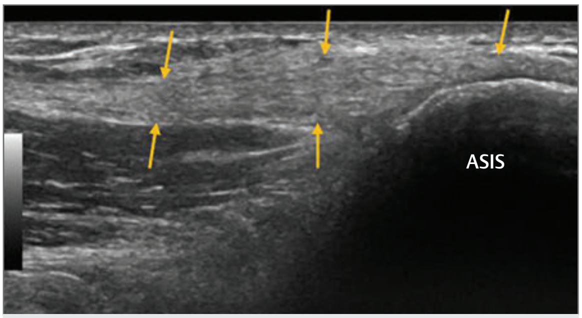

Fig. 8.11 Longitudinal image at the anterior superior iliac spine (ASIS). The probe has been placed in the sagittal oblique plane so that it is directed medially to lie over the tendon of sartorius (*yellow arrows*). If directed laterally over the tendon of tensor fascia lata, a similar appearance would be seen.

Lateral Femoral Cutaneous Nerve and Inguinal Ligament: Transverse Scan

Immediately medial to the anterior superior iliac spine in the transverse oblique plane the lateral femoral cutaneous nerve may be seen deep to the inguinal ligament as an ovoid hypoechoic foci (▶Fig. 8.12).

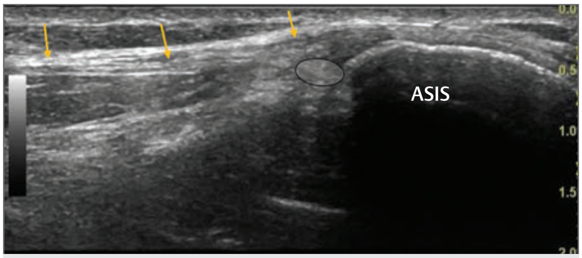

Fig. 8.12 Ultrasound image of the anterior superior iliac spine (ASIS) and the medial inguinal ligament (*yellow arrows*). The probe has been placed in the transverse oblique plane so that its medial edge lies over the ASIS. Immediately medial to the ASIS and deep to the inguinal ligament the lateral cutaneous nerve of the thigh may be seen (*black oval*).

Fig. 8.14 X-ray of anteroposterior (AP) pelvis corresponding with the ultrasound image in ▶Fig. 8.13. The X-ray demonstrates marked degenerative changes within the right hip joint with complete loss of joint space superiorly, subchondral cysts, and subchondral sclerosis. Moderate degenerative changes are noted within the left hip joint.

Anterior Hip: Pathology

See ▶Fig. 8.13, ▶Fig. 8.14, ▶Fig. 8.15, ▶Fig. 8.16a,b, and ▶Fig. 8.17.

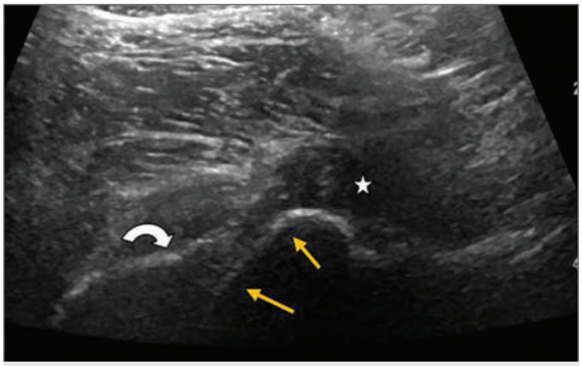

Fig. 8.13 Longitudinal image of the anterior aspect of the right hip joint demonstrating flattening of the femoral head (*yellow arrows*) with an associated effusion in the anterior aspect of the hip joint (*white star*). These findings are indicative of marked degenerative change. Curved white arrow, acetabulum.

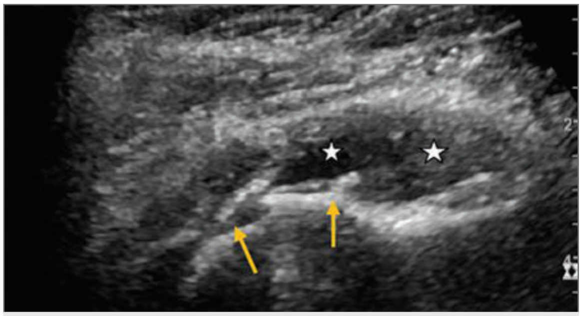

Fig. 8.15 Longitudinal image of the anterior aspect of the hip joint (here the use of a low-frequency curvilinear probe has been used). The image demonstrates marked irregularity of the femoral head (*yellow arrows*) and a large effusion in the anterior femoral recess (*white stars*). These findings are indicative of advanced degenerative change.

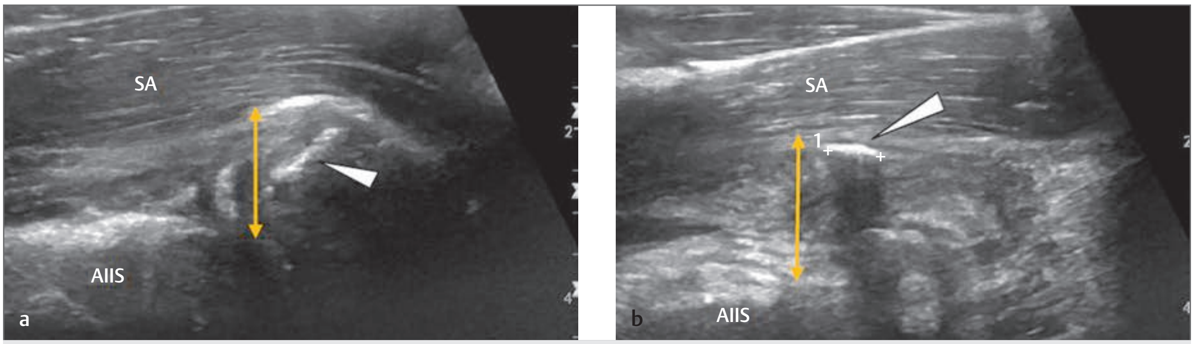

Fig. 8.16 (a,b) Longitudinal and transverse images, respectively, of the anterior aspect of the hip joint and anterior inferior iliac spine (AIIS). Images demonstrate disruption of the AIIS and thickening of the rectus femoris tendon (direct tendon) (*yellow arrow*). In addition, an avulsed fragment can be seen within the tendon substance measuring 6 mm in transverse view (*white arrowhead*). These findings are in keeping with a partial tear of the rectus femoris tendon and avulsion fracture of the AIIS. SA, sartorius.

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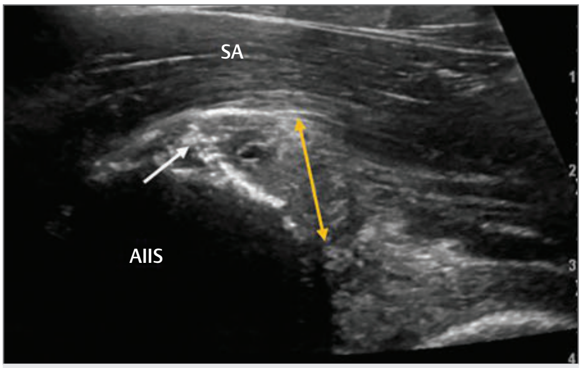

Fig. 8.17 Longitudinal image of the anterior inferior iliac spine (AIIS). There appears to be some cortical irregularity of the AIIS (*white arrow*). In addition, there appears to be marked thickening and loss of normal echogenicity within the tendon of rectus femoris (*yellow arrow*). These findings are in keeping with an insertional tendinopathy of the right rectus femoris tendon. SA, sartorius; white arrow, cortical irregularity of the AIIS; yellow arrow, rectus femoris tendon (direct tendon).

8.1.2 Medial

Medial Hip: Longitudinal Scan

The patient is positioned in supine with the leg to be examined flexed and abducted a few degrees at the hip and in some external hip rotation (frog-leg position). The knee should be in a few degrees flexion. The probe is placed in the anatomical coronal plane so that it lies longitudinally over the bulk of the adductor muscles and tendons. The proximal edge of the probe should lie against the inferior pubic rami. In this position three distinct layers should be visible with the adductor insertion being visible proximally as a triangular hypoechoic structure (▶Fig. 8.18, ▶Fig. 8.19, ▶Fig. 8.20).

- **Superficial:** Adductor longus (anterior) and gracilis (posterior).
- **Intermediate:** Adductor brevis.
- **Deep:** Adductor magnus.

Fig. 8.18 Longitudinal scan of the medial aspect of the hip. The probe is placed in the anatomical coronal plane to lie over the midline of the medial thigh and longitudinally over the adductor muscles and tendons. The proximal edge of the probe should lie against the inferior pubic rami.

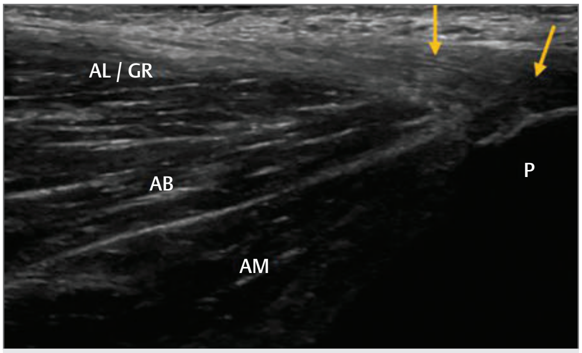

Fig. 8.19 Longitudinal image of the medial aspect of the hip. The adductor muscles can be seen to form three distinct layers. With the probe placed just anterior to the midline, the most superficial muscle is adductor longus (AL). If placed more posteriorly, the most superficial muscle is gracilis (GR). Whether the probe is anteriorly or posteriorly positioned, the next layer is formed by adductor brevis (AB) with the deepest layer being formed by adductor magnus (AM). P, pubic rami; yellow arrows, common adductor tendon.

8

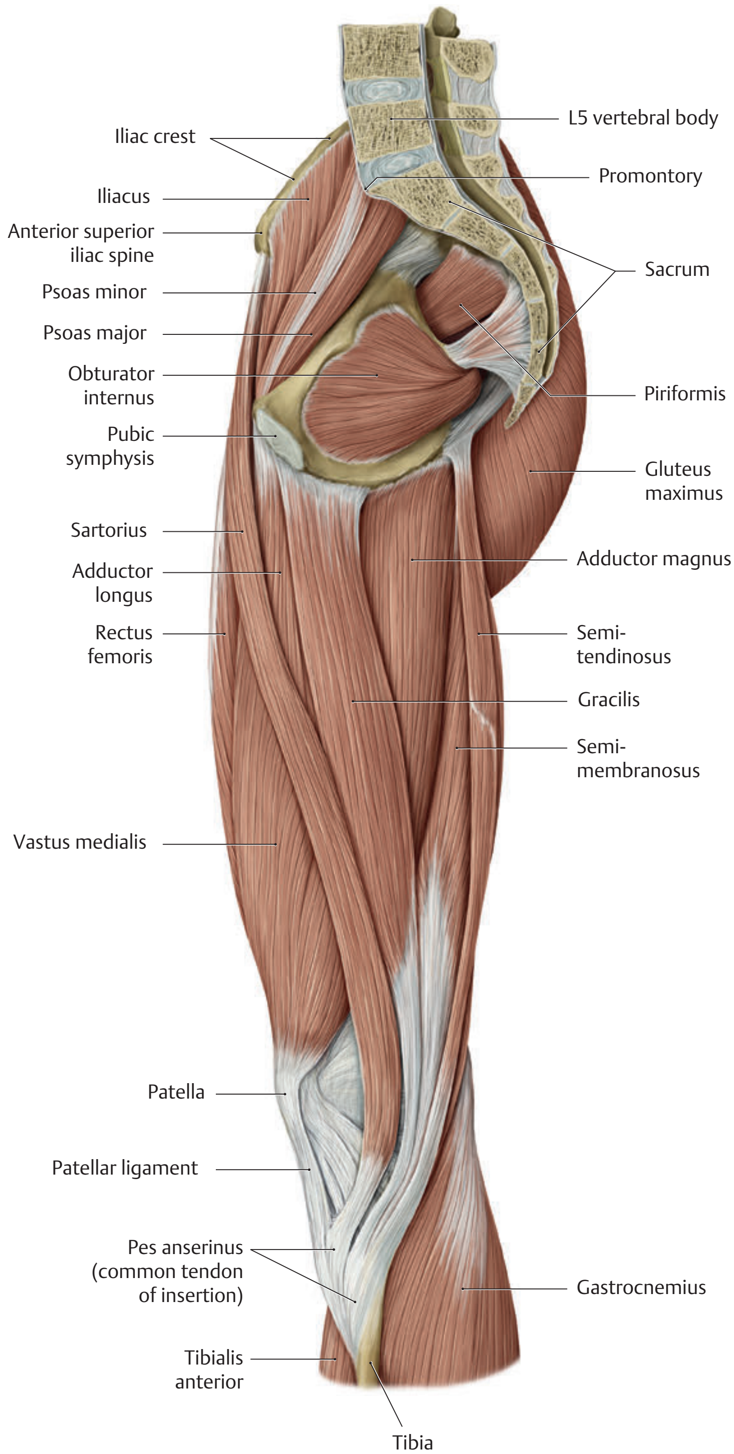

Fig. 8.20 Medial sagittal view of the right hip and medial thigh muscles. The medial compartment of thigh is one of the fascial compartments of the leg. The muscles in the medial compartment are gracilis, adductor longus, adductor brevis, and adductor magnus. The obturator externus and pectineus muscles may also be considered part of this group although these are not clearly seen on ultrasound imaging. The adductor magnus muscle consists of two parts. The portion which arises from the ischiopubic ramus is called the pubofemoral portion or adductor portion, and the portion arising from the tuberosity of the ischium is called the ischiocondylar portion or hamstring portion. (Reproduced from Schuenke, Schulte, and Schumacher, Atlas of Anatomy, 2nd edition, ©2014, Thieme Publishers, New York. Illustration by Karl Wesker/Markus Voll.)

Medial Hip: Pathology

See ▶Fig. 8.21.

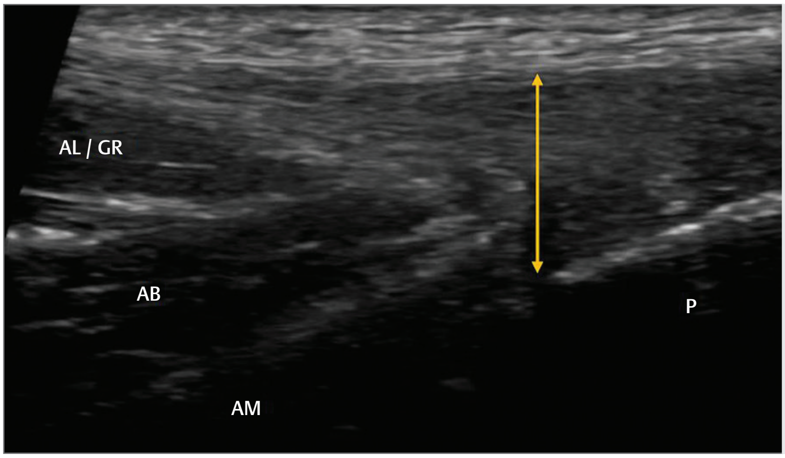

Fig. 8.21 Longitudinal image of the medial aspect of the thigh at the origin of the common adductor tendon. The tendon appears thickened and of low echogenicity (*yellow arrow*) in keeping with an adductor tendinopathy. AB, adductor brevis; AL, adductor longus; AM, adductor magnus; GR, gracilis; P, pubis; yellow arrow, thickened adductor tendon.

8.1.3 Lateral

Lateral Hip: Longitudinal Scan

The patient is positioned in side lying with the hips and knees in flexion. The probe is placed in the anatomical coronal plane so that it lies longitudinally over the greater trochanter. In this position, it should be possible to visualize the lateral fascia of the thigh overlying the gluteus medius and minimus tendons at their insertion onto the greater trochanter. It should be noted that although a diagnosis of trochanteric bursitis is often given, ultrasound more commonly demonstrates evidence of a gluteal tendinopathy (▶Fig. 8.22, ▶Fig. 8.23, ▶Fig. 8.24).

Fig. 8.22 Longitudinal scan of the lateral aspect of the hip. The probe is placed in the anatomical coronal plane to lie in longitudinal axis over the greater trochanter.

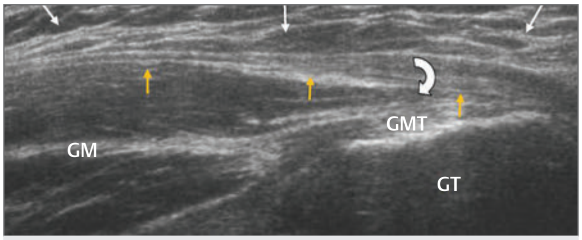

Fig. 8.23 Longitudinal image of the lateral aspect of the hip. The probe is placed in the coronal plane. The image demonstrates the superficial subcutaneous fatty tissue (*white arrows*) with the lateral fascia of the thigh lying deep to this (*yellow arrows*). Deep to this can be seen the gluteus medius (GM) muscle and gluteus medius tendon (GMT) attaching to the greater trochanter (GT). The curved arrow demonstrates the position of the trochanteric bursa. In practice this is rarely seen.

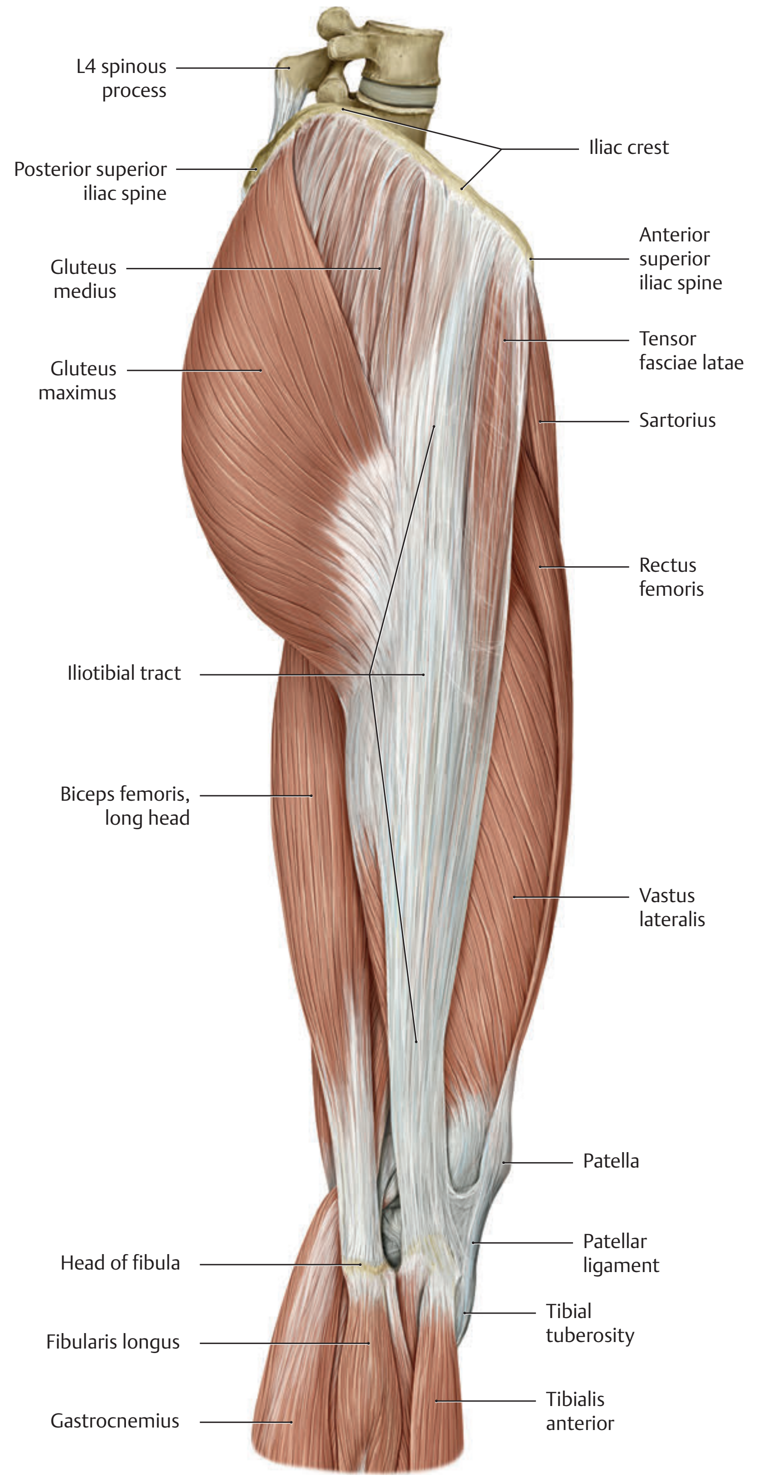

Fig. 8.24 Lateral coronal view of the hip and thigh. The iliotibial tract or iliotibial band (ITB) is a longitudinal fibrous reinforcement of the fascia lata. The action of the ITB and its associated muscles is to extend, abduct, and laterally rotate the hip. In addition, the ITB contributes to lateral knee stabilization. During knee extension, the ITB moves anterior to the lateral condyle of the femur, while at approximately 30 degrees knee flexion the ITB moves posterior to the lateral condyle. It originates at the anterolateral iliac tubercle portion of the external lip of the iliac crest and inserts at the lateral condyle of the tibia at Gerdy's tubercle. The figure shows only the proximal and midportions of the iliotibial tract. The part of the iliotibial band which lies beneath the tensor fasciae latae is prolonged upward to join the lateral part of the capsule of the hip joint. The tensor fasciae latae effectively tightens the iliotibial band around the area of the knee allowing for bracing of the knee especially in lifting the opposite foot during normal gait.
The gluteus maximus muscle and the tensor fasciae latae insert upon the tract. (Reproduced from Schuenke, Schulte, and Schumacher, Atlas of Anatomy, 2nd edition, ©2014, Thieme Publishers, New York. Illustration by Karl Wesker/Markus Voll.)

Lateral Hip: Transverse Scan

The patient is positioned in side lying with the hips and knees in flexion. The probe is placed in the anatomical transverse plane so that it lies over the greater trochanter.

In this position, it should be possible to visualize the lateral fascia of the thigh overlying the gluteus medius and minimus tendons at their insertion onto the greater trochanter (▶Fig. 8.25, ▶Fig. 8.26).

Fig. 8.25 Transverse scan of the lateral aspect of the hip. The probe is placed in the anatomical transverse plane over the greater trochanter.

Lateral Hip: Pathology

See ▶Fig. 8.27.

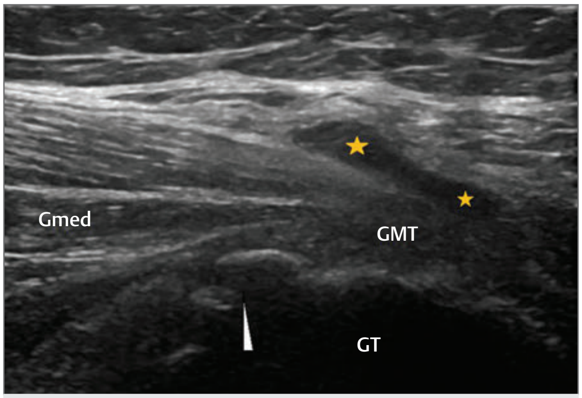

Fig. 8.27 Longitudinal image of the lateral hip. The probe has been placed in the coronal plane over the greater trochanter (GT). Some irregularity is noted on the greater trochanter (*white arrowhead*). The gluteus medius tendon (GMT) appears intact. Overlying the gluteus medius tendon a low echo swelling (*yellow stars*) indicates a trochanteric bursitis. Gmed, gluteus medius muscle; white arrowhead, cortical irregularity; yellow stars, trochanteric bursitis.

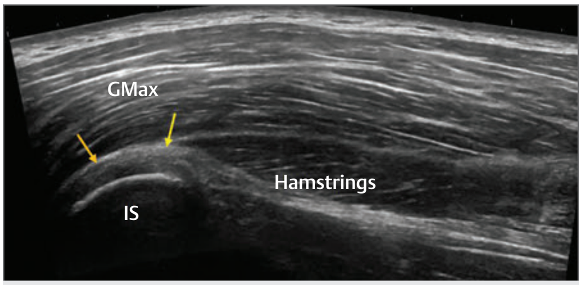

Fig. 8.29 Longitudinal image (extended field of view) of the ischium (IS) and common proximal hamstring tendon (*yellow arrows*). The common tendon is formed from the tendons of biceps femoris, semimembranosus, and semitendinosus although the individual tendons cannot be identified. The tendon should have a uniformly echogenic appearance and demonstrate no evidence of thickening. GMax, gluteus maximus.

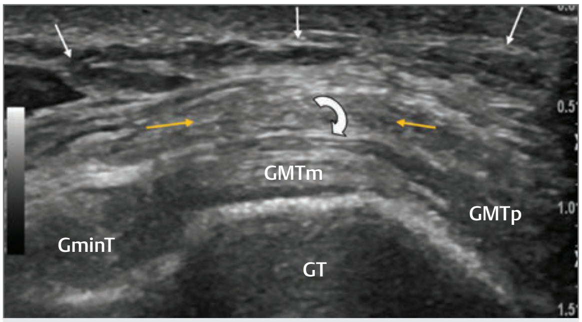

Fig. 8.26 Transverse image of the lateral aspect of the hip. The probe is placed in the transverse plane over the greater trochanter. The subcutaneous fatty tissue can be seen to lie superficially (*white arrows*). Below this can be seen the lateral fascia of the thigh (*yellow arrows*). The tendon of gluteus medius can be seen to attach to the middle (GMTm) and posterior (GMTp) aspect of the greater trochanter (GT). The tendon of gluteus minimus attaches to the anterior facet of the trochanter (GminT). Curved arrow, position of trochanteric bursa; GminT, gluteus minimus tendon; GMTm, gluteus medius middle attachment; GMTp, gluteus medius posterior attachment; GT, greater trochanter; white arrows, subcutaneous fat; Yellow arrows, lateral fascia.

8.1.4 Posterior

Posterior Hip: Longitudinal Scan

The patient is positioned in side lying with the hips and knees in flexion. This allows better visualization of the ischium. The probe is placed in the anatomical sagittal plane so that it lies longitudinally over the ischium and common hamstring tendon (▶Fig. 8.28, ▶Fig. 8.29, ▶Fig. 8.30).

Fig. 8.28 Longitudinal scan of the ischium and common hamstring tendon. The probe is placed in the anatomical sagittal plane over the ischium and proximal hamstring tendon.

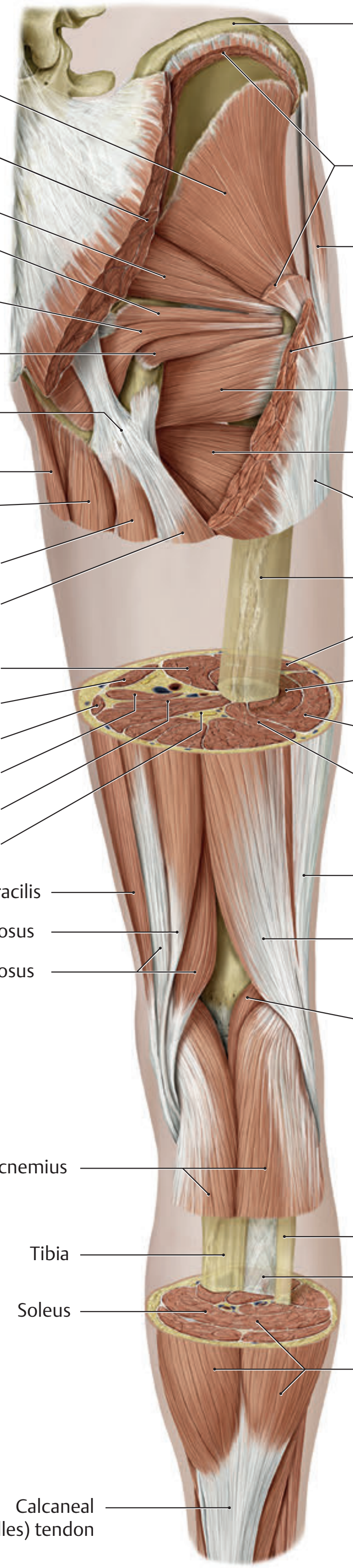

Fig. 8.30 Posterior windowed dissection of the hip and thigh. The illustration demonstrates the relationship between the gluteus maximus, medius, and minimus muscles. The long head of biceps femoris arises from the medial facet of the ischial tuberosity (the short head arising from the lateral linea aspera, lateral supracondylar line, and intermuscular septum). The semitendinosus tendon arises from the inferomedial impression of the upper portion of the ischial tuberosity by way of a conjoint tendon with the long head of the biceps femoris muscle. The semimembranosus tendon originates on the superolateral aspect of the ischial tuberosity beneath the proximal half of the semitendinosus muscle. The semimembranosus tendon runs medial and anterior to the other hamstring tendons. Clinically, the biceps femoris is most commonly injured, followed by semitendinosus. Semimembranosus injury is rare. Imaging may be useful in differentiating the grade of injury serving as a useful guide to treatment. The deep muscles of the hip including the obturator internus, the superior and inferior gemelli, and quadratus femoris are not easily visualized with ultrasound. (Reproduced from Schuenke, Schulte, and Schumacher, Atlas of Anatomy, 2nd edition, ©2014, Thieme Publishers, New York. Illustration by Karl Wesker/Markus Voll.)

Posterior Hip: Transverse Scan

The patient is positioned in side lying with the hips and knees in flexion. This allows better visualization of the ischium. The probe is placed in the anatomical transverse plane so that it lies over the ischium and common hamstring tendon (▶Fig. 8.31, ▶Fig. 8.32).

Fig. 8.31 Transverse scan of the ischium and common hamstring tendon. The probe is placed in the anatomical transverse plane over the ischium and proximal hamstring tendon.

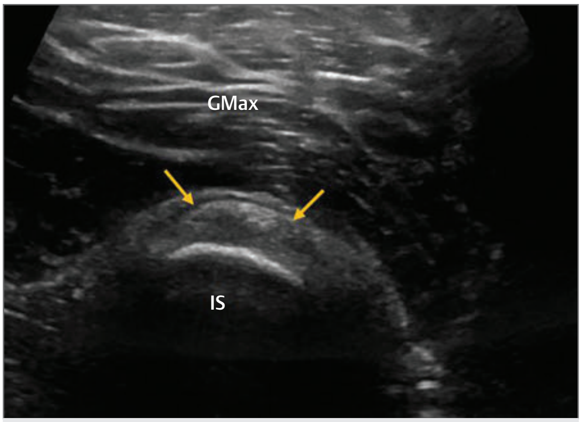

Fig. 8.32 Transverse image of the ischium (IS) and common proximal hamstring tendon (*yellow arrows*). The common tendon is formed from the tendons of biceps femoris, semimembranosus, and semitendinosus although the individual tendons cannot be identified. The tendon should have a uniformly echogenic appearance and demonstrate no evidence of thickening as is seen in this image. GMax, gluteus maximus.

Posterior Hip: Pathology

See ▶Fig. 8.33 and ▶Fig. 8.34.

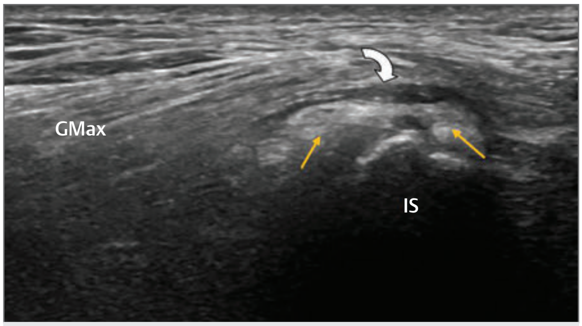

Fig. 8.33 Transverse image of the ischium (IS) which appears irregular. The common hamstring tendon (*yellow arrows*) can be seen to be irregular in keeping with tendinopathy and possible partial tear. An anechoic swelling can be seen to overlie the tendon (*curved arrow*). These findings are in keeping with fluid in the ischial bursa. GMax, gluteus maximus.

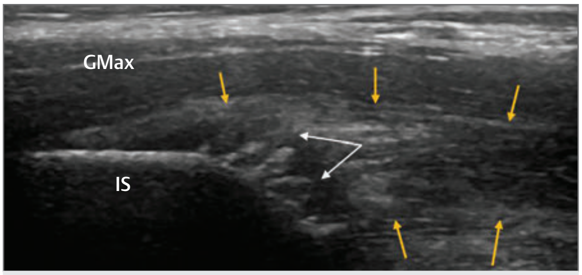

Fig. 8.34 Longitudinal image of the ischium (IS) and common hamstring tendon (*yellow arrows*). The tendon demonstrates a loss of normal echogenicity and echogenic foci at the origin of the tendon in keeping with tendinopathy and enthesiophytes. GMax, gluteus maximus; white arrows, enthesiophytes.

8.1.5 Symphysis Pubis

The patient is positioned in supine and the probe is placed in the transverse oblique plane so that it lies over the anterosuperior aspect of the symphysis pubis (▶Fig. 8.35).

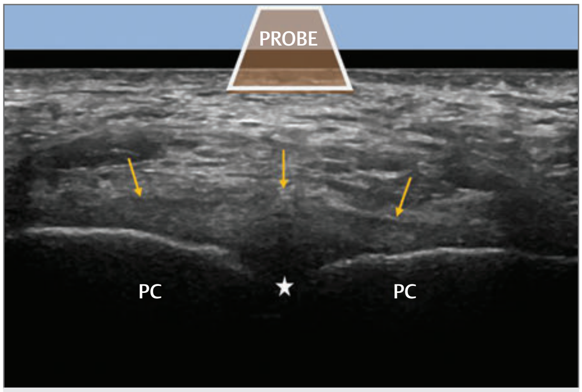

Fig. 8.35 Transverse image of the symphysis pubis. The probe is placed in the transverse oblique plane over the anterosuperior aspect of the symphysis pubis. The fibrocartilage (*white star*) of the symphysis pubis appears as an anechoic 'gap' between the two pubic crests (PC). The superior pubic ligament is seen as an echogenic layer arching over the fibrocartilage from one pubic crest to another (*yellow arrows*). White star, fibrocartilage of symphysis pubis; yellow arrows, superior pubic ligament.

Symphysis Pubis: Pathology

See ▶Fig. 8.36 and ▶Fig. 8.37.

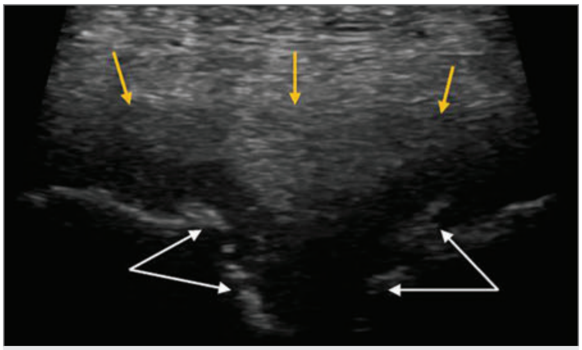

Fig. 8.36 Transverse image of the symphysis pubis. The probe is placed in the transverse oblique plane over the anterosuperior aspect of the symphysis pubis. The image demonstrates significant bony irregularity bilaterally at the pubic bones (*white arrows*). In addition, the superior pubic ligament appears thickened (*yellow arrows*). These findings are in keeping with a chronic osteitis pubis.

Fig. 8.37 Anteroposterior (AP) X-ray of the pelvis. The X-ray is of the same symphysis pubis as outlined in ▶Fig. 8.36 and demonstrates marked cortical irregularity of both pubic bones (*white arrows*) in keeping with a chronic osteitis pubis.

9 The Hip: Guided Injection Techniques

Abstract
This chapter outlines commonly used injection techniques around the hip joint. The aim is to detail the position and alignment of the probe and needle to allow accurate placement into the target tissue. In addition, a brief clinical presentation is given for each condition as well as some of the anatomical considerations which should be noted. The drugs, dosages, and volumes given are those used in the author's clinic.

Keywords: hip joint, labrum, psoas bursa, trochanteric bursa, iliopsoas, rectus femoris, sartorius, tensor fascia latae, gluteus maximus, gluteus medius, gluteus minimus, ischium, hamstrings, adductors

9.1 Hip Joint Injection

9.1.1 Cause

- Most commonly due to an underlying osteoarthritis.
- A common presentation in the athlete with a femoral–acetabular impingement (CAM and pincer lesion).
- May be secondary to trauma or overuse.

9.1.2 Presentation

Pain felt in the groin with referral into the anterior thigh region. Occasionally pain may radiate into the lower lumbar region.

If the cause of pain is osteoarthritis, the hip presents in a classic capsular pattern of restriction with a painful loss of the following:

- Most internal rotation with a hard end feel.
- Less extension.
- Least abduction.

If the cause of pain is a femoral–acetabular impingement, pain may be reproduced with flexion, abduction, and internal rotation of the hip.

9.1.3 Equipment

See ▶Table 9.1.

Table 9.1 Equipment needed for hip joint injection

Syringe	Needle	Corticosteroid	Local anesthetic	Transducer
10 mL	22-gauge spinal needle	40-mg Depo-Medrone	5-mL 1% lidocaine	Large linear footprint or curvilinear probe in larger patients

9.1.4 Anatomical Considerations

The safest and easiest technique is to use an anterolateral approach. The clinician need not worry about any major blood vessels or nerves if this technique is used. The needle is directed toward the femoral head or the anterior femoral recess.

9.1.5 Procedure

- The patient is positioned in the supine position with the knee flexed on a pillow to 20 degrees. The hip is in slight abduction.
- The probe is positioned over the anterior aspect of the hip joint in the transverse oblique plane. This should be in the same plane as the femoral neck and approximately 45 degrees to the long axis of the femur.
- The needle is directed along the long axis of the probe from an inferolateral aspect superomedially.
- The target is the anterior aspect of the femoral head or the anterior femoral recess.

9.1.6 The Injection

See ▶Fig. 9.1 and ▶Fig. 9.2.

Fig. 9.1 Hip joint injection. The probe is positioned over the anterior aspect of the hip joint in the transverse oblique plane. This should be in the same plane as the femoral neck and approximately 45 degrees to the long axis of the femur. The needle is directed along the long axis of the probe from an inferolateral aspect superomedially. The target is the anterior aspect of the femoral head or the anterior femoral recess.

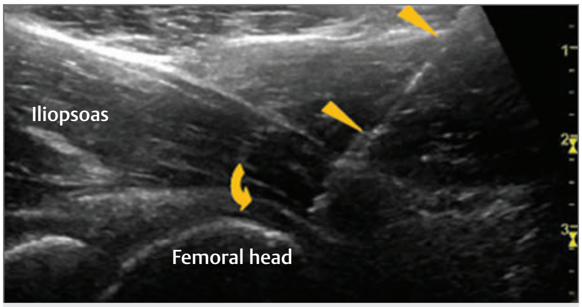

Fig. 9.2 Longitudinal image of the anterior hip joint. The needle (*yellow arrowheads*) may be seen entering the capsule of the hip joint (*curved arrow*) from the right side of the image.

9.1.7 Notes

Using an anterolateral approach the femoral neurovascular structures are easily avoided. If there are concerns as to the position of these vessels, they may be imaged prior to injection by moving the probe medially and utilizing the Doppler function. Once the femoral neurovascular structures are seen, the probe can be moved back into line with the femoral neck and the injection can be given with confidence.

In the patient with mild to moderate osteoarthritis of the hip, injection may allow sufficient symptomatic relief to initiate a programme of rehabilitation.

As an alternative to corticosteroid injection a hyaluronan may result in longer-term symptomatic relief. Hyaluronan may be of particular benefit in the active patient with mild degenerative change.

In the patient with a mild femoral–acetabular impingement, injection of corticosteroid may be sufficient to settle symptoms so long as other factors such as tightness within the iliopsoas complex are addressed. In more severe cases of femoral–acetabular impingement, surgery may be required to address bony change or damage to the anterosuperior labrum. However, even in more severe cases of femoral–acetabular impingement, injection may be of diagnostic benefit and an indicator of the likely benefit of surgery.

9.2 Psoas Bursa Injection

9.2.1 Cause

Most commonly, an overuse injury particularly associated with sports and activities involving repeated flexion of the hip such as cycling.

9.2.2 Presentation

Pain is felt in the groin and anterior thigh and exacerbated with abduction and end-range flexion. Signs and symptoms can be difficult to distinguish from a femoral–acetabular impingement without imaging.

9.2.3 Equipment

See ▶Table 9.2.

9.2.4 Anatomical Considerations

The psoas bursa, like many bursae, is not usually clearly visible with ultrasound imaging unless it becomes pathologically thickened and/or effused. The bursa lies between the iliopsoas tendon and the anterior aspect of the head and neck of the femur. It also extends somewhat medially to lie beneath the femoral vein, artery, and nerve. For this reason, it is essential to utilize ultrasound imaging to successfully secure accurate needle placement.

9.2.5 Procedure

- The patient is positioned in the supine position with the knee flexed on a pillow to 20 degrees. The hip is in slight abduction.
- The probe is positioned over the anterior aspect of the hip joint approximately 20 degrees off the sagittal plane. This places the probe in a line approximately halfway between a line drawn along the shaft of the femur and another along the femoral neck.
- The needle is directed along the long axis of the probe from an inferolateral aspect superomedially.
- The target is the anterior aspect of the femoral head and neck deep to the iliopsoas tendons.

Table 9.2 Equipment needed for psoas bursa injection

Syringe	Needle	Corticosteroid	Local anesthetic	Transducer
10 mL	22-gauge spinal needle	20-mg Depo-Medrone	2-mL 1% lidocaine	Large linear footprint or curvilinear probe in larger patients

9.2.6 The Injection

See ▶Fig. 9.3 and ▶Fig. 9.4.

9.2.7 Notes

During injection of the hip, using an anterolateral approach ensures that the femoral neurovascular structures are easily avoided. If there are concerns as to the position of these vessels, they may be imaged prior to injection by moving the probe medially and utilizing the Doppler function. Once the femoral neurovascular structures are seen, the probe can be moved back into position and the injection can be given with confidence.

Differentiation between a psoas bursitis and the more commonly seen femoral–acetabular impingement is difficult clinically as presentation and history are likely to be similar. Imaging should include plain X-ray to assess for bony change such as the CAM lesion of the femoral head and associated pincer of the acetabulum. An ultrasound will identify a thickened or effused psoas bursa. A magnetic resonance imaging (MRI) or magnetic resonance arthrogram (MRA) should be considered if labral pathology is suspected and surgical review is being considered.

The clinician should always consider addressing any muscular imbalance around the hip and pelvis to help prevent recurrence and increase the likelihood of successful outcome. In particular tightness in the hip, flexors should be addressed.

Fig. 9.3 Psoas bursa injection. The probe is positioned over the anterior aspect of the hip joint approximately 20 degrees from the sagittal plane. This places the probe in a line approximately halfway between a line drawn along the shaft of the femur and another along the femoral neck. The needle is directed along the long axis of the probe from an inferolateral aspect superomedially. The target is the anterior aspect of the femoral head deep to the iliopsoas tendons but superficial to the anterior capsule of the hip joint.

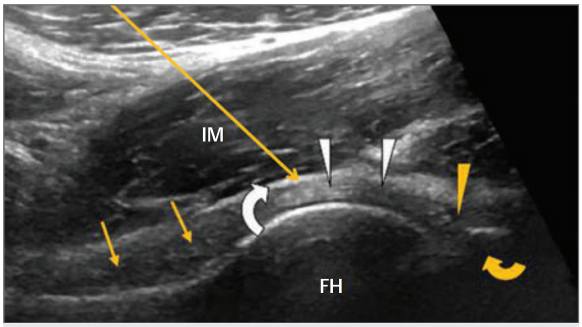

Fig. 9.4 Longitudinal image of the anterior aspect of the hip joint. The iliopsoas muscle (IM) may be seen to overlay the anterior capsule of the hip joint (*white arrowheads*). The bursa lies over the anterior capsule (*white curved arrow*). The needle (*yellow arrow*) is directed so that the tip lies immediately superficial to the capsule. FH, femoral head; long straight arrow, direction of the needle; short yellow arrows, anterior femoral recess; white curved arrow, position of the psoas bursa; yellow arrowhead, anterosuperior labrum; yellow curved arrow, acetabulum.

9.3 Ischial Bursa/Hamstring Tendon Origin Injection

9.3.1 Cause

Most commonly, an overuse injury leading to tendinopathy, the mechanism of onset is often associated with sports and activities such as kicking requiring the hamstring to function as a decelerator of the leg following forceful quadriceps contraction, for example, in either football or karate.

The hamstring origin may also be affected more acutely after a "one-off" forceful contraction of the hamstring muscle associated with simultaneous lengthening of the muscle, for example, a sliding tackle during football. This mechanism of injury may also precipitate an avulsion fracture of the ischium.

An ischial bursitis although uncommon may be caused following a direct fall onto the buttock.

9.3.2 Presentation

Pain is felt deep in the buttock and exacerbated with resisted knee flexion and passive straight-leg raise of the leg. Direct palpation of the ischium is normally painful.

9.3.3 Equipment

See ▶Table 9.3.

Table 9.3 Equipment needed for ischial bursa/hamstring tendon origin injection

Syringe	Needle	Corticosteroid	Local anesthetic	Transducer
5 mL	22-gauge	20-mg Depo-Medrone	2-mL 1% lidocaine	Large linear footprint or curvilinear probe in larger patients

9.3.4 Anatomical Considerations

The hamstring muscles consist of the bicep femoris, semimembranosus, and semitendinosus and stem from a conjoined tendon at their origin at the ischium. Although ultrasound imaging is able to provide detailed information in regard to pathological change involving these tendons, it is not possible to clearly differentiate them. The ischial bursa lies between the gluteus maximus and the underlying ischial tuberosity and in its normal state it is not readily seen on ultrasound imaging.

9.3.5 Procedure

- The patient is positioned prone with the hip and knee of the side to be injected flexed over the side of the couch facilitating better visualization of the ischium as it moves in an inferior direction from below gluteus maximus.
- The probe is positioned in the sagittal plane over the ischium and the hamstring tendons.
- The needle is directed along the long axis of the probe from an inferior to superior direction.
- The injection is delivered to the superficial and deep aspects of the hamstring tendons. If there is a significant tendinopathy, then this should be followed with repeated fenestration of the tendon itself.
- If the target is the ischial bursa, then the injection is given as a bolus with no need to fenestrate the tendons themselves.

9.3.6 The Injection

See ▶Fig. 9.5 and ▶Fig. 9.6.

9.3.7 Notes

While not the commonest site for tendinopathy the hamstring origin when it becomes a problem can persist and be extremely recalcitrant in nature. Injection with fenestration of the tendon can assist in recovery; however, treatment must also include a vigorous program of rehabilitation.

In particular, an imbalance between the quadriceps and the hamstring should be addressed. It is not uncommon for the athlete to strengthen the quadriceps relatively more than the hamstrings leading to an imbalance which puts undue stress on the hamstrings which struggle to act in a decelerating mode to control quadriceps contraction.

Fig. 9.5 Ischial bursa/hamstring injection. The probe is positioned in the sagittal plane over the ischium and the hamstring tendons. The needle is directed along the long axis of the probe from an inferior to superior direction.

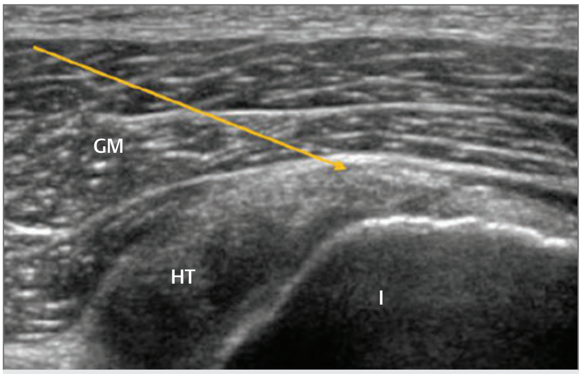

Fig. 9.6 Longitudinal image of the ischium (I) and hamstring tendon (HT) laying deep to the gluteus maximus (GM) muscle. The needle is directed from an inferior direction toward the ischium (*yellow arrow*). Yellow arrow, direction of the needle.

9.4 Greater Trochanter Injection

9.4.1 Cause

Pain over the greater trochanter is commonly described as being due to a trochanteric bursitis. In practice, this is extremely unusual and pain in this region is more commonly due to an insertional tendinopathy of the gluteus medius tendon with ultrasound demonstrating little evidence of distension of the trochanteric bursa.

Given that pain in the trochanteric region is commonly due to a tendinopathy, onset is usually related to overuse and muscle imbalance. This affects not only the athlete, but is a common presentation in the middle-aged and older patients.

Pain may also be due to a direct fall onto the lateral aspect of the hip. This is more likely to lead to a bursitis.

9.4.2 Presentation

- Pain and tenderness are felt over the greater trochanter.
- In addition, pain may be elicited with resisted abduction and passive adduction.

9.4.3 Equipment

See ▶Table 9.4.

Table 9.4 Equipment needed for greater trochanter injection

Syringe	Needle	Corticosteroid	Local anesthetic	Transducer
5 mL	22-gauge	20-mg Depo-Medrone	4-mL 1% lidocaine	Large linear footprint

Fig. 9.7 Greater trochanter injection. The probe is positioned in the coronal plane over the greater trochanter. The needle is directed along the long axis of the probe from a superior to inferior direction.

9.4.4 Anatomical Considerations

The gluteus medius tendon inserts onto the middle and posterior aspect of the greater trochanter with gluteus minimus inserting onto the anterior aspect. The trochanteric bursa lies over the tendons deep to the lateral fascia of the thigh. In its normal state the bursa is not visible on ultrasound and only becomes so when distended.

9.4.5 Procedure

- The patient is positioned in side lying with the affected side uppermost.
- The probe is positioned in the coronal plane over the greater trochanter.
- The needle is directed along the long axis of the probe from a superior to inferior direction.
- The injection is delivered to the superficial and deep aspects of the gluteus medius tendon. If there is a significant tendinopathy, then this should be followed with repeated fenestration of the tendon itself.
- If the target is the trochanteric bursa, then the injection is given as a bolus with no need to fenestrate the tendons themselves.

9.4.6 The Injection

See ▶Fig. 9.7 and ▶Fig. 9.8.

9.4.7 Notes

Pain in the trochanteric region is a common presentation in patients following total hip replacement due to inadequate postsurgical rehabilitation with subsequent weakness in the gluteal muscles.

Occasionally, a direct fall or blow to the trochanteric region will result in a hemorrhagic bursitis. If the patient can be seen promptly, aspiration of the bursa can provide immediate relief.

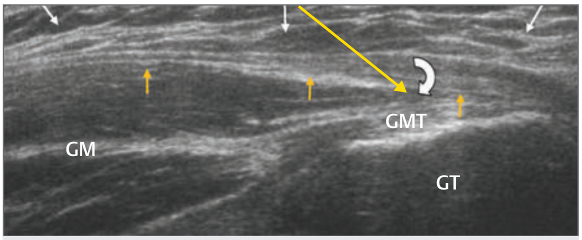

Fig. 9.8 Longitudinal image of the greater trochanter (GT) and gluteus medius (GM) muscle and gluteus medius tendon (GMT). The needle (*yellow arrow*) is directed so that the tip is positioned deep to the lateral fascia (*short yellow arrows*). Curved arrow, position of trochanteric bursa; short yellow arrows, lateral fascia; white arrows, subcutaneous tissue.

10 The Knee: Diagnostic Imaging

Abstract
Ultrasound examination of the knee is an accurate and sensitive imaging modality for many common disorders around the knee joint. The presence and grade of tendinopathies can be quickly evaluated and changes over time monitored. Injured ligaments appear swollen and of altered echogenicity and may be assessed dynamically for patency. Ultrasound can demonstrate different types of injury in the peripheral part of the meniscus although MRI is more sensitive than ultrasound for detection of meniscal lesions. Ultrasound is able to demonstrate synovial thickening and effusion in inflammatory arthropathy and erosions of the articular surface in degenerative arthritis. It can be used effectively to monitor changes in the activity of rheumatoid arthritis in response to treatment and for grading degenerative arthritis. Ultrasound examination of the knee should be undertaken using a large foot-print linear high frequency linear probe (7.5–15 MHz). Findings can be correlated with the point of maximal tenderness located with palpation and readily compared with those obtained in the contralateral joint.

Keywords: knee joint, patellar tendon, quadriceps tendon, suprapatellar, Hoffa's fat pad, pes anserine, lateral collateral ligament, medial collateral ligament, meniscus, popliteal, semimembranosus, semitendinosus, gastrocnemius

10.1 Diagnostic Imaging of the Knee: Introduction

The knee may be considered as consisting of four quadrants, anterior, medial, lateral, and posterior. Ultrasound would normally be focused only one or two of these quadrants depending on the clinical diagnosis.

Imaging includes the following quadrants:

- Anterior
  - Patellar tendon.
  - Tibial tubercle and deep and superficial infrapatellar bursae.
  - Quadriceps muscle and tendon.
  - Prepatellar bursa.
  - Suprapatellar pouch (for effusion).
  - Vastus medialis muscle and medial retinaculum.
- Medial
  - Medial collateral ligament (MCL) (includes valgus stressing if indicated).
  - Medial tibiofemoral joint space and medial meniscus.
  - Pes anserine tendons and bursa (if pathological).
- Lateral
  - Lateral collateral ligament (including varus stressing if indicated).
  - Iliotibial band and bursa (if pathological).
  - Lateral tibiofemoral joint space and meniscus.
  - Popliteus tendon.
  - Proximal tibiofibular joint.
- Posterior
  - Semimembranosus and semitendinosus muscle and tendon.
  - Biceps femoris muscle and tendon.
  - Medial and lateral gastrocnemius muscles and tendons.
  - Popliteal fossa.
  - Popliteal artery and vein.

10.1.1 Anterior

Anterior Knee—Infrapatellar: Longitudinal Scan

The patient is positioned in supine with the knee placed in 20 to 30 degrees flexion. This puts both the patellar and quadriceps tendon under some tension allowing better visualization of these structures.

The probe is placed in the anatomical sagittal plane so that it lies over the tibial tuberosity and distal patellar tendon. The probe is then moved proximally to visualize in turn the proximal patellar tendon, the quadriceps tendon, and suprapatellar region (▶Fig. 10.1, ▶Fig. 10.2, ▶Fig. 10.3).

The infrapatellar fat pad also known as Hoffa's fat pad may be seen deep to the patellar tendon and inferior pole of the patella. This may become painful in a condition known as fat pad impingement or Hoffa's disease. The cause is usually due to single or repetitive traumatic episodes. The inflamed fat pad becomes hypertrophied which may lead to further impingement between the tibia, femur, and inferior pole of the patella. Treatment should consist of appropriate rehabilitation and, if symptoms persist, guided injection.

Fig. 10.1 Longitudinal scan of the infrapatellar region. The probe is placed so that its distal edge lies over the tibial tuberosity and its proximal edge over the distal patella.

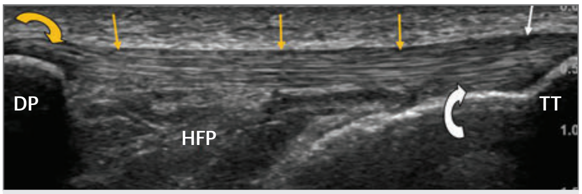

Fig. 10.2 Longitudinal image of the infrapatellar region. The distal pole of the patella can be seen to the left of the image (DP). The patella tendon (*yellow arrows*) can be seen to be of a good clear fibrillar pattern with no evidence of tendinopathy. The tibial tuberosity (TT) is of normal appearance. Hoffa's fat pad (HFP) can be seen deep to the patellar tendon. The straight and curved white arrows indicate where the superficial and deep infrapatellar bursae are located, respectively, and the curved yellow arrow indicates the prepatellar bursa. In the nonpathological state these bursae may not be visible. DP, distal patella.

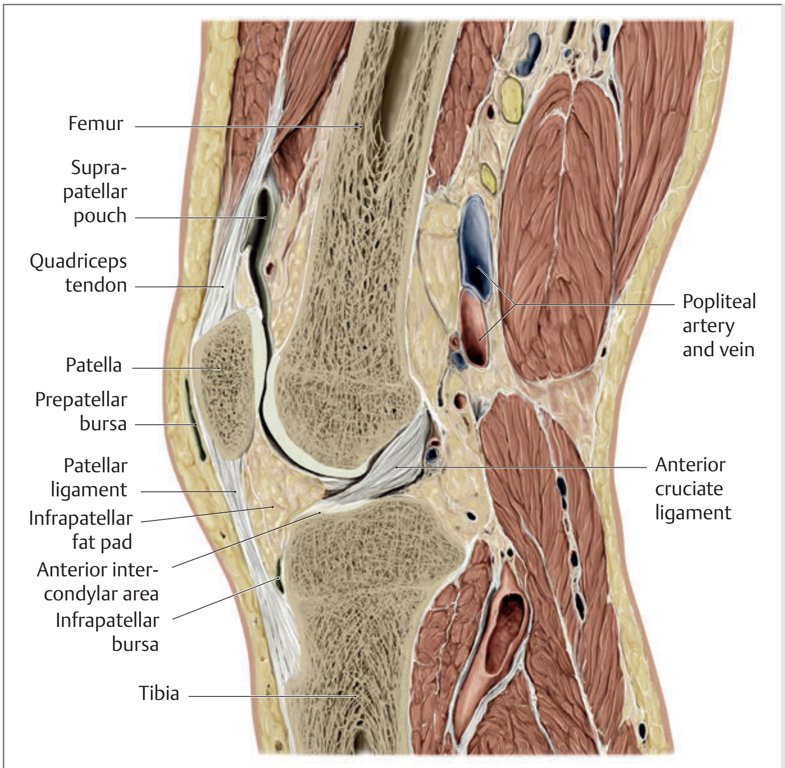

Fig. 10.3 Midsagittal section through the knee joint. Note the extent to which the suprapatellar pouch extends proximally above the patella lying deep to the quadriceps tendon and suprapatellar fat and anterior to the femur and prefemoral fat. The infrapatellar fat pad also known as Hoffa's fat pad may be seen deep to the patellar tendon and inferior pole of the patella. This may become painful in a condition known as fat pad impingement or Hoffa's disease. The cause is usually due to single or repetitive traumatic episodes. The inflamed fat pad becomes hypertrophied which may lead to further impingement between the tibia, femur, and inferior pole of the patella. Treatment should consist of appropriate rehabilitation and, if symptoms persist, guided injection. (Reproduced from Schuenke, Schulte, and Schumacher, Atlas of Anatomy, 2nd edition, ©2014, Thieme Publishers, New York. Illustration by Karl Wesker/Markus Voll.)

Anterior Knee—Infrapatellar: Transverse Scan

The patient is positioned in supine with the knee positioned in 20 to 30 degrees flexion. This puts both the patellar and quadriceps tendon under some tension allowing better visualization of these structures.

The probe is placed in the anatomical transverse plane so that it lies over the tibial tuberosity and then moved in a proximal direction over the patellar tendon as far as the distal pole of the patella (▶Fig. 10.4, ▶Fig. 10.5).

Fig. 10.4 Transverse scan of the infrapatellar region. The probe is placed in the transverse plane to lie first over the tibial tuberosity and then moved in a proximal direction to scan the patellar tendon and finally its attachment onto the distal patella.

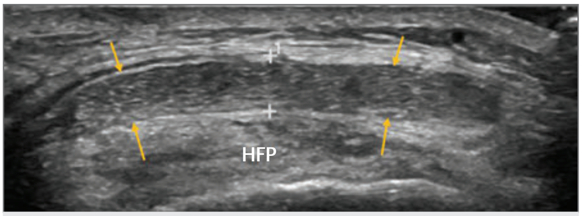

Fig. 10.5 Transverse image of the patellar tendon. The probe is over the midsubstance of the tendon (*yellow arrows*). The tendon can be seen to be of good echogenicity and of normal thickness at 4 mm (*caliper crosses*). Hoffa's fat pad (HFP) can be seen deep to the tendon.

Anterior Knee—Suprapatellar: Longitudinal Scan

The knee is maintained in 20 to 30 degrees of flexion and the probe is moved proximally preserving its alignment in the anatomical sagittal plane so that it lies over the quadriceps tendon and suprapatellar region (▶Fig. 10.6, ▶Fig. 10.7).

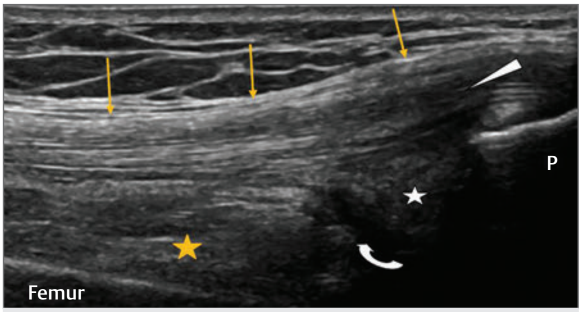

Fig. 10.6 Longitudinal image of the suprapatellar region of the knee. The quadriceps tendon (*yellow arrows*) can be seen to have an intact fibrillar pattern. The loss of echogenicity within the tendon (*white arrowhead*) toward its insertion onto the proximal patella (P) is an example of anisotropy and does not represent pathology. Deep to the quadriceps tendon and proximal to the patella is the superior patella fat pad (*white star*). The anterior cortex of the femur can be seen to the bottom left of the image with the prefemoral fat lying above this (*yellow star*). The dark area superior to the superior fat pad represents the suprapatellar pouch (*curved arrow*).

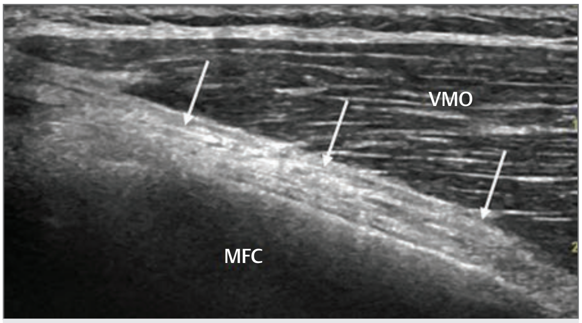

Fig. 10.7 Longitudinal image of the medial patella retinaculum. From imaging the quadriceps tendon, the probe may be moved into a sagittal oblique orientation to lie over the medial femoral condyle (MFC), the medial patella retinaculum (*white arrows*), and vastus medialis obliquus (VMO).

Anterior Knee—Suprapatellar: Transverse Scan

The knee is maintained in 20 to 30 degrees of flexion and the probe is moved proximally over the suprapatellar region in the anatomical transverse plane so that it lies over the quadriceps tendon and suprapatellar region.

Maintaining the probe in the transverse plan and flexing the knee allows for visualization of the femoral trochlea (▶Fig. 10.8, ▶Fig. 10.9, ▶Fig. 10.10).

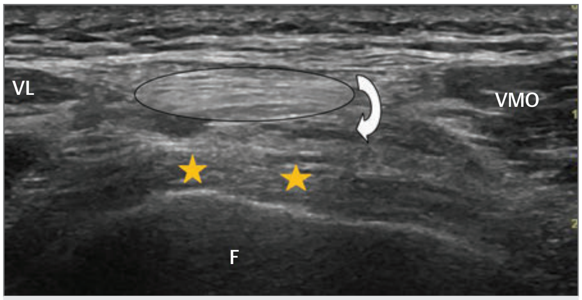

Fig. 10.8 Transverse image of the suprapatellar region. The probe is placed in the anatomical transverse plane over the quadriceps tendon (*oval*). Deep to the tendon can be seen the prefemoral fat (*yellow stars*). The suprapatellar pouch cannot be seen as it has been compressed with the action of knee flexion. The white curved arrow indicates where it lies and where it would be seen if distended due to pathology.

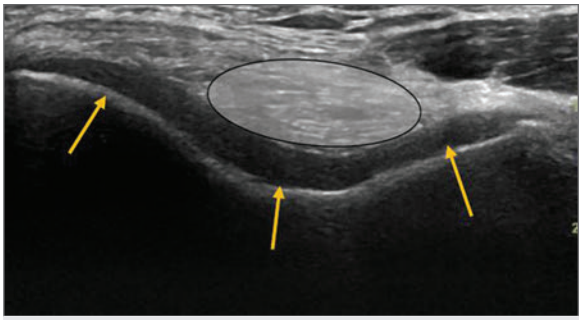

Fig. 10.9 Transverse image of the suprapatellar region. The knee has been fully flexed to allow visualization of the femoral trochlea (*yellow arrows*). The anechoic layer over the femoral trochlea represents the hyaline cartilage covering. The quadriceps tendon can be seen superior to the trochlea (*oval*).

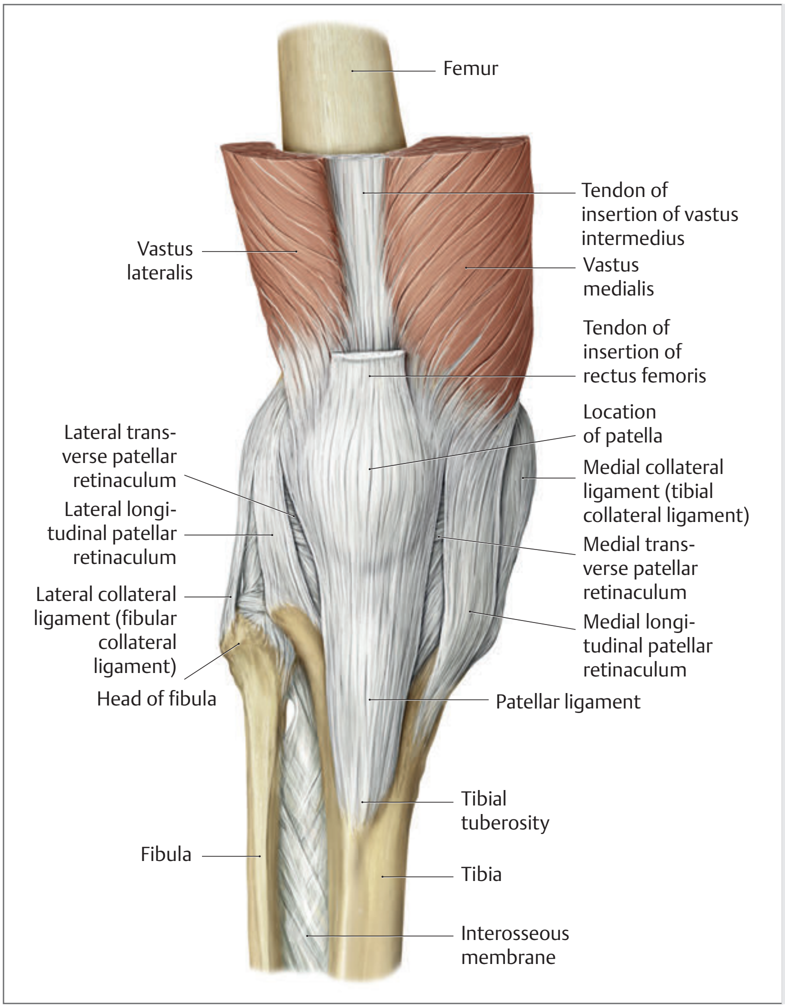

Fig. 10.10 Coronal view of the anterior aspect of the right knee illustrating the extensor mechanism and the medial and lateral supporting ligamentous structures. The extensor mechanism is a complex structure formed by quadriceps muscle and quadriceps tendon, the patella and patellar tendon. The quadriceps tendon is formed from the four quadriceps femoris muscles. Rectus femoris forming the most superficial layer (removed in this illustration), vastus lateralis and vastus medialis forming the middle layer, and vastus intermedius forming the deepest layer of the tendon. (Reproduced from Schuenke, Schulte, and Schumacher, Atlas of Anatomy, 2nd edition, ©2014, Thieme Publishers, New York. Illustration by Karl Wesker/Markus Voll.)

Anterior Knee: Common Pathology

Infrapatellar Region

See ▶Fig. 10.11, ▶Fig. 10.12, ▶Fig. 10.13, ▶Fig. 10.14, ▶Fig. 10.15, ▶Fig. 10.16, ▶Fig. 10.17, ▶Fig. 10.18, and ▶Fig. 10.19.

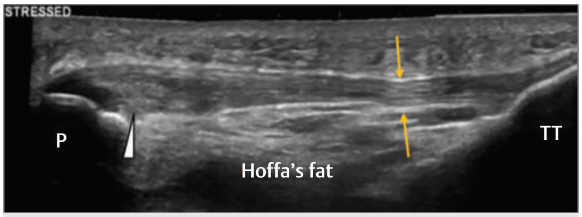

Fig. 10.11 Longitudinal image of a patellar tendon. The knee has been flexed to place stress through the tendon. However, the tendon still demonstrates a "wavy-like" appearance within its lower third (*yellow arrows*). This appearance is suggestive of either partial or complete rupture as the tendon lacks firm anchorage in such cases. In this image the tendon has lost its normal fibrillar pattern within its deeper portion toward its attachment on the patella (*white arrowhead*). These findings are in keeping with a partial tear of the deeper portion of the tendon. P, patella; TT, tibial tuberosity.

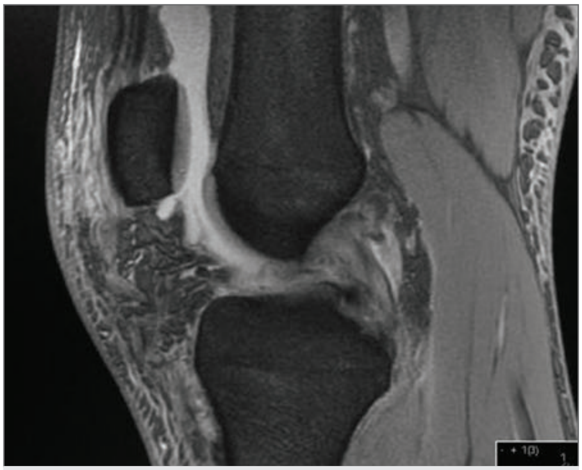

Fig. 10.13 MRI scan of the sagittal view of the same knee as in ▶Fig. 10.12. The image also demonstrates a complete loss of the normal fibrillar pattern of the patella tendon. In addition, a large intra-articular effusion is seen.

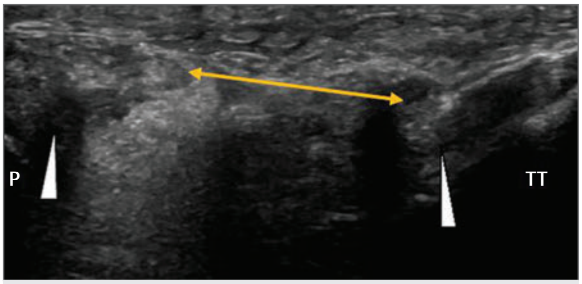

Fig. 10.12 Longitudinal image of the infrapatellar region of the knee demonstrating a complete loss of the normal fibrillar pattern of the patella tendon in keeping with complete rupture. The proximal and distal stumps of the tendon can be seen (*white arrowheads*). The double headed yellow arrow demonstrates a considerable gap between the two stumps. P, patella; TT, tibial tuberosity.

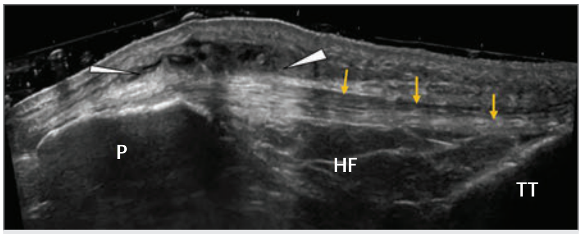

Fig. 10.14 Longitudinal image of the patella and infrapatellar region of the knee. The patella tendon (*yellow arrows*) appears intact, however, a hybrid anechoic/low echo swelling (*white arrowheads*) is seen overlying the lower half of the patella and upper third of the patellar tendon (note the posterior acoustic enhancement). The findings are indicative of a prepatellar bursitis. HF, Hoffa's fat pad; P, patella; TT, tibial tuberosity.

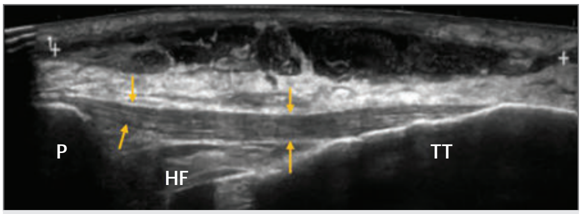

Fig. 10.15 Longitudinal image of the infrapatellar region of the knee in a patient who had sustained a fall onto the knee 10 days prior to examination. The patella tendon (*yellow arrows*) appears intact, however, there is a large low echo swelling measuring approximately 9 cm in length (*white crosses*) superficial to the patellar tendon within the subcutaneous tissue. With Power Doppler, there was no associated increase in vascularity. These findings are indicative of a subcutaneous posttraumatic hematoma. HF, Hoffa's fat pad; P, patella; TT, tibial tuberosity; white arrowheads, prepatellar bursitis; white crosses, subcutaneous hematoma.

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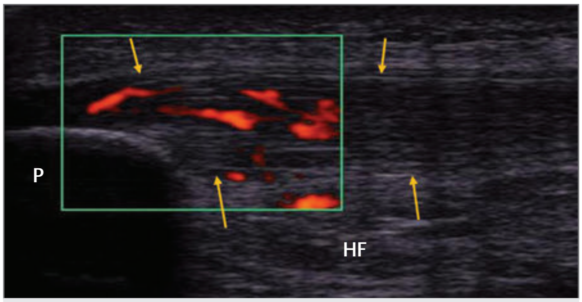

Fig. 10.16 Longitudinal image of the proximal patella tendon. The rectangular box indicates Power Doppler imaging. The image demonstrates some thickening of the proximal patella tendon and with Power Doppler in place, there is a clear neovascularity throughout the tendon. These findings indicate a proximal patellar tendinopathy, commonly termed "jumper's knee." HF, Hoffa's fat pad; P, patella; yellow arrows, patella tendon.

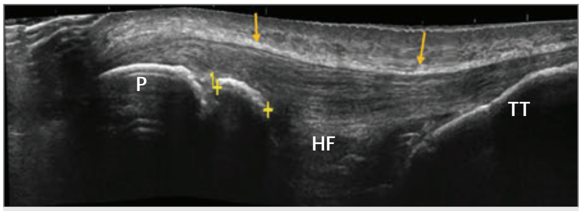

Fig. 10.17 Longitudinal image of the patella and patella tendon of the knee. The patella tendon (*yellow arrows*) appears intact. Large calcified foci may be seen at the distal point of the patella measuring approximately 1 cm in longitudinal length (*yellow crosses*). There is some thickening of the patella tendon around the foci. Findings indicate a possible old Sinding-Larsen-Johansson disease. HF, Hoffa's fat pad; P, patella; TT, tibial tuberosity; yellow crosses, calcified foci.

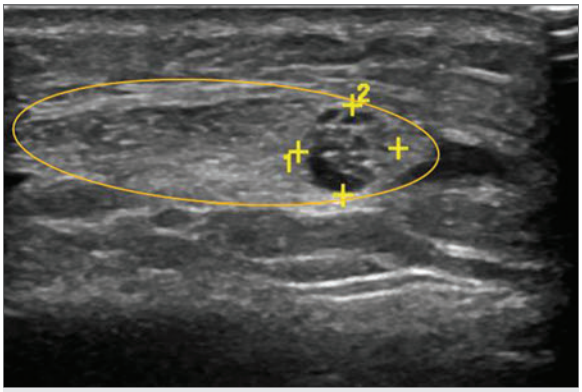

Fig. 10.18 Transverse image of the patella tendon (*yellow ellipse*). The tendon is of good echogenicity and appears intact other than a spherical low echo foci within the lateral aspect measuring approximately 5 mm in transverse diameter (*yellow crosses*). Findings are suggestive of an intrasubstance tear/ cystic degeneration.

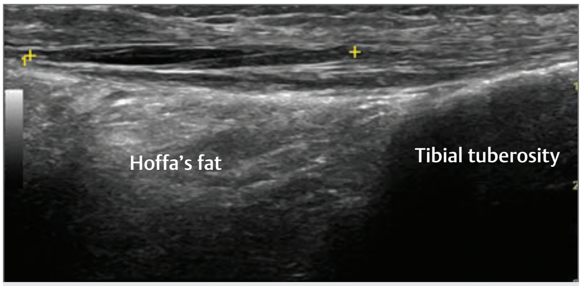

Fig. 10.19 Longitudinal image of the patella tendon outlined in ▶Fig. 10.18. The low echo foci (*yellow crosses*) can be seen to extend through the tendon approximately 2.8 cm. Yellow crosses, intrasubstance foci suggestive of a partial tear or degenerative cystic lesion.

Anterior Knee: Pathology

Suprapatellar Region

See ▶Fig. 10.20, ▶Fig. 10.21, ▶Fig. 10.22, ▶Fig. 10.23, ▶Fig. 10.24, and ▶Fig. 10.25.

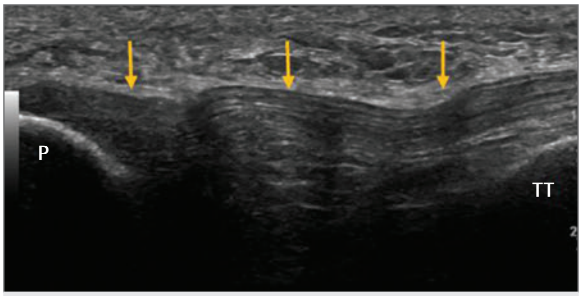

Fig. 10.20 Longitudinal image of the patellar tendon (*yellow arrows*). Although the knee has been flexed to stress the tendon and there appears to be a relatively intact fibrillar pattern, the tendon itself is of a wavy appearance. This is highly suggestive of a quadriceps tendon rupture (see ▶Fig. 10.21). P, patella; TT, tibial tuberosity.

Fig. 10.22 X-ray of the knee demonstrated in ▶Fig. 10.20 and ▶Fig. 10.21. The image shows the wavy appearance of the patella tendon (*yellow arrow*). Proximal to the patella the bony fragment may be seen (*white star*).

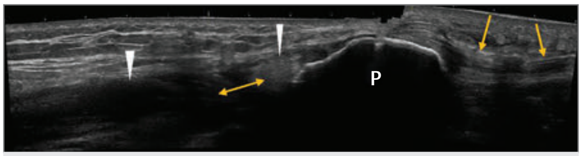

Fig. 10.24 Longitudinal image of the extensor mechanism of the knee. The quadriceps tendon (*white arrowheads*) appears discontinuous. A complete rupture of the quadriceps tendon with retraction of the proximal stump is noted (*double headed yellow arrow*). The patella tendon (*yellow arrows*) can be seen to have a wavy-like appearance (seen more clearly in ▶Fig. 10.23). P, patella.

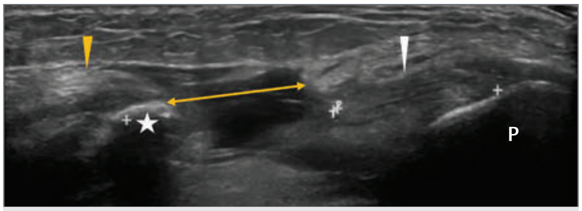

Fig. 10.21 Longitudinal image of the suprapatellar region of the knee. The image demonstrates a complete rupture of the quadriceps tendon (*double headed yellow arrow*). The distal stump (*white arrowhead*) can be seen still attached to the proximal patella (P). The proximal stump (*yellow arrowhead*) appears retracted and contains an avulsed fragment of bone (*white star*).

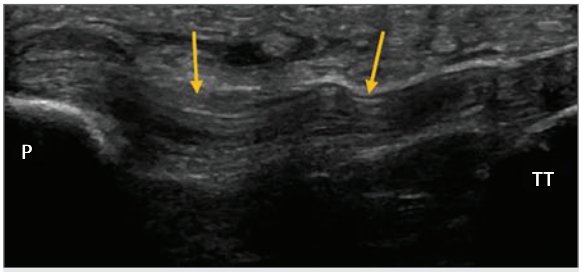

Fig. 10.23 Longitudinal image of the patella tendon (*yellow arrows*) in a 56-year-old power lifter. The knee has been placed in 30 degrees of flexion, however, the tendon still has a wavy-like appearance suggestive of a quadriceps rupture (see ▶Fig. 10.24). P, patella; TT, tibial tuberosity.

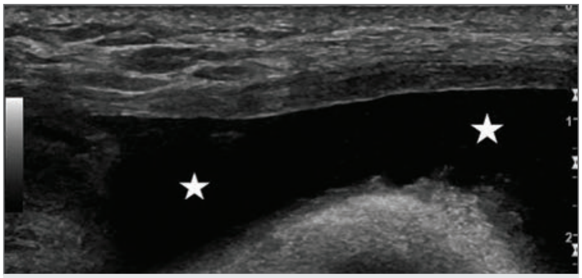

Fig. 10.25 Transverse image of the suprapatellar region of the knee outlined in ▶Fig. 10.23 and ▶Fig. 10.24. There is a complete loss of the quadriceps tendon with effusion noted in the suprapatellar pouch (*white stars*).

Anterior Thigh: Pathology

See ▶ Fig. 10.26, ▶ Fig. 10.27, ▶ Fig. 10.28, ▶ Fig. 10.29, ▶ Fig. 10.30, and ▶ Fig. 10.31.

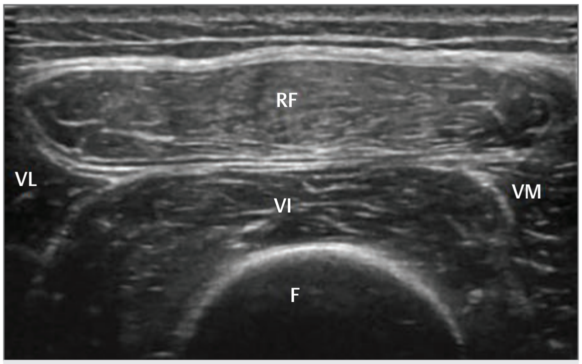

Fig. 10.26 Transverse image of the lower third of the thigh. The four parts of the quadriceps can be seen overlying the femur (F). This is a normal image. RF, rectus femoris; VI, vastus intermedius; VL, vastus lateralis; VM, vastus medialis.

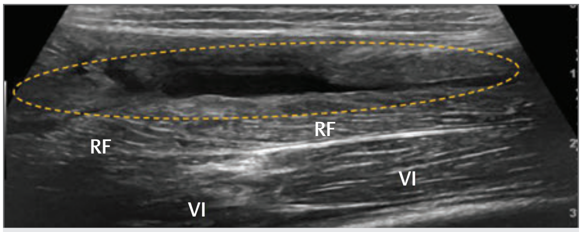

Fig. 10.28 Longitudinal image of the lower third of the thigh. Marked disruption is noted within the rectus femoris (RF) muscle (*dashed line*) affecting more its superficial fibers with the deeper aspect of the muscle appearing relatively intact. The deeper vastus intermedius (VI) appears intact. Appearances are consistent with an extensive tear of the rectus femoris muscle around its central tendon. Dashed line, tear within rectus femoris.

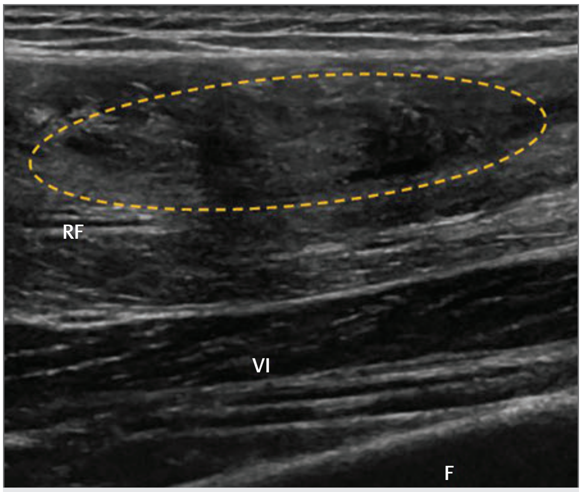

Fig. 10.30 Longitudinal image of the lower third of the thigh. This image is of the same patient as demonstrated in ▶ Fig. 10.28 but taken 1 month later. The area of the tear can still be seen (*dashed line*) but has filled with echogenic tissue representing a resolving tear with in rectus femoris (RF). F, femur; VI, vastus intermedius.

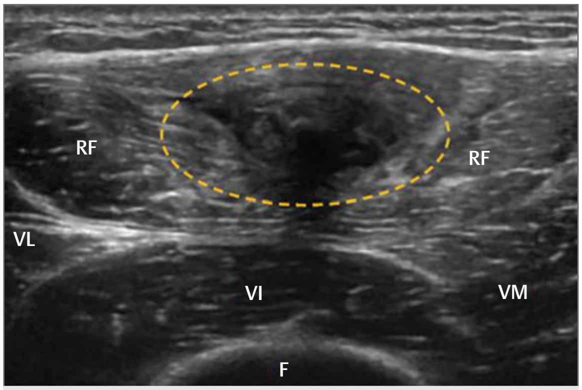

Fig. 10.27 Transverse image of the lower third of the thigh. There is a marked disruption with loss of normal muscle architecture (*dashed line*) within the rectus femoris (RF) muscle. The image is consistent with a tear of the central region of rectus femoris. ▶ Fig. 10.28 demonstrates how the tear extends longitudinally through the muscle. F, femur; VI, vastus intermedius; VL, vastus lateralis; VM, vastus medialis.

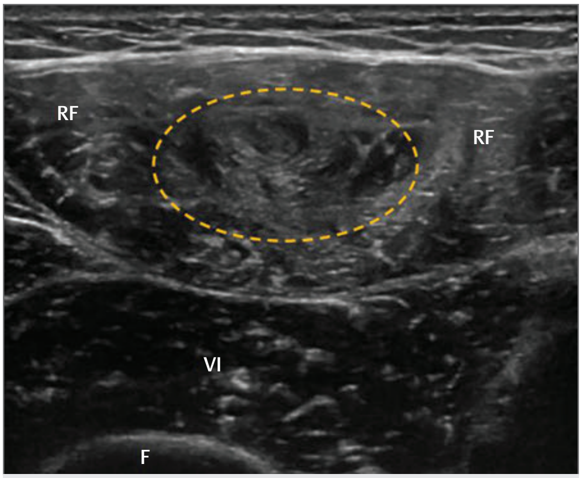

Fig. 10.29 Transverse image of the lower third of the thigh. This image is of the same patient as demonstrated in ▶ Fig. 10.27 but taken 1 month later. The area of the tear outlined in ▶ Fig. 10.27 can still be seen (*dashed line*) but has filled with echogenic tissue representing a resolving tear within rectus femoris (RF). F, femur; VI, vastus intermedius.

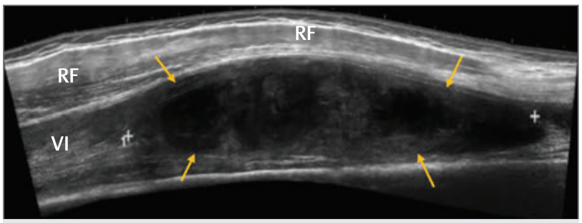

Fig. 10.31 Longitudinal image of the lower third of the thigh. A large low echo intramuscular collection (*yellow arrows*) is seen within vastus intermedius (VI) measuring approximately 16 cm longitudinally (*white crosses*). The overlying rectus femoris (RF) appears intact. The patient described a sudden onset of pain following a kicking movement during karate training. The image is in keeping with a significant rupture involving the vastus intermedius muscle and subsequent collection.

10.1.2 Medial

Medial Knee Joint: Longitudinal Scan

The patient is positioned in supine with the knee placed in 80 to 90 degrees of flexion. The probe is placed in the anatomical coronal plane so that it lies over the MCL and medial joint line (▶Fig. 10.32, ▶Fig. 10.33, ▶Fig. 10.34).

The superficial portion is attached proximally to the posterior aspect of medial femoral condyle and distally to the metaphyseal region of the tibia approximately 4 to 5 cm distal to the joint.

The deep MCL is divided into meniscofemoral and meniscotibial portions inserting directly into the edge of the tibial plateau and the medial meniscus. While the superficial portion resists valgus force, the deep portion does not provide significant resistance to valgus force.

Crossing over the lower part of the MCL is the pes anserine tendon formed from the tendons of the sartorius, gracilis, and semitendinosus. A bursa may be interposed between the MCL and the pes anserine tendon.

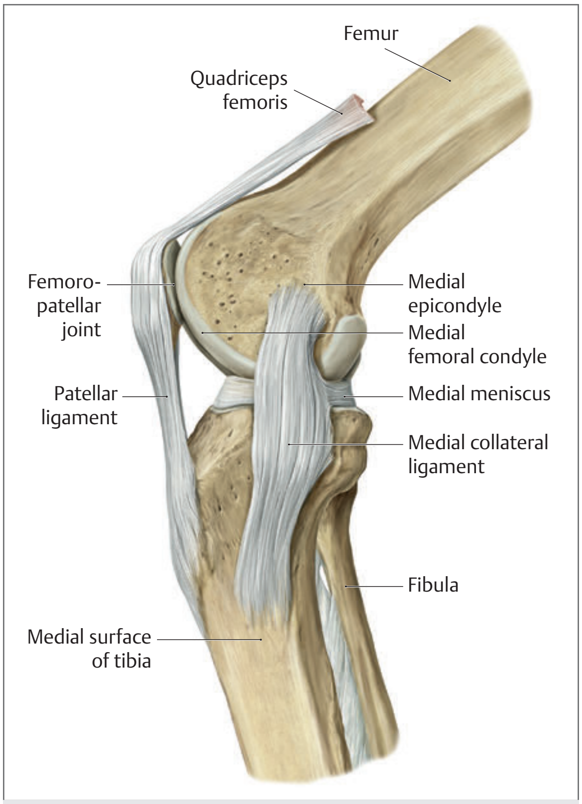

Fig. 10.34 Sagittal view of the medial aspect of the knee demonstrating the patellar and quadriceps tendons and the medial collateral ligament (MCL). The MCL is a broad, flat, membranous band situated slightly posterior on the medial side of the knee joint. The MCL is composed of both superficial and deep portions. The superficial portion is attached proximally to the posterior aspect of medial femoral condyle and distally to the metaphyseal region of the tibia approximately 4 to 5 cm distal to the joint. The deep MCL is divided into meniscofemoral and meniscotibial portions inserting directly into the edge of the tibial plateau and the medial meniscus. While the superficial portion resists valgus force, the deep portion does not provide significant resistance to valgus force. Crossing over the lower part of the MCL is the pes anserine tendon formed from the tendons of the sartorius, gracilis, and semitendinosus. A bursa may be interposed between the MCL and pes anserine tendon. (Reproduced from Schuenke, Schulte, and Schumacher, Atlas of Anatomy, 2nd edition, ©2014, Thieme Publishers, New York. Illustration by Karl Wesker/Markus Voll.)

Fig. 10.32 Longitudinal scan of the medial aspect of the knee joint and medial collateral ligament. The probe in the anatomical coronal plane so that its proximal edge lies over the medial femoral condyle and its distal edge over the medial tibial plateau.

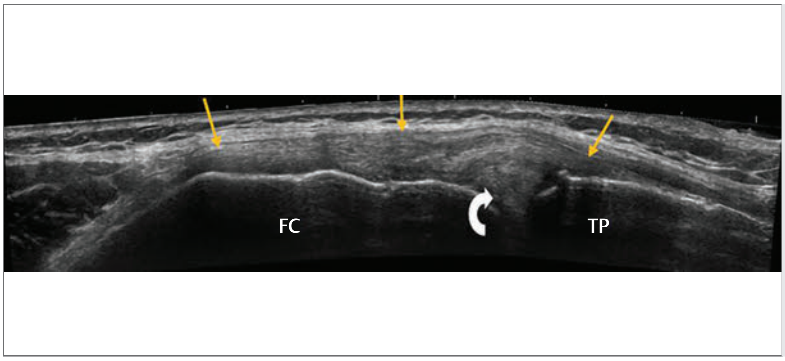

Fig. 10.33 Longitudinal image of the medial aspect of the knee. The medial collateral ligament (*yellow arrows*) can be seen to run superficially over the joint from the medial femoral condyle (FC) to the medial tibial plateau (TP). The medial meniscus (*white curved arrow*) can be seen as an echogenic triangle below the medial collateral ligament. Although the meniscus can be seen with ultrasound and many peripheral tears may be identified, subtle tears and tears located more centrally cannot be seen.

Medial Knee: Pes Anserine Insertion

The patient is positioned in supine with the knee placed in 20 to 30 degrees of flexion. The probe is placed in the sagittal oblique plane over the upper aspect of the medial tibia approximately halfway between the tibial tuberosity and the medial collateral ligament (▶Fig. 10.35, ▶Fig. 10.36).

Fig. 10.35 Longitudinal scan of the pes anserine insertion. The probe is positioned over the upper medial aspect of the tibia in the sagittal oblique plane. The proximal edge of the probe is just distal to the anterior aspect of the knee joint line and the distal edge medial to the insertion of the patellar tendon onto the tibial tuberosity.

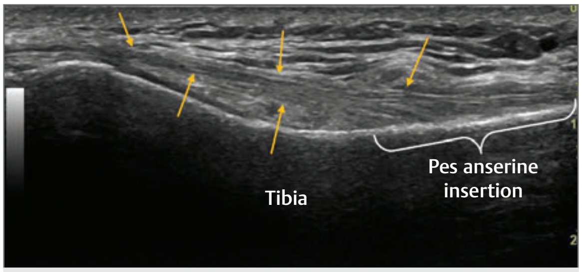

Fig. 10.36 Longitudinal image of the pes anserine insertion onto the upper anteromedial shaft of tibia. The tendon itself may be seen as a relatively flat fibrillar structure (*yellow arrows*). The insertion can be seen to be relatively wide (*white bracket*). In the normal state the pes anserine bursa cannot be visualized. White bracket, pes anserine insertion; yellow arrows, pes anserine tendon.

Medial Knee: Pathology

10

See ▶Fig. 10.37, ▶Fig. 10.38, ▶Fig. 10.39, ▶Fig. 10.40, ▶Fig. 10.41, ▶Fig. 10.42, ▶Fig. 10.43, and ▶Fig. 10.44.

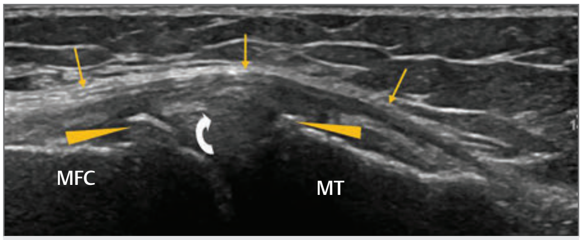

Fig. 10.37 Longitudinal image of the medial joint line of the knee. The medial collateral ligament (*yellow arrows*) can be seen laying over the joint and appears to be bowed outward due to extrusion of the underlying medial meniscus (*white curved arrow*) and marginal osteophytes (*yellow arrowheads*). These findings are in keeping with osteoarthritis of the medial joint compartment. MFC, medial femoral condyle; MT, medial tibial plateau.

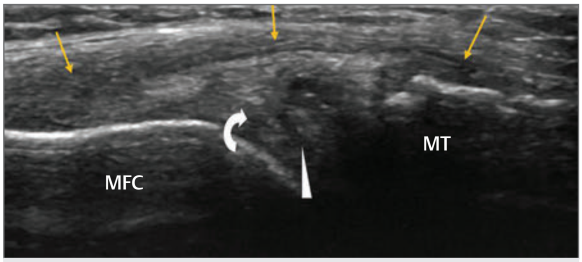

Fig. 10.38 Longitudinal image of the medial aspect of the knee joint. The medial collateral ligament appears intact and can be seen over the joint line (*yellow arrows*). There is no evidence of significant degenerative change. The medial meniscus (*curved white arrow*) appears extruded with evidence of a C-shaped low echo foci within its substance (*white arrowhead*). These findings are in keeping with significant meniscal tear. MRI would be required to further evaluate the meniscus. MFC, medial femoral condyle; MT, medial tibial plateau; white arrowhead, meniscal tear.

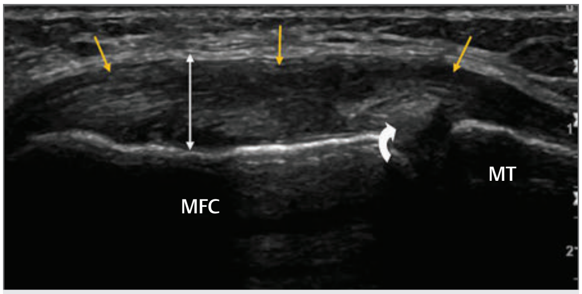

Fig. 10.39 Longitudinal image of the medial collateral ligament of the knee (*yellow arrows*). The ligament although appearing patent is significantly thickened at its femoral attachment (*double-headed arrow*). The medial meniscus can be seen deep to the ligament (*white curved arrow*). These findings are in keeping with a partial tear (grade 2) and subsequent fibrosis of the proximal attachment of the medial collateral ligament. MFC, medial femoral condyle; MT, medial tibial plateau.

Fig. 10.40 MRI (STIR). The image is of the same knee demonstrated in ▸Fig. 10.39. The medial collateral ligament is thickened and oedematous proximally (*white arrows*) in keeping with a grade 2 tear. White crosses, measurement calipers.

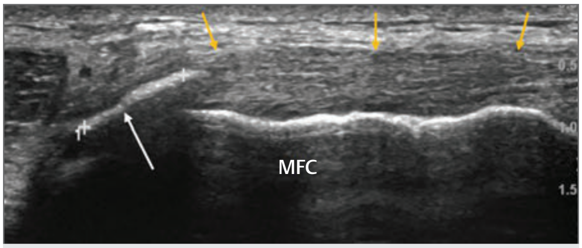

Fig. 10.41 Longitudinal image of the medial aspect of the knee joint. The medial collateral ligament (*yellow arrows*) appears intact and of good fibrillar pattern. There appears to be some thickening of the medial collateral ligament at its proximal attachment onto the medial femoral condyle. In addition, there appears to be an avulsed fragment of bone within the proximal attachment of the medial collateral ligament measuring approximately 9 mm longitudinally (*white arrow*). MFC, medial femoral condyle.

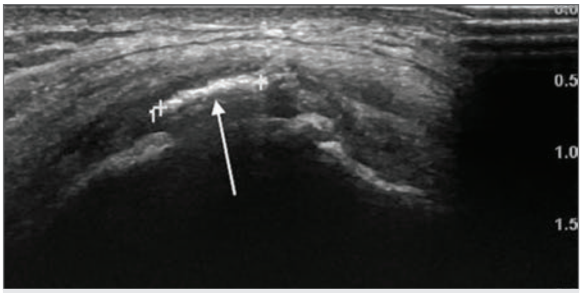

Fig. 10.42 Transverse image of the medial aspect of the knee at the level of the medial femoral condyle. The image is of the same knee outlined in ▸Fig. 10.41. The bony fragment (*white arrow*) can clearly be seen measuring approximately 7 mm transversely .

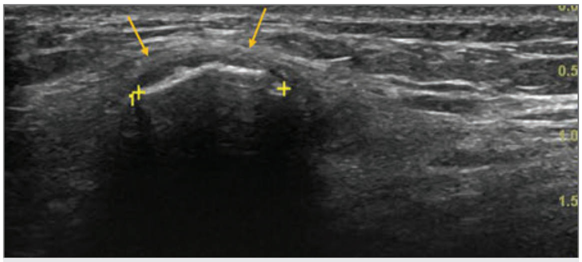

Fig. 10.43 Transverse image of the superomedial tibia at the insertion of the pes anserine tendon. The calcific foci measuring approximately 10 mm (*yellow crosses*) can be seen deep to the pes anserine tendon (*yellow arrows*). Note the acoustic shadow deep to the calcific foci. With active knee flexion and extension, the pes anserine tendon could be seen "flicking" over this prominence eliciting the patient's discomfort.

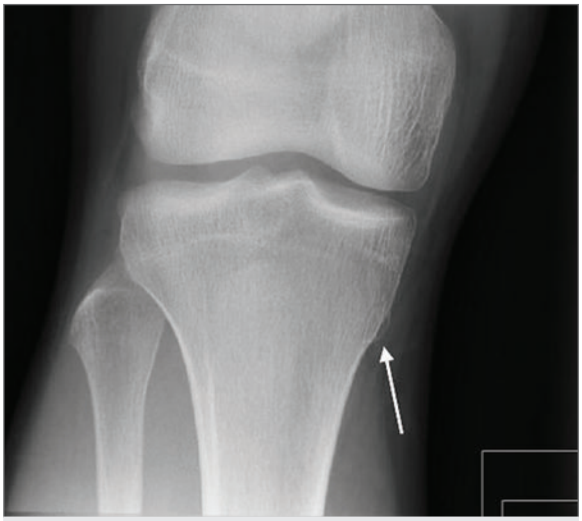

Fig. 10.44 Anteroposterior (AP) X-ray of the knee outlined in ▸Fig. 10.43. The small calcific foci may be seen at the superomedial aspect of the tibia (*white arrow*).

10

10.1.3 Lateral

Lateral Knee Joint and Lateral Collateral Ligament—Longitudinal Scan

The patient is positioned in supine with the knee placed in 80 to 90 degrees of flexion. To view the lateral collateral ligament, the probe is placed in the anatomical coronal plane so that it lies along the long axis of the tibia and fibula. The distal edge of the probe is placed over the head of the fibula which can be used as a landmark to find the ligament at its insertion (▶Fig. 10.45, ▶Fig. 10.46, ▶Fig. 10.47).

Fig. 10.45 Longitudinal scan of the lateral aspect of the knee and lateral collateral ligament. The probe is placed in the anatomical coronal plane in alignment with the tibia and fibula. The distal edge of the probe is placed up against the head of the fibular and insertion of the lateral collateral ligament.

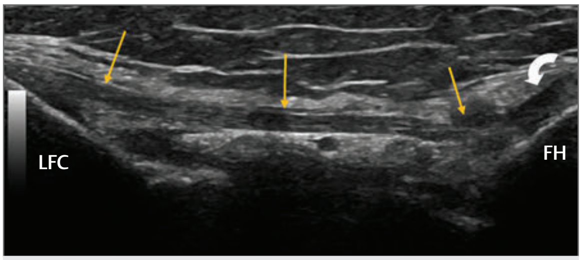

Fig. 10.46 Longitudinal image of the lateral aspect of the knee and lateral collateral ligament (*yellow arrows*). The ligament can be seen to be intact with a good fibrillar pattern. There appears to be a loss of normal echogenicity within the distal tendon (*curved white arrow*) at its insertion onto the fibular head (FH). This does not represent pathology but anisotropy. LFC, lateral femoral condyle; white curved arrow, anisotropy.

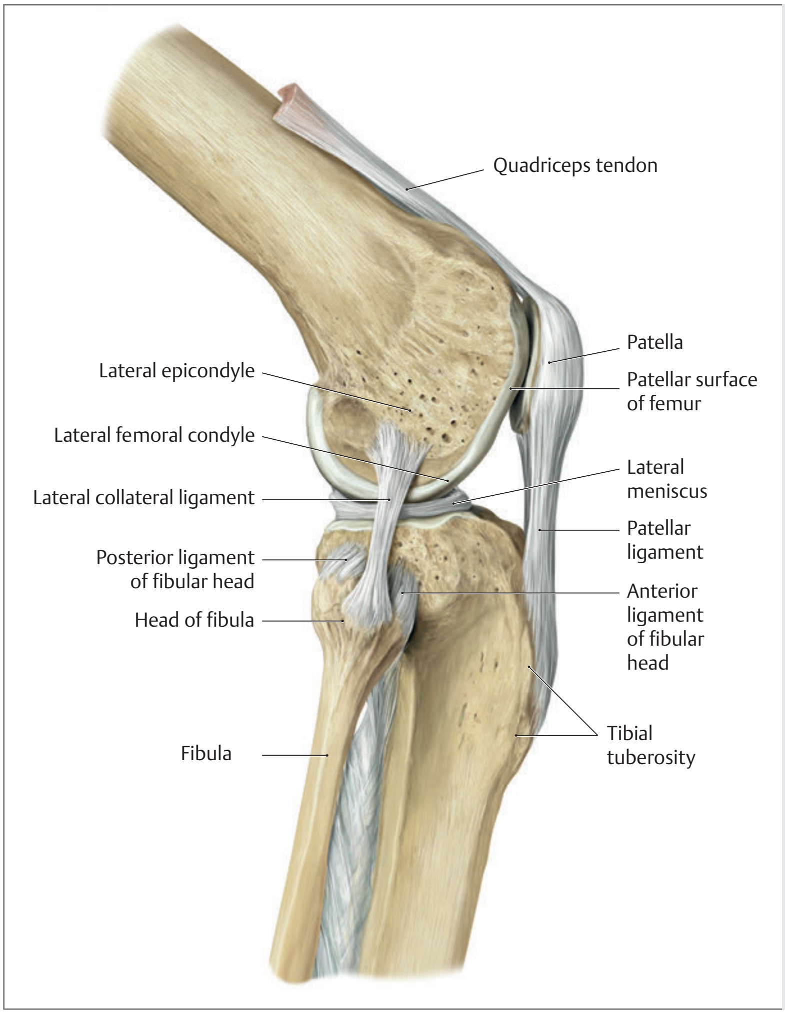

Fig. 10.47 Sagittal view of the lateral aspect of the knee demonstrating the extensor mechanism and the lateral collateral ligament. The lateral collateral or fibular ligament is rounded, more narrow, and less broad than the medial collateral ligament. The lateral collateral ligament stretches obliquely downward and backward from the lateral condyle of the femur above to the head of the fibula below. In contrast to the medial collateral ligament, it is fused with neither the capsular ligament nor the lateral meniscus. Because of this the lateral collateral ligament is more flexible than its medial counterpart and is therefore less susceptible to injury. Immediately deep to the lateral collateral ligament at its origin on the femoral condyle is the groove containing the tendon of popliteus. Superficially the greater part of the lateral collateral ligament's outer surface is covered by the tendon of biceps femoris which divides at its insertion into two parts to wrap around the ligament. (Reproduced from Schuenke, Schulte, and Schumacher, Atlas of Anatomy, 2nd edition, ©2014, Thieme Publishers, New York. Illustration by Karl Wesker/Markus Voll.)

Lateral Knee Joint—Distal Iliotibial Band: Longitudinal Scan

The patient is positioned in supine with the knee placed in 80 to 90 degrees of flexion. To view the distal iliotibial band, the probe is placed in the anatomical coronal plane so that it lies along the long axis of the femur over the lateral femoral condyle (▶Fig. 10.48, ▶Fig. 10.49, ▶Fig. 10.50).

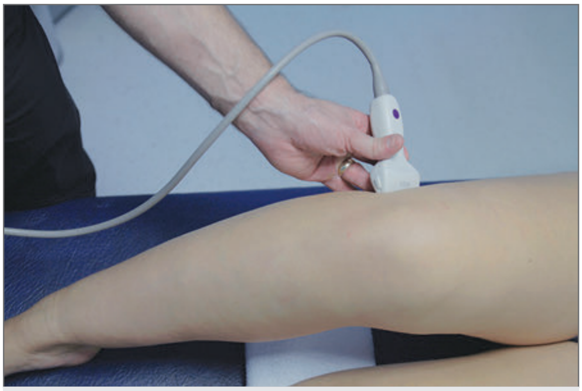

Fig. 10.48 Longitudinal scan of the distal iliotibial band. The probe is placed in the anatomical coronal plane so that it lies in the same longitudinal axis as the femur and over the lateral femoral condyle.

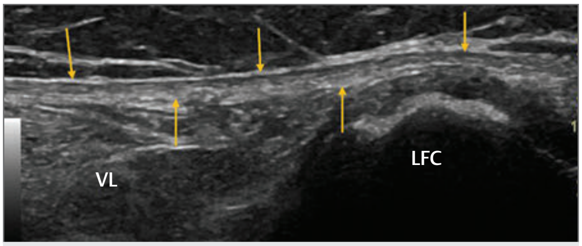

Fig. 10.49 Longitudinal image of the distal iliotibial band at the lateral aspect of the knee. The iliotibial band may be seen as an echogenic band (*yellow arrows*) superficial to the vastus lateralis (VL). As it nears the knee joint, it passes over the lateral femoral condyle (LFC). In the normal state the iliotibial bursa cannot be seen.

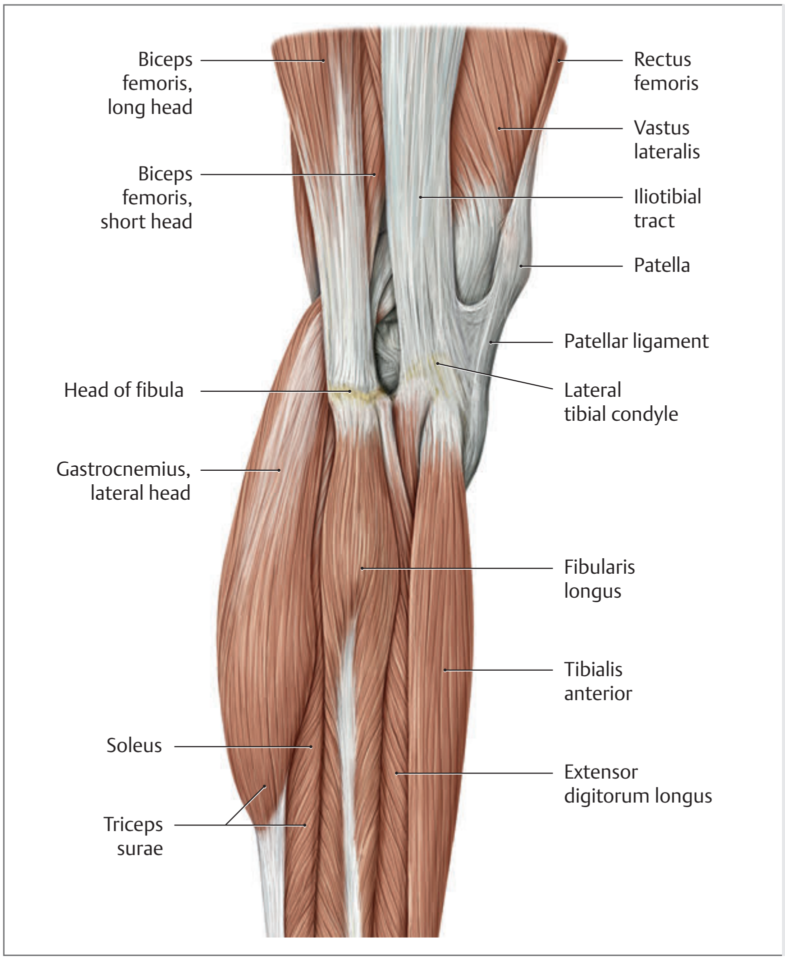

Fig. 10.50 Sagittal view of the lateral aspect of the knee demonstrating the relationship of the muscles of the lateral thigh and lower leg. The tendon of biceps femoris divides into two portions at its attachment onto the head of the fibula embracing the fibular collateral ligament of the knee joint. The iliotibial band originating from the anterolateral iliac tubercle portion of the external lip of the iliac crest inserts at the lateral condyle of the tibia at Gerdy's tubercle anterior to the head of the fibula. The iliotibial band stabilizes the knee both in extension and in partial flexion, and is therefore used constantly during walking and running. (Reproduced from Schuenke, Schulte, and Schumacher, Atlas of Anatomy, 2nd edition, ©2014, Thieme Publishers, New York. Illustration by Karl Wesker/Markus Voll.)

Lateral Knee Joint: Popliteus Tendon

The patient is positioned in supine with the knee placed in 80 to 90 degrees of flexion. To view the popliteus tendon, the probe is placed in the anatomical coronal plane so that it lies along the long axis of the femur over the lateral femoral condyle and lateral knee joint (▶Fig. 10.51, ▶Fig. 10.52).

Fig. 10.51 Longitudinal scan of the popliteus tendon at the lateral aspect of the knee joint. The probe is placed in the coronal plane along the long axis of the femur.

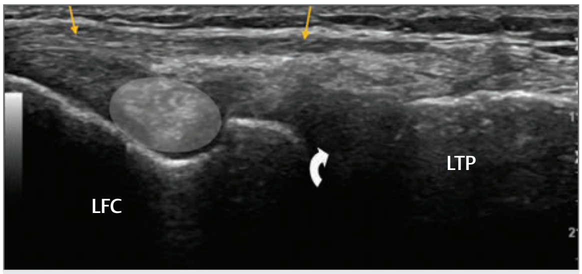

Fig. 10.52 Longitudinal image of the lateral knee joint (*white curved arrow*). The tendon of popliteus (*gray oval*) may be seen to lie in the groove formed within the lateral femoral condyle. In this position the tendon is seen in transverse section as it becomes intra-articular. LFC, lateral femoral condyle; LTP, lateral tibial plateau; white curved arrow, lateral knee joint and meniscus; yellow arrows, iliotibial band.

Lateral Knee Joint: Proximal Tibiofibular Joint

The patient is positioned in supine with the knee placed in 80 to 90 degrees of flexion. To view the proximal tibiofibular joint, the probe is placed in the anatomical transverse oblique plane over the anterior aspect of the joint at the upper aspect of the shin (▶Fig. 10.53).

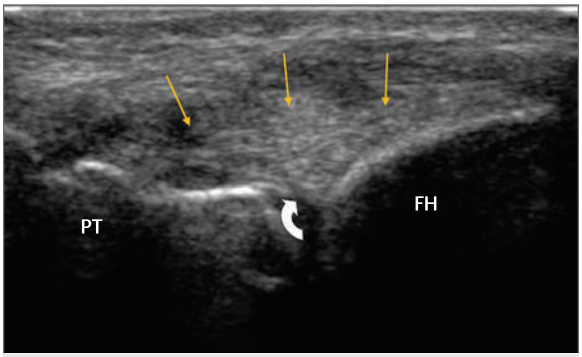

Fig. 10.53 Transverse image of the superior tibiofibular joint. The probe is placed in the anatomical transverse oblique plane over the joint. The anterior superior tibiofibular ligament (*yellow arrows*) may be seen as an echogenic fibrillar structure passing between the fibular head (FH) and proximal tibia (PT). White curved arrow, superior tibiofibular joint.

Lateral Knee Joint: Pathology

See ▶Fig. 10.54 and ▶Fig. 10.55.

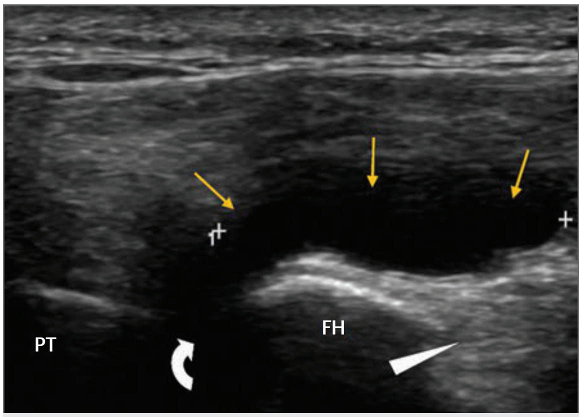

Fig. 10.54 Transverse image of the superior tibiofibular joint. The image demonstrates a well-defined anechoic swelling measuring approximately 1.5 cm in diameter extending from the joint at its anterior aspect (*yellow arrows*). Findings are indicative of a ganglion cyst of the superior tibiofibular joint. Note the posterior enhancement (*white arrowhead*) generated by the low density of the overlying cyst. FH, fibular head; PT, proximal tibia; white curved arrow, superior tibiofibular joint.

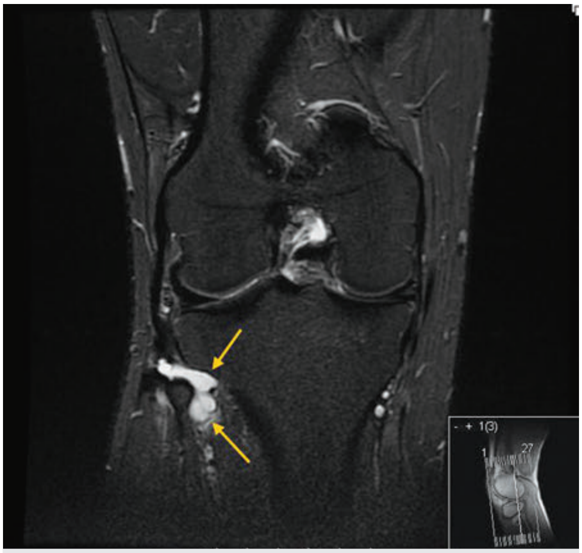

Fig. 10.55 MRI (Coronal STIR). The image in this picture is of the same patient demonstrated in ▶Fig. 10.54. A lobulated high signal can be seen to extend from the superior tibiofibular joint in keeping with a likely cyst (*yellow arrows*).

10.1.4 Posterior

Posterior Knee Joint: Transverse Popliteal Fossa

The patient is positioned in prone with the ankle and foot placed over a pillow so that the knee rests in 20 to 30 degrees of flexion. The probe is placed in the anatomical transverse plane over the medial aspect of the popliteal fossa (▶Fig. 10.56, ▶Fig. 10.57, ▶Fig. 10.58).

Fig. 10.56 Transverse scan of the medial aspect of the popliteal fossa. The probe is placed in the anatomical transverse plane. In this position the medial hamstring tendons semimembranosus and semitendinosus may be visualized as well as the medial gastrocnemius. Moving the probe more laterally allows visualization of the lateral hamstring tendon biceps femoris.

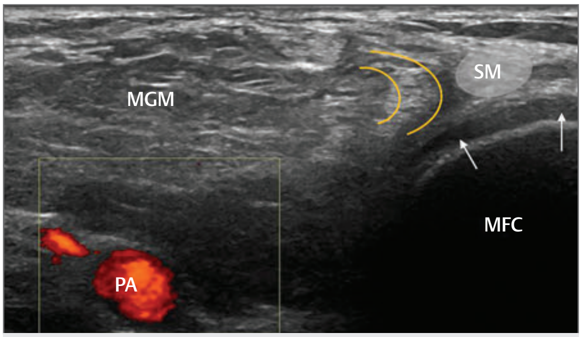

Fig. 10.57 Transverse image of the medial aspect of the popliteal fossa. The semimembranosus tendon (SM) may be seen over the posterior aspect of the medial femoral condyle (MFC). At this level the tendon of semitendinosus cannot be seen as it has moved more medially on its way to become part of the pes anserine tendon. The tendon of the medial gastrocnemius muscle (MGM) can be seen as the curved echogenic foci next to the semimembranosus tendon. PA, popliteal artery; white arrows, articular cartilage; yellow curved lines, medial gastrocnemius tendon.

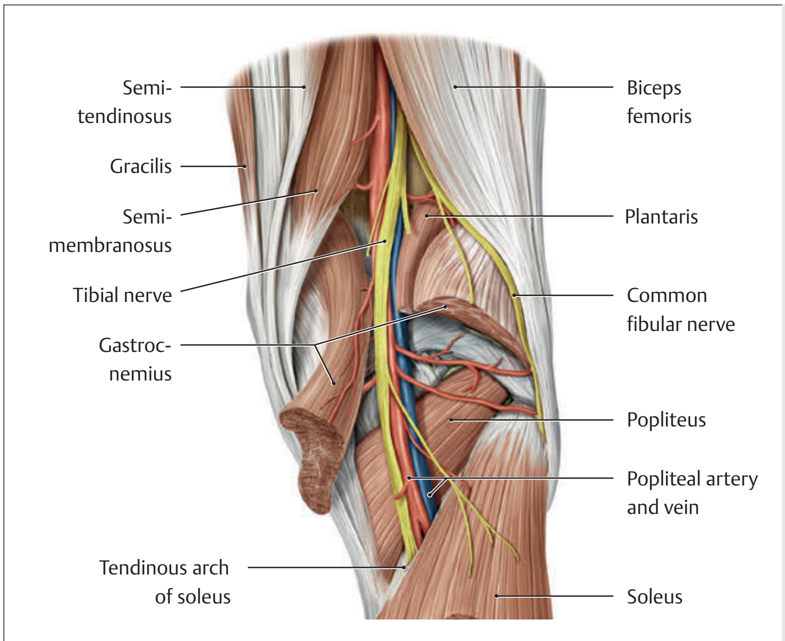

Fig. 10.58 Coronal view of the right popliteal fossa. The boundaries of the fossa are formed by the semimembranosus muscle superomedially, the biceps femoris muscle superolaterally, the medial head of gastrocnemius inferomedially, and the lateral head of gastrocnemius and plantaris inferolaterally. The floor of the fossa is formed by the popliteal surface of the femur, the capsule of the knee joint, the oblique popliteal ligament, and the strong fascia covering the popliteus muscle. Structures within the popliteal fossa include the tibial nerve, popliteal vein and popliteal artery, the small saphenous vein, and the common fibular (also known as the peroneal) nerve. (Reproduced from Schuenke, Schulte, and Schumacher, Atlas of Anatomy, 2nd edition, ©2014, Thieme Publishers, New York. Illustration by Karl Wesker/Markus Voll.)

Posterior Knee Joint: Longitudinal Popliteal Fossa

The patient is positioned in prone with the ankle and foot placed over a pillow so that the knee rests in 20 to 30 degrees of flexion. The probe is placed in the anatomical sagittal plane along the medial side of the popliteal fossa to view the tendon of semimembranosus in longitudinal aspect (▶Fig. 10.59, ▶Fig. 10.60).

Fig. 10.59 Longitudinal scan over the medial aspect of the popliteal fossa. The probe is placed in the anatomical sagittal plane to lie over the tendon of semimembranosus.

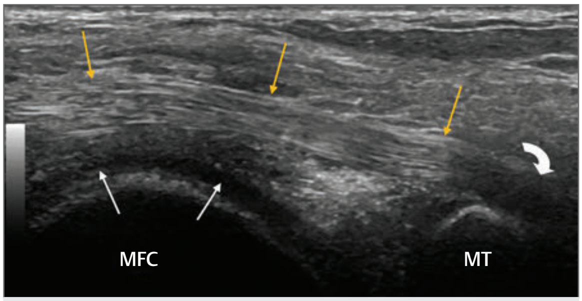

Fig. 10.60 Longitudinal image of the medial aspect of the popliteal fossa. The tendon of semimembranosus (*yellow arrows*) can be seen to pass over the posterior aspect of the medial femoral condyle (MFC) to insert onto the posterior aspect of the medial tibial plateau (MT). The loss of normal fibrillar pattern within the tendon toward its insertion is due to anisotropy (*curved arrow*). White arrows, articular cartilage.

Posterior Knee Joint: Pathology

See ▶Fig. 10.61, ▶Fig. 10.62, ▶Fig. 10.63, ▶Fig. 10.64, ▶Fig. 10.65, and ▶Fig. 10.66.

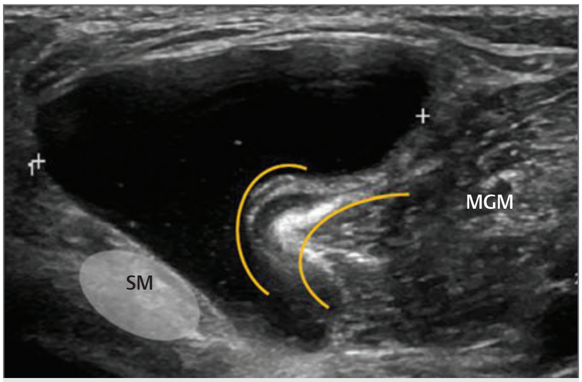

Fig. 10.61 Transverse image of the medial popliteal fossa. The medial gastrocnemius tendon can be seen between the two yellow lines. The semimembranosus tendon (SM) can be seen to the bottom left of the image. From between these two tendons may be seen a large anechoic swelling in keeping with a large Baker's cyst. The cyst is of typical "speech-bubble" appearance. MGM, medial gastrocnemius muscle; white crosses, measurement calipers.

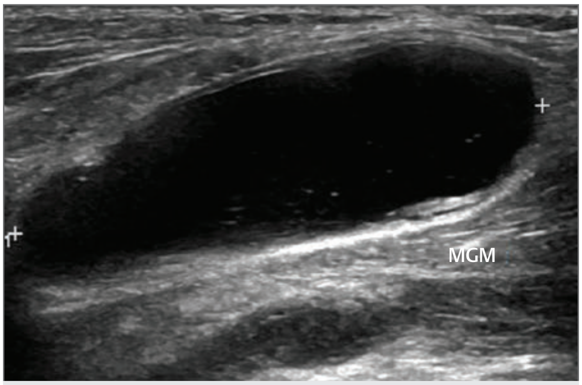

Fig. 10.62 Longitudinal image of the medial aspect of the popliteal fossa. The image is the same as outlined transversely in ▶Fig. 10.61. A large anechoic swelling is demonstrated lying above the medial gastrocnemius muscle (MGM). The image demonstrates the classic appearance of a Baker's cyst. White crosses, measurement calipers.

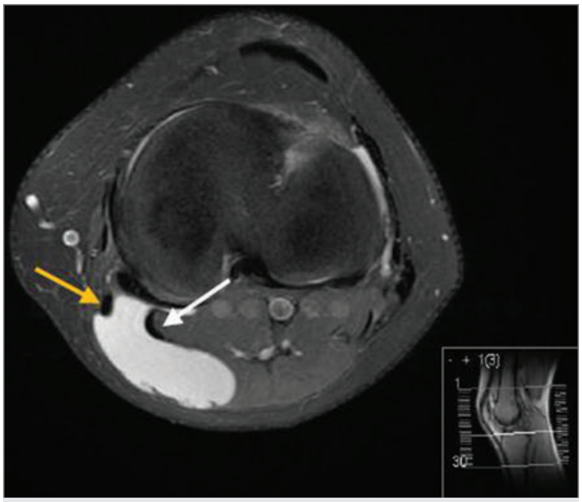

Fig. 10.63 Axial MRI of the same knee demonstrated in ▶Fig. 10.61 and ▶Fig. 10.62. A high-signal swelling in keeping with a Baker's cyst may be seen to extend posteriorly between the tendons of semimembranosus (*yellow arrow*) and medial gastrocnemius (*white arrow*).

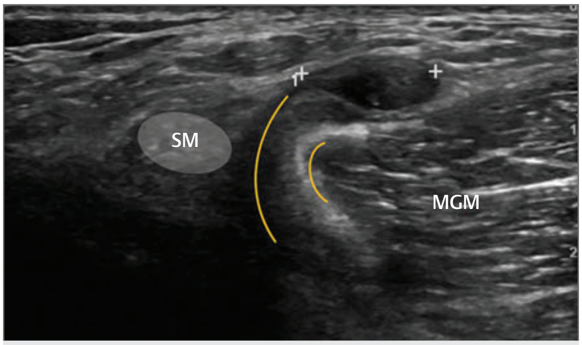

Fig. 10.65 Transverse image of the medial aspect of the popliteal fossa. A small low echo swelling may be seen to extend from between the tendon of semimembranosus (SM) and the medial gastrocnemius tendon (*yellow curve*). The image is in keeping with a small Baker's cyst. MGM, medial gastrocnemius muscle; white crosses, measurement calipers.

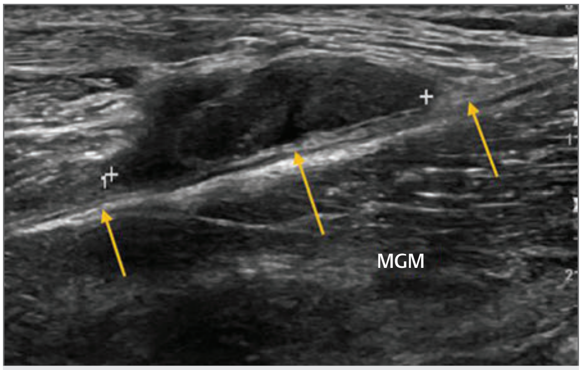

Fig. 10.66 Longitudinal image of the medial aspect of the popliteal fossa. The image is the same as outlined transversely in▶Fig. 10.65. A small low echo swelling is seen lying above the medial gastrocnemius muscle (MGM) and tendon (*yellow arrows*). The image demonstrates a small resolving Baker's cyst. The swelling appears to contain material and not simple fluid most likely representing a degree of polymerization of hyaluronan and synovial thickening. White crosses, measurement calipers.

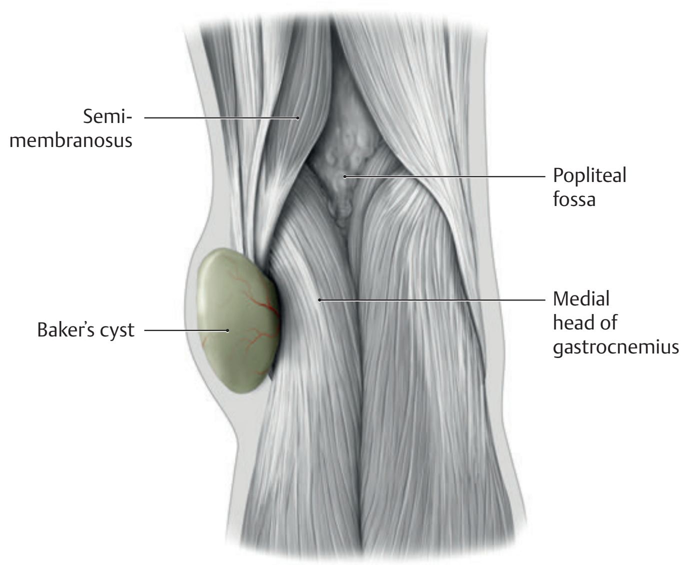

Fig. 10.64 Coronal view of the right popliteal region demonstrating a Baker's or popliteal cyst. First described by William Morrant Baker (1838–1896) this is not a "true" cyst as an open communication with the synovial sac of the knee joint is often maintained. In adults, Baker's cysts usually arise from either an arthritis of the knee joint or meniscal tear. Baker's cysts arise from the knee joint passing posteriorly between the tendons of the medial head of the gastrocnemius and the semimembranosus tendons to lay posterior to the medial femoral condyle. A Baker's cyst can rupture producing acute pain and swelling both behind the knee and into the calf. (Reproduced from Schuenke, Schulte, and Schumacher, Atlas of Anatomy, 2nd edition, ©2014, Thieme Publishers, New York. Illustration by Karl Wesker/Markus Voll.)

11 The Knee: Guided Injection Techniques

Abstract

This chapter outlines commonly used injection techniques around the knee joint. The aim is to detail the position and alignment of the probe and needle to allow accurate placement into the target tissue. In addition, a brief clinical presentation is given for each condition as well as some of the anatomical considerations which should be noted. The drugs, dosages, and volumes given are those used in the author's clinic.

Keywords: knee joint, patellar tendon, quadriceps tendon, suprapatellar, Hoffa's fat pad, pes anserine, lateral collateral ligament, medial collateral ligament, meniscus, popliteal, semimembranosus, semitendinosus, gastrocnemius

11.1 Knee Joint Aspiration/Injection

11.1.1 Cause

- Osteoarthritis, rheumatoid arthritis, or trauma.

11.1.2 Presentation

An effusion may be visible or detected on clinical examination. The patient may be able to describe an initiating traumatic event or change in activity which precipitated an exacerbation of pain and swelling. However, in the patient with osteoarthritis the patient may be unable to describe any such mechanism.

11.1.3 Equipment

See ▶Table 11.1.

Table 11.1 Equipment needed for knee joint aspiration/injection

Syringe	Needle	Corticosteroid	Local anesthetic	Transducer
10 mL	21 gauge – 2 inch	40-mg Depo-Medrone	5-mL 1% lidocaine	Large linear footprint

11.1.4 Anatomical Considerations

The safest and easiest technique is to use a lateral to medial approach immediately proximal to the superior edge of the patella. The clinician need not worry about any major blood vessels or nerves if this technique is used and excellent needle visualization is obtained for both aspiration if needed and injection.

11.1.5 Procedure

- Supine with the knee flexed approximately 20 degrees.
- Transducer placed in the transverse plane over the suprapatellar recess.
- Needle introduced lateral to medial in long axis to the transducer.
- Aim for the suprapatellar recess between the quadriceps tendon or quadriceps fat pad (superficial) and prefemoral fat (deep).

Note: Medial/lateral patellar gliding can improve identification of the suprapatellar recess.

11.1.6 The Aspiration/Injection

See ▶Fig. 11.1 and ▶Fig. 11.2.

Fig. 11.1 Knee joint aspiration/injection. The probe is placed in the transverse plane over the suprapatellar recess. The needle is introduced from the lateral to medial in long axis to the probe. Aim for the suprapatellar recess between the quadriceps tendon and quadriceps fat pad (superficial) and prefemoral fat (deep).

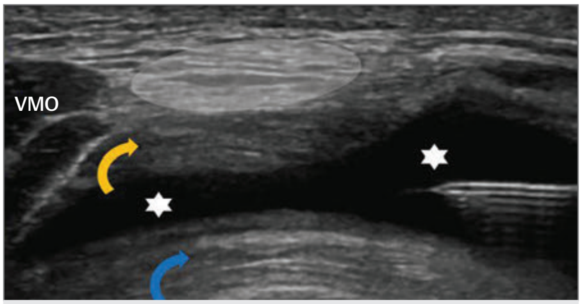

Fig. 11.2 Transverse image of the suprapatellar region of the knee. The quadriceps tendon may be seen at the top of the image (*shaded oval*). The suprapatellar pouch is effused (*white stars*). A needle may be seen to enter the suprapatellar pouch from the lateral side (note the reverberation artefact). Blue curved arrow, prefemoral fat; shaded oval, quadriceps tendon; VMO, vastus medialis obliquus; white stars, suprapatellar effusion; yellow curved arrow, suprapatellar fat.

11.1.7 Notes

In the case of trauma the possibility of a fracture should be excluded before an injection is considered. This is particularly the case in the elderly or osteoporotic patient who may sustain a fracture in return for a relatively innocuous injury. In the case of the younger patient consider a meniscal injury, ligamentous damage, or osteochondral lesion prior to injection.

In addition as in any corticosteroid injection infection or reactive arthritis should be considered when presented with an effused knee for which the patient can describe no significant initiating trauma.

If no effusion is present in the suprapateller region it may be easier to give the injection into the medial margin of the patellofemoral joint. In this case, the probe is placed in the transverse plane over the patella and medial patella femoral joint. The needle is introduced in line with the probe at a 45 degree angle deep to the patella.

In the case of an osteoarthritic knee with no clear effusion consider injection of a hyaluronan rather than a corticosteroid.

11.2 Semimembranosus Bursa/Baker's Cyst Aspiration/ Injection

11.2.1 Cause

Spontaneous and insidious onset. The Baker's cyst is often related to an underlying osteoarthritis of the knee joint. In the case of a semimembranosus bursa onset may follow a history of repetitive sporting activity such as repeated deep squatting during powerlifting.

11.2.2 Presentation

Swelling in the popliteal fossa may be quite large. More subtle swellings may only be seen on ultrasound.

11.2.3 Equipment

See ▸Table 11.2.

Table 11.2 Equipment needed for semimembranosus bursa/ Baker's cyst aspiration/injection

Syringe	Needle	Corticosteroid	Local anesthetic
10 or 20 mL	21 gauge	N/A	N/A

11.2.4 Anatomical Considerations

A Baker's cyst is a synovial fluid–filled herniation through the posterior wall of the knee joint capsule. The cyst can usually be seen to originate deeply from the posterior aspect of the joint extending between the tendon of the medial gastrocnemius medially and the tendon of semimembranosus laterally in transverse imaging. Smaller swellings may represent a distension of the semimembranosus bursa in which case there may be no clear extension more deeply.

11.2.5 Procedure

- The patient is positioned in prone with the knee supported on a pillow.
- The transducer is placed in the anatomical sagittal plane.
- The needle is introduced in a line progressing from inferior to superior in the long axis of the transducer.
- Fluid is aspirated from the bursa.
- If injection is also required, the needle may be left in place and a fresh syringe connected with the injectable drug.
- Injection is given as a bolus.

11.2.6 The Aspiration/Injection

See ▸Fig. 11.3 and ▸Fig. 11.4.

Fig. 11.3 Aspiration/injection of a semimembranosus bursa/ Baker's cyst. The probe is placed in the anatomical sagittal plane. The needle is introduced in a line progressing from inferior to superior in the long axis of the probe. Fluid is aspirated from the bursa. If injection is also required, the needle may be left in place and a fresh syringe connected with the injectable drug.

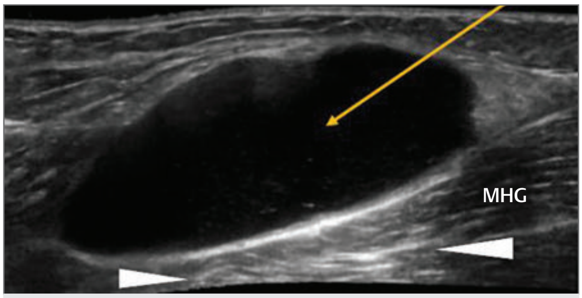

Fig. 11.4 Longitudinal image of the medial aspect of the popliteal fossa. The Baker's cyst appears as a large well-defined anechoic swelling laying superficially to the medial head of gastrocnemius (MHG). The needle direction is indicated by the yellow arrow and is in an inferior to superior line. Note the posterior enhancement (*arrowheads*) which indicate the swelling is of relatively low density.

11.2.7 Notes

Identify the popliteal artery, veins, and tibial nerve which should be seen medial to the swelling. The cyst/bursa may be lobulated and require that the different parts are targeted. In the case of the semimembranosus bursa corticosteroid injection may follow aspiration.

It should be noted that a Baker's cyst is often related to an underlying osteoarthritis of the knee joint. In such cases treatment should be directed at the osteoarthritis as the predisposing factor.

When imaging the popliteal fossa, an accessory fabella (Latin for *little bean*) may be noted lying within the medial or lateral gastrocnemius tendon. This small sesamoid bone is a normal variant present in 10 to 30% of patients. Rarely there may be two to three of these bones (fabella bi or tripartite). The fabella rarely causes problems unless the patient's occupation or sport involves repeated end-range flexion and heavy loading of the knee such as required in powerlifting or weightlifting. In this case guided injection around the fabella may be of both diagnostic and therapeutic benefit.

Although relatively rare, a popliteal artery aneurysm should always be excluded with the use of Doppler imaging. Popliteal artery aneurysms are the most common true peripheral aneurysm occurring more frequently than femoral artery aneurysm but less frequently than abdominal aortic aneurysm.

11.3 Distal Iliotibial Band/ Bursa Injection

11.3.1 Cause

- Commonly overuse.
- Often related to long distance running or fell running.

11.3.2 Presentation

The patient describes pain over the lateral aspect of the knee which may be diffuse in nature but on palpation centered over the lateral femoral condyle. If the bursa is inflamed, there may be a palpable swelling.

11.3.3 Equipment

See ▸Table 11.3.

Table 11.3 Equipment needed for distal iliotibial band/bursa injection

Syringe	Needle	Corticosteroid	Local anesthetic
5 mL	23 gauge – 1.25 inch	20-mg Depo-Medrone	2-mL 1% lidocaine

11.3.4 Anatomical Considerations

The bursa lies deep to the iliotibial band over the lateral femoral condyle of the femur. In its normal state it is not visible on ultrasound.

11.3.5 Procedure

- The patient is positioned in side lying with the symptomatic side up and knee flexed to 20 degrees and supported on a pillow.
- The transducer is placed in the anatomical coronal plane so that it lies longitudinally over the iliotibial band at the level of the lateral femoral condyle.
- The needle is introduced from a superior to inferior line in the long axis of the transducer.
- The needle tip should be positioned between the iliotibial band and the lateral femoral condyle.

11.3.6 The Injection

See ▸Fig. 11.5 and▸Fig. 11.6.

11.3.7 Notes

Inflammation and distension of the bursa is unusual. More commonly the bursa itself cannot be seen on imaging, but the iliotibial band appears thickened suggesting a more chronic condition. If this is the case, a higher-volume injection may be given with up to 10 mL to help stretch and free any adhesions.

As always the patient should be assessed in regard to any muscle imbalance or tightness of the iliotibial band itself. In addition, gait analysis should be considered if foot position is considered an issue.

Fig. 11.5 Injection of the distal iliotibial band/bursa. The probe is placed in the anatomical coronal plane over the iliotibial band at the level of the lateral femoral condyle. The needle is introduced from a superior to inferior line in the long axis of the transducer. The needle tip should be positioned between the iliotibial band and the lateral femoral condyle.

11.4 Pes Anserine Bursa/ Tendon Injection

11.4.1 Cause

- Most commonly overuse.
- Often related to long-distance running.

11.4.2 Presentation

The patient describes pain over the superior medial aspect of the tibia at the insertion of the tendons of sartorius, semitendinosus, and gracilis (pes anserine tendons). There may be some pain on resisted knee flexion. More commonly the only clinical finding is pain to direct palpation. If the bursa is inflamed, there may be a visible swelling.

11.4.3 Equipment

See ▶Table 11.4.

11.4.4 Anatomical Considerations

The pes anserine tendon is a conjoined tendon formed by sartorius, semitendinosus, and gracilis. It is not possible to clearly distinguish the individual tendons. The pes anserine tendon is attached to the superior medial aspect of the tibia just inferior to the joint line and medial to the tibial tuberosity and patella tendon insertion. The pes bursa is situated deep to the tendon. In the normal non-pathological state the bursa is not visible on ultrasound; it becomes visible only if distended with fluid.

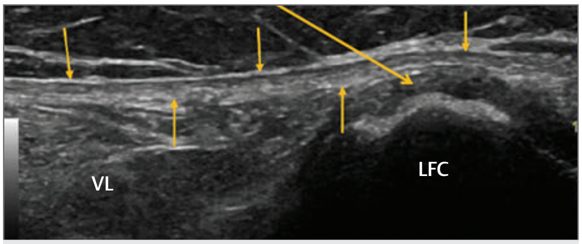

Fig. 11.6 Longitudinal image of the distal iliotibial band (*short yellow arrows*). The lateral femoral condyle (LFC) may be seen deep to the iliotibial band. The direction of the needle is indicated by the long yellow arrow. VL, vastus lateralis.

Table 11.4 Equipment needed for pes anserine bursa/tendon injection

Syringe	Needle	Corticosteroid	Local anesthetic
5 mL	25 gauge – 1 inch	20-mg Depo-Medrone	2-mL 1% lidocaine

11.4.5 Procedure

- The patient is positioned in supine with the knee flexed to 20 degrees on a pillow. The hip may be slightly externally rotated.
- The transducer is placed in the anatomical sagittal/ oblique plane.
- The needle should be introduced from inferior to superior in the long axis of the transducer.
- The needle tip should be positioned either deep to the pes anserine tendon or if a bursitis is present within the bursa itself.

11.4.6 The Injection

See ▶Fig. 11.7 and ▶Fig. 11.8.

Fig. 11.7 Pes anserine injection. The probe is placed in the anatomical sagittal/oblique plane. The needle should be introduced from inferior to superior in the long axis of the transducer. The needle tip should be positioned either deep to the pes anserine tendon or if a bursitis is present within the bursa itself.

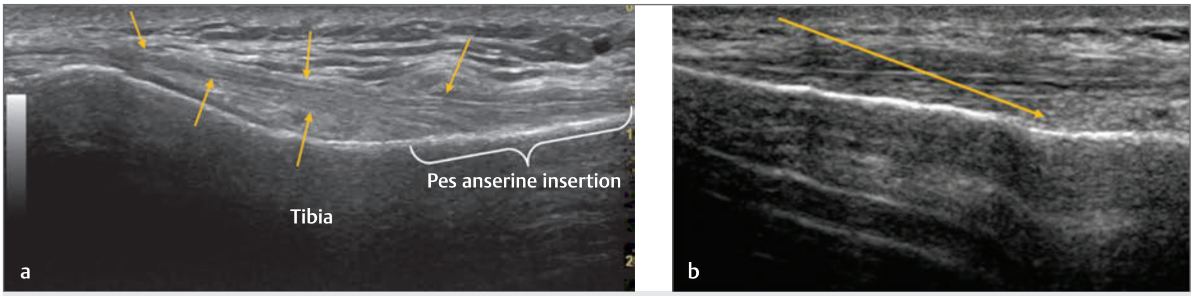

Fig. 11.8 (**a,b**) Longitudinal image of the pes anserine tendon (*short yellow arrows*). The insertion onto the anteromedial tibia may be seen as a broad attachment. The needle direction is indicated by the long yellow arrow.

11.4.7 Notes

It is unusual for the pes bursa to be distended and therefore visible on ultrasound. More commonly there is little to see on scanning. If clinical examination points to a problem with the pes bursa or tendon with little evidence of change on ultrasound, injection may still be given deep to the pes tendon with positive results.

11.5 Medial Collateral Ligament Injection

11.5.1 Cause

- Traumatic valgus strain or twisting injury.
- Acute injuries may be expected to do well with protective bracing and correct rehabilitation.
- Injection is indicated in more chronic cases which have not fully resolved.

11.5.2 Presentation

- The patient describes pain over the medial aspect of the joint.
- Pain may be reproduced with valgus strain or end-range flexion and extension.

11.5.3 Equipment

See ▶Table 11.5.

Table 11.5 Equipment needed for medial collateral ligament injection

Syringe	Needle	Corticosteroid	Local anesthetic
5 mL	25 gauge – 1 inch	20-mg Depo-Medrone	2-mL 1% lidocaine Up to 5 mL if chronic

11.5.4 Anatomical Considerations

The medial collateral ligament (MCL) is attached proximally to the medial femoral condyle and runs distally over the joint line to attach to the medial aspect of the upper shaft of the tibia. At the joint line it is approximately the width of two fingers and is closely related to the underlying joint capsule and medial meniscus.

11.5.5 Procedure

- The patient is positioned in supine with the knee flexed to 20 degrees and resting on a pillow. The hip may be slightly externally rotated.
- The transducer is placed in the anatomical sagittal plane over the MCL.
- The needle is introduced from inferior to superior in the long axis of the transducer.
- The needle tip should be positioned deep to the MCL fibers. Care should be taken not to place the needle too deeply so as to inject the medial meniscus.
- The injection may be given as a bolus deep to the ligament between its deeper fibres and the medial capsule. Following this fenestration of the ligament may be carried out if indicated in more chronic cases.

11.5.6 Medial Collateral Ligament Injection

See ▶Fig. 11.9 and ▶Fig. 11.10.

11.5.7 Notes

Acute injuries should be treated with a protective hinged brace which may be used to restrict flexion of the knee and protect against valgus and shear forces. Injection is reserved for more chronic cases resulting in a thickened ligament. If this is the case, the injection is initially given as a bolus deep to the ligament followed by fenestration of the ligament itself. A vigorous program of rehabilitation should be instigated immediately following injection.

Fig. 11.9 Injection of the medial collateral ligament. The probe is placed in the anatomical sagittal plane over the medial collateral ligament. The needle is introduced from inferior to superior in the long axis of the probe.

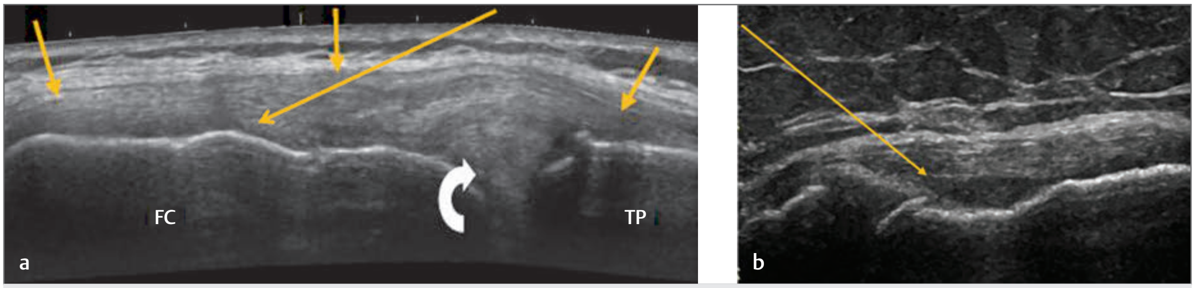

Fig. 11.10 (**a,b**) Longitudinal image of the medial collateral ligament (*short yellow arrows*). The medial meniscus (*white curved arrow*) may be seen deep to the ligament. The needle direction is indicated by the long yellow arrow.

11.6 Deep and Superficial Infrapatellar Bursa Injection

11.6.1 Cause

- Traumatic following a fall or blow to the anterior aspect of the knee.
- May also be related to overuse such as in long-distance running or excessive kneeling.

11.6.2 Presentation

The patient describes a localized pain over the anterior aspect of the knee below the patella at the level of the insertion of the patella tendon onto the tibial tuberosity. Pain may be reproduced with direct palpation of the area. Ultrasound can help to differentiate between a deep of superficial bursa and insertional tendinopathy involving the patella tendon.

11.6.3 Equipment

See ▶Table 11.6.

Table 11.6 Equipment needed for deep and superficial infrapatellar bursa injection

Syringe	Needle	Corticosteroid	Local anesthetic
2 mL	25 gauge–1 inch	20-mg Depo-Medrone	2-mL 1% lidocaine

11.6.4 Anatomical Considerations

The deep infrapatellar bursa lies deep to the patella tendon just above its attachment onto the tibial tuberosity. The superficial bursa lies anterior to the patella tendon at the level of the tibial tuberosity which it helps protect. In the normal nonpathological state ultrasound may not demonstrate either bursae which only become apparent if distended and/or inflamed.

11.6.5 Procedure

- The patient is positioned in supine with the knee flexed to 20 degrees and resting on a pillow.
- The transducer is placed in the anatomical transverse plane over the infrapatellar bursa.
- The needle is introduced in the long axis of the transducer.

- The needle tip should be positioned with either the deep or superficial bursa depending on presentation and imaging.
- Injection is given as a bolus.

11.6.6 The Injection

See ▶Fig. 11.11.

11.6.7 A. Deep Infrapatellar Bursa

See ▶Fig. 11.12.

11.6.8 B. Superficial Infrapatellar Bursa

See ▶Fig. 11.13.

11.6.9 Notes

Care should be taken to avoid injecting the substance of the patellar tendon itself. The patient should be instructed to avoid direct pressure against the anterior aspect of the knee or excessive flexion for at least 1 week following injection. A program of vigorous stretching for the quadriceps muscle and patella tendon should then be implemented.

The clinician should exclude an infective bursitis if the superficial bursa is affected given its anatomical position and vulnerability to puncture wounds particularly in patients who describe working on their knees.

Fig. 11.11 Injection of the deep and superficial infrapatellar bursa. The probe is placed in the anatomical transverse plane over the infrapatellar bursa. The needle is introduced in the long axis of the transducer. The needle tip should be positioned with either the deep or superficial bursa depending on presentation and imaging.

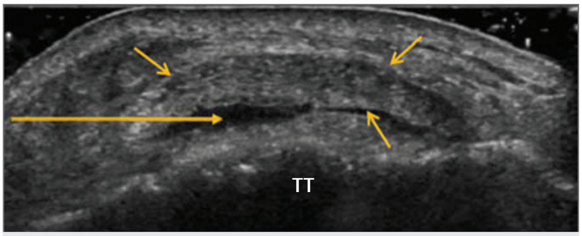

Fig. 11.12 Transverse image of the distal patellar tendon (*short yellow arrows*) at its insertion onto the tibial tuberosity (TT). The needle (*yellow arrow*) is positioned deep to the patellar tendon immediately proximal to its insertion on to the tibial tuberosity.

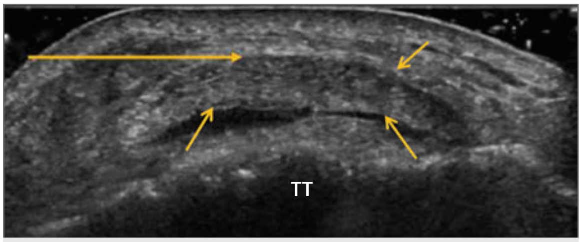

Fig. 11.13 Transverse image of the distal patellar tendon (*short yellow arrows*) at its insertion onto the tibial tuberosity (TT). The needle (*yellow arrow*) is positioned superficial to the patellar tendon immediately proximal to its insertion on to the tibial tuberosity.

11

11.7 Popliteus Tendon Sheath Injection

11.7.1 Cause

- May be traumatic following a twisting injury to the knee if the foot is fixed such as in football or rugby.
- Often related to overuse in the fell runner or the athlete who has increased their training on hills.

11.7.2 Presentation

The patient describes a localized pain over the posterolateral aspect of the knee related to activities such as running and twisting during sport. Pain may be reproduced with resisted external rotation of the lower leg with the knee flexed to 90 degrees and with direct palpation of the popliteus tendon as it wraps around the lateral aspect of the knee joint.

11.7.3 Equipment

See ▶Table 11.7.

11.7.4 Anatomical Considerations

The popliteus tendon originates on the lateral surface of the lateral femoral condyle in front of and inferior to the origin of the lateral collateral ligament and from the fibular head. In addition, it also has an origin from the posterior horn of the lateral meniscus. The tendon then courses under the lateral collateral ligament, descending into the "popliteal hiatus" where it becomes extra-articular before joining its muscle belly. It inserts into the tibia above the soleal line. Given this course the tendon and muscle both lie in a relatively horizontal plane.

Popliteus assists in flexing the lower leg upon the thigh when the leg is flexed. It also externally rotates the tibia on the femur. When the knee is in full extension, the femur slightly medially rotates on the tibia to lock the knee joint in place. Popliteus is often referred to as the "key" to unlocking the knee since it begins knee flexion by external rotation of the femur on the tibia.

Table 11.7 Equipment needed for popliteus tendon sheath injection

Syringe	Needle	Corticosteroid	Local anesthetic
2 mL	25 gauge – 1 inch	20-mg Depo-Medrone	2-mL 1% lidocaine

11.7.5 Procedure

- The patient is positioned in side lying with the affected knee uppermost and flexed to 20 degrees.
- The transducer is placed in the anatomic coronal/ oblique plane. In the same plane as the popliteus tendon.
- The needle is introduced from anterosuperior to posteroinferior in long axis to the transducer
- The needle tip should be positioned either deep or superficial to the popliteus tendon and the injection should be given as a bolus.

11.7.6 The Injection

See ▶Fig. 11.14 and ▶Fig. 11.15.

Fig. 11.14 Injection of the popliteus tendon sheath. The probe is placed in the anatomical coronal/oblique plane in the same plane as the popliteus tendon. The needle is introduced from an anterosuperior to posteroinferior direction in the long axis of the probe.

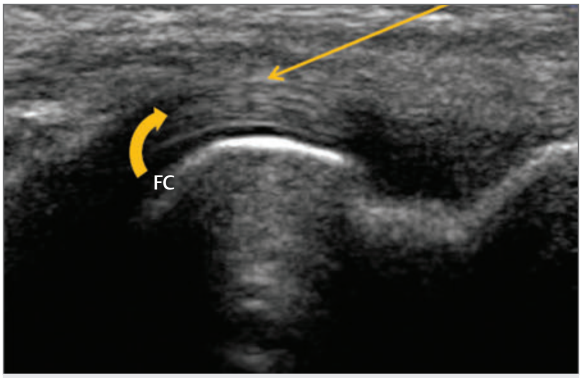

Fig. 11.15 Longitudinal image of the popliteus tendon as it passes around the lateral femoral condyle (FC). The tendon may be seen as an echogenic fibrillar structure (*curved arrow*). The straight arrow gives the direction of the needle. Curved arrow, popliteus tendon.

11.7.7 Notes

Care should be taken to avoid injecting the substance of the popliteus tendon itself. The patient is advised to avoid high impact and twisting activities involving the knee for at least 1 week following injection. A programme of vigorous stretching for the hamstrings muscle should then be implemented.

11.8 Proximal Tibiofibular Joint Injection

11.8.1 Cause

- Usually traumatic involving a twisting injury of the ankle on a flexed knee.
- May be overuse related to long-distance running with poor unsupportive footwear in an overpronating foot.

11.8.2 Presentation

Pain is localized to the superior tibiofibular joint with possible referral down the lateral aspect of the lower leg. Pain may be reproduced with full passive internal rotation of the knee or resisted flexion of the knee.

11.8.3 Equipment

See ▶Table 11.8.

11.8.4 Anatomical Considerations

The superior tibiofibular joint line runs in a medial direction from superior to inferior. As the peroneal nerve lies posterior to the joint, injection is best given using an anterior approach.

Table 11.8 Equipment needed for proximal tibiofibular joint injection

Syringe	Needle	Corticosteroid	Local anesthetic
2 mL	25 gauge – 1 inch	20-mg Depo-Medrone	1-mL 1% lidocaine

11.8.5 Procedure

- The patient is positioned in supine with the knee slightly flexed and supported on a pillow.
- The transducer is placed in the anatomical transverse/oblique line over the proximal tibiofibular joint line.
- The needle is introduced from an inferior to superior line in the short axis of the transducer.
- It is helpful to use a “walk-down” technique gently “walking” the needle tip along the anterior surface of the fibular head until the needle is felt to pierce the capsule and enter the joint. The injection is then given as a bolus.

11.8.6 The Injection

See ▶Fig. 11.16 and ▶Fig. 11.17.

11.8.7 Notes

Particular attention should be given to the patient’s gait especially if the problem is related to running. Careful gait analysis will ensure that the patient has the correct footwear for his/her foot type and help prevent recurrence of problems.

Fig. 11.16 Injection of the proximal tibiofibular joint. The probe is placed in the anatomical transverse/oblique line over the proximal tibiofibular joint line. The needle is introduced from an inferior to superior line in the short axis of the probe.

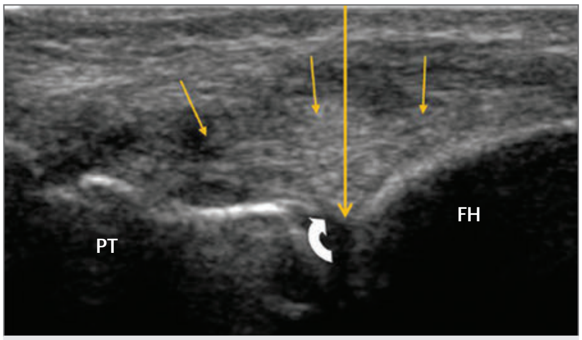

Fig. 11.17 Transverse image of the proximal tibiofibular joint. The anterior superior tibiofibular ligament may be seen superficially (*short yellow arrows*). The joint is shown deep to this (*curved arrow*). The straight arrow indicates the direction of the needle. FH, fibular head; PT, proximal tibia; white curved arrow, superior tibiofibular joint.

11.9 Patellar Tendon—Fenestration and Injection of Autologous Blood

11.9.1 Cause

- Commonly overuse.
- Particularly a problem with jumpers and sprinters and activities involving explosive acceleration and contraction of the quadriceps muscle.

11.9.2 Presentation

The patient is able to locate the pain to the inferior pole of the patella and origin of the patella tendon. Pain may be reproduced by direct palpation of this area and with strong contraction of the quadriceps muscle.

11.9.3 Equipment

See ▶Table 11.9.

11.9.4 Anatomical Considerations

The patella tendon takes its origin from the inferior pole of the patella. At this point it is approximately two to three fingers wide. It is at this point that the tendon is commonly affected the so called "jumper's knee." This is not an inflammatory condition and ultrasound will demonstrate evidence of tendinopathic change with tendon thickening, loss of normal echogenicity, and neovascularity depending on the individual. These changes are frequently seen in the deeper portion of the tendon.

Fig. 11.18 Injection of the patellar tendon—autologous blood. The probe is placed in the anatomical sagittal plane over the patellar tendon. The needle is introduced from inferior to superior in the long axis of the probe.

Table 11.9 Equipment needed for patellar tendon—fenestration and injection of autologous blood

Syringe	Needle	Corticosteroid	Local anesthetic
5 mL	23 gauges – 1.25 inch	N/A	4-mL 1% lidocaine

11.9.5 Procedure

- The patient is positioned in supine with the knee flexed to 20 degrees and supported on a pillow.
- About 2 mL of blood is taken from the patient's antecubital fossa.
- The transducer is placed in the anatomical sagittal plane over the patellar tendon.
- The needle is introduced form inferior to superior in the long axis of the transducer.
- The needle should be used to repetitively fenestrate the entire region of tendinopathic change identified with ultrasound slowly injecting blood.

Note: Injection of local anesthetic superficial and deep to the patellar tendon may be administered prior to fenestration.

11.9.6 Fenestration and Injection of Autologous Blood

See ▶Fig. 11.18 and ▶Fig. 11.19.

11.9.7 Notes

The patient should be advised on avoidance of high-impact loading of the tendon for 2 weeks post injection. Low-impact loading such as a stationary bicycle and gentle stretching should be commenced after 2 to 3 days. The injection may be repeated after 1 month.

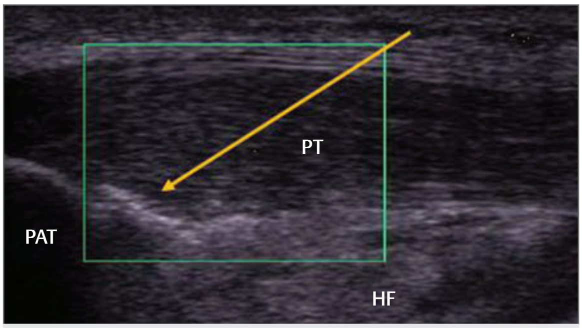

Fig. 11.19 Longitudinal image of the proximal patellar tendon (PT). The straight arrow indicates the direction of the needle. HF, Hoffa's fat pad; PAT, patella.

11.10 Patellar Tendon—High-Volume–Guided Injection

11.10.1 Cause

- Commonly overuse.
- Particularly a problem with jumpers and sprinters and activities involving explosive acceleration and contraction of the quadriceps muscle.

11.10.2 Presentation

The patient is able to locate the pain to the inferior pole of the patella and origin of the patellar tendon. Pain may be reproduced by direct palpation of this area and with strong contraction of the quadriceps muscle.

11.10.3 Equipment

See ▶Table 11.10.

Table 11.10 Equipment needed for patellar tendon—high-volume–guided injection

Syringe	Needle	Corticosteroid	Local anesthetic
10 mL (up to 5 syringes may be required)	23 gauge – 1.25 inch	20-mg Depo-Medrone	5-mL 1% lidocaine and up to 40-mL normal saline

The use of connecting tubing (Angiotech–Connecting Tube/LP OWS/Female–Male) allows the clinician to hold the needle in place under ultrasound guidance while an assistant provides the pressure necessary to administer the injection without direct pressure on the needle. The use of connecting tubing also allows the assistant to change syringes over without disturbing the needle position (▶Fig. 11.20, ▶Fig. 11.21).

Fig. 11.20 Syringes, connecting tubing, and 23-gauge needle ready for use.

Fig. 11.21 Syringe connected to 23-gauge needle via connecting tubing.

11.10.4 Anatomical Considerations

The patellar tendon takes its origin from the inferior pole of the patella. At this point it is approximately two to three fingers wide. It is at this point that the tendon is commonly affected the so-called “jumper’s knee.” This is not an inflammatory condition and ultrasound will demonstrate evidence of tendinopathic change with tendon thickening, loss of normal echogenicity, and neovascularity depending on the individual. These changes are frequently seen in the deeper portion of the tendon.

11.10.5 Procedure

- The patient is positioned in supine with the knee flexed to 20 degrees and supported on a pillow.
- The transducer is placed in the anatomical transverse plane over the proximal patellar tendon.
- The needle is connected to the connecting tubing and introduced from a medial to lateral line in the long axis

of the transducer. The needle should be placed deep to the posterior surface of the patellar tendon between the tendon and fat pad.

- The first syringe containing corticosteroid and local anesthetic is connected to the tubing and injected as a bolus.
- Following this the remaining syringes containing normal saline are connected sequentially to the tubing and injected as a bolus.
- In total, the injection consists of 20-mg Depo-Medrone, 5-mL 1% local anesthetic and up to 40-mL normal saline.

Fig. 11.22 Injection of the patellar tendon—high-volume injection. The probe is placed in the anatomical transverse plane over the proximal patellar tendon. The needle is introduced from a medial to lateral line in the long axis of the probe. The needle should be placed deep to the posterior surface of the patellar tendon between the tendon and Hoffa's fat pad.

11.10.6 High-Volume Saline Injection

See ▶Fig. 11.22, ▶Fig. 11.23, ▶Fig. 11.24, and ▶Fig. 11.25.

11.10.7 Notes

Postinjection the patient is advised on relative rest for 3 days. During this time the patient is allowed to carry out gentle stretching but no excessive loading of the tendon. Following this 3-day period the patient can restart a programme of more vigorous eccentric loading for further 3 days but no sport. Following this second period the patient is allowed a gradual return to sport as pain allows. The injection may be repeated after 1 month if required.

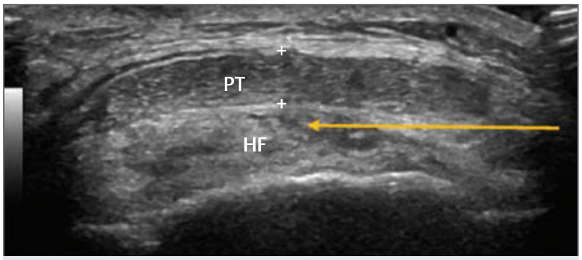

Fig. 11.23 Transverse image of the proximal patellar tendon (PT). The straight arrow gives the direction of the needle. HF, Hoffa's fat pad.

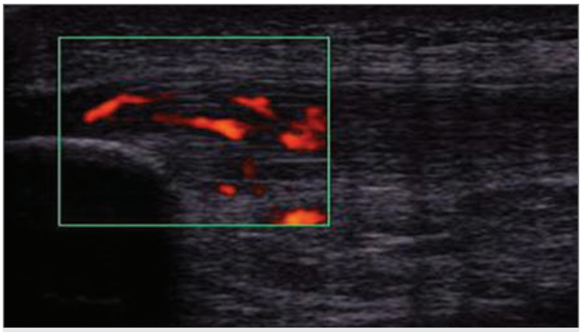

Fig. 11.24 Preinjection: Power Doppler demonstrating extensive neovascularity within the proximal patellar tendon.

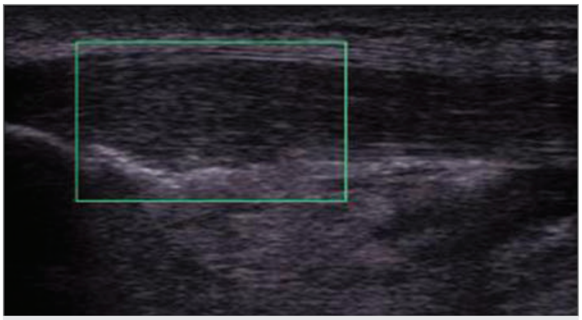

Fig. 11.25 Postinjection: Power Doppler demonstrates complete absence of neovascularity within the proximal patellar tendon.

12 The Ankle and Foot: Diagnostic Imaging

Abstract
Given the superficial location of many structures around the ankle and foot, ultrasound examination together with plain X-rays may now be considered to be the “first-line” technique for imaging many patients with ankle and foot pathologies. Recent advances in ultrasound technology, including developments of high-resolution probes and enhanced software capabilities, have led to an improvement in image quality. In addition, ultrasound is particularly useful in allowing dynamic assessment of structure including ligament patency.

Due to the superficial position of most ankle and foot structures ultrasound examination should be undertaken with a high frequency probe of (12–18 MHz). A large footprint linear probe gives better anatomical resolution; however, a smaller footprint “hockey stick” probe should also be available for smaller structures and for interventional work.

Keywords: talocrural, subtalar, midfoot, forefoot, metatarsophalangeal, anterior talofibular, calcaneofibular, anterior inferior tibiofibular, calcaneocuboid, Achilles, plantar fascia, tibialis posterior, flexor digitorum longus, flexor hallucis

12.1 Diagnostic Imaging of the Ankle and Foot: Introduction

The ankle may be considered as consisting of four quadrants, anterior, medial, lateral, and posterior with the foot being considered separately. Ultrasound would normally be focused only one or two of these quadrants or the foot depending on the clinical diagnosis.

Imaging of the ankle and foot includes the following:

- Anterior
  - Tibialis anterior muscle and tendon.
  - Extensor hallucis longus muscle and tendon.
  - Extensor digitorum longus muscle and tendon.
  - Deep peroneal nerve and dorsalis pedis artery.
  - Talocrural joint including anterior joint recess.
  - Anterior tibiofibular ligament.
  - Talonavicular joint.
  - Navicular-cuneiform and intercuneiform joints.
  - Tarsometatarsal joints.
- Medial
  - Posterior tibialis muscle and tendon.
  - Flexor digitorum longus muscle and tendon.
  - Flexor hallucis longus muscle and tendon.
  - Posterior tibial nerve and medial and lateral plantar nerves.
  - Tibial artery and veins.
- Lateral
  - Peroneus longus and brevis muscle and tendon.
  - Anterior talofibular ligament (including dynamic stressing—the sonographic draw test—as indicated).
  - Calcaneofibular ligament.
  - Calcaneocuboid joint.
- Posterior
  - Achilles tendon and insertion.
  - Posterior calcaneum.
  - Gastrocnemius and soleus muscles and musculotendinous junctions.
  - Plantaris tendon (may be absent).
  - Retrocalcaneal bursa.
  - Kager’s fat and posterior aspect of tibiotalar joint (os trigonum if present).
- Inferior
  - Plantar fascia origin at anteromedial calcaneal tubercle (including dynamic stressing).
- Interdigital
  - Dynamic scanning for a Morton’s neuroma if present (ultrasonographic Mulder’s click test).
  - Intermetatarsal bursa (if present).
- Digital
  - Assess for synovitis, dorsal, and/or plantar.
  - Dorsal aspect of the metatarsophalangeal joints including metatarsal recess.
  - Plantar aspect of metatarsophalangeal joints including plantar plate.
  - First metatarsophalangeal joint including sesamoid bones.
  - Interphalangeal joints as indicated.

12.1.1 Anterior

Anterior Ankle Joint: Longitudinal Scan

The patient is positioned in supine with the knee flexed to approximately 90 degrees of flexion and the foot placed on the couch so that it lies in a plantar flexed position. This facilitates both a better visualization of the talar dome and allows a better contact of the probe with the ankle. The probe is placed in the anatomical sagittal plane so that it lies over the anterior aspect of the talocrural joint (▶Fig. 12.1, ▶Fig. 12.2, ▶Fig. 12.3).

Anterior Ankle Joint: Transverse Scan

The patient is positioned in supine with the knee flexed to approximately 90 degrees flexion and the foot placed on the couch so that it lies in a plantar flexed position. This facilitates a better visualization of the talar dome. The probe is placed in the anatomical transverse plane so that it lies over the anterior aspect of the talar dome (▶Fig. 12.4, ▶Fig. 12.5, ▶Fig. 12.6).

Fig. 12.1 Longitudinal scan of the anterior aspect of the ankle joint. The probe is placed in the anatomical sagittal plane over the talocrural joint. The foot is in a plantar flexed position to allow better visualization of the talar dome and facilitate a good contact of the probe with the ankle. The probe should be moved from medial to lateral to fully examine the whole joint.

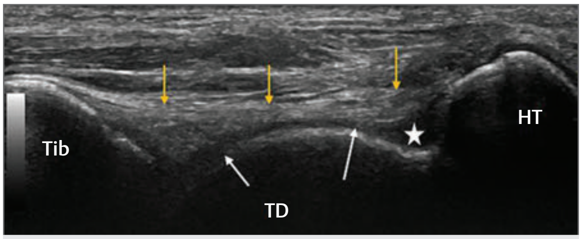

Fig. 12.2 Longitudinal image of the anterior aspect of the talocrural joint and talus. The image demonstrates the anterior edge of the tibia (Tib), the talar dome (TD) and articular cartilage (*white arrows*), the head of the talus (HT), and the anterior talar recess (*white star*). The anterior talocrural capsule can be seen to extend over the talar dome and anterior recess (*yellow arrows*).

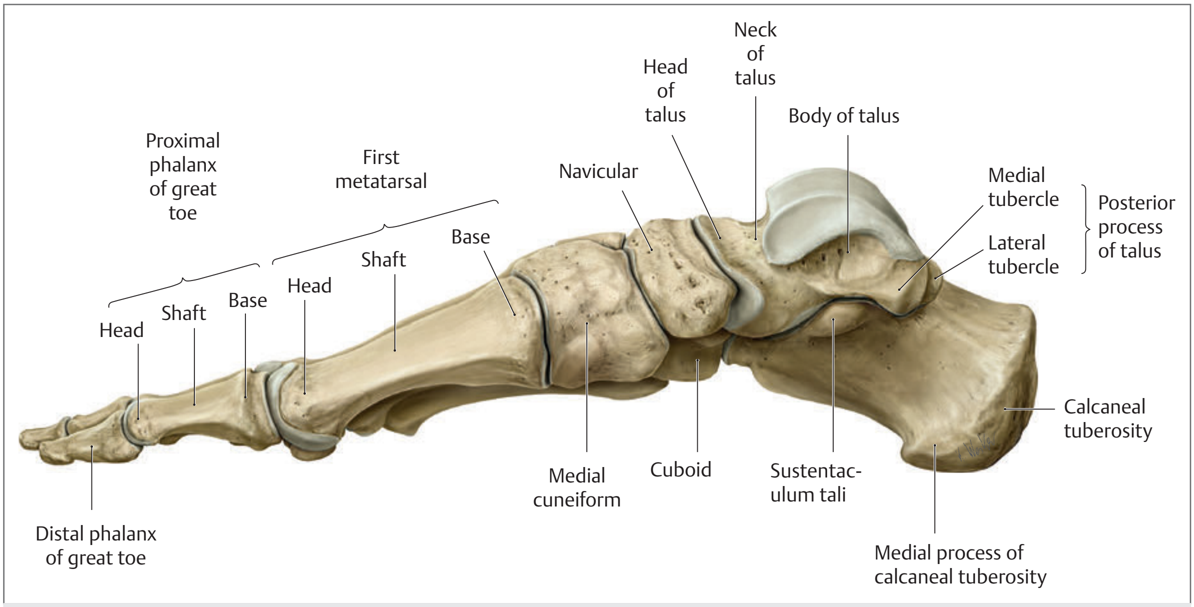

Fig. 12.3 Sagittal view of the medial aspect of the right ankle and foot. The sustentaculum tali may be seen immediately below the body of the talus. It is a horizontal shelf that arises from the anteromedial portion of the calcaneus. The superior surface is concave and articulates with the middle calcaneal surface of the talus. The inferior surface has a groove for the tendon of flexor hallucis longus. The navicular tuberosity forms a rounded eminence on the medial surface of the navicular bone anterior to the talus giving attachment to a part of the tendon of the tibialis posterior muscle. An accessory bone known as an os naviculare accessorium (also known as an os tibiale externum) is a large accessory ossicle that can be present adjacent to the medial side of the navicular tuberosity. The tibialis posterior tendon often inserts with a broad attachment into the ossicle. An os naviculare is present in approximately 10% of the population and more common in female patients. The medial cuneiform (also known as first cuneiform) is the largest of the cuneiforms situated anterior to the navicular bone and posterior to the base of the first metatarsal. The tibialis anterior and peroneus longus tendon inserts onto the medial cuneiform bone. (Reproduced from Schuenke, Schulte, and Schumacher, Atlas of Anatomy, 2nd edition, ©2014, Thieme Publishers, New York. Illustration by Karl Wesker/Markus Voll.)

Fig. 12.4 Transverse scan of the anterior aspect of the ankle joint. The probe is placed in the anatomical transverse plane over the talocrural joint and the talar dome. The probe should be moved from proximal to distal to fully assess the lower tibia, talocrural joint, and the talar dome in turn.

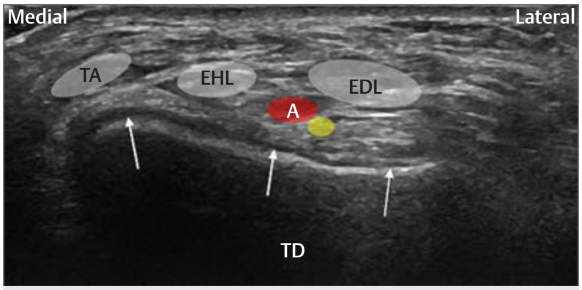

Fig. 12.5 Transverse image of the ankle at the level of the talar dome (TD). The most medial tendon is that of tibialis anterior which can be seen to advance in a medial direction toward its insertion onto the medial cuneiform and base of the first metatarsal. The next tendon is that of extensor hallucis longus (EHL). The most laterally placed tendon is that of extensor digitorum longus (EDL) which if followed distally may be seen to split into four slips to insert into dorsal aponeuroses and the bases of the distal phalanges of the second through fifth toes. Lying between and deep to the tendons of EHL and EDL is found the anterior tibial artery (A) and the deep peroneal nerve (*yellow circle*). TA, tibialis anterior tendon; white arrows, articular cartilage over the talar dome.

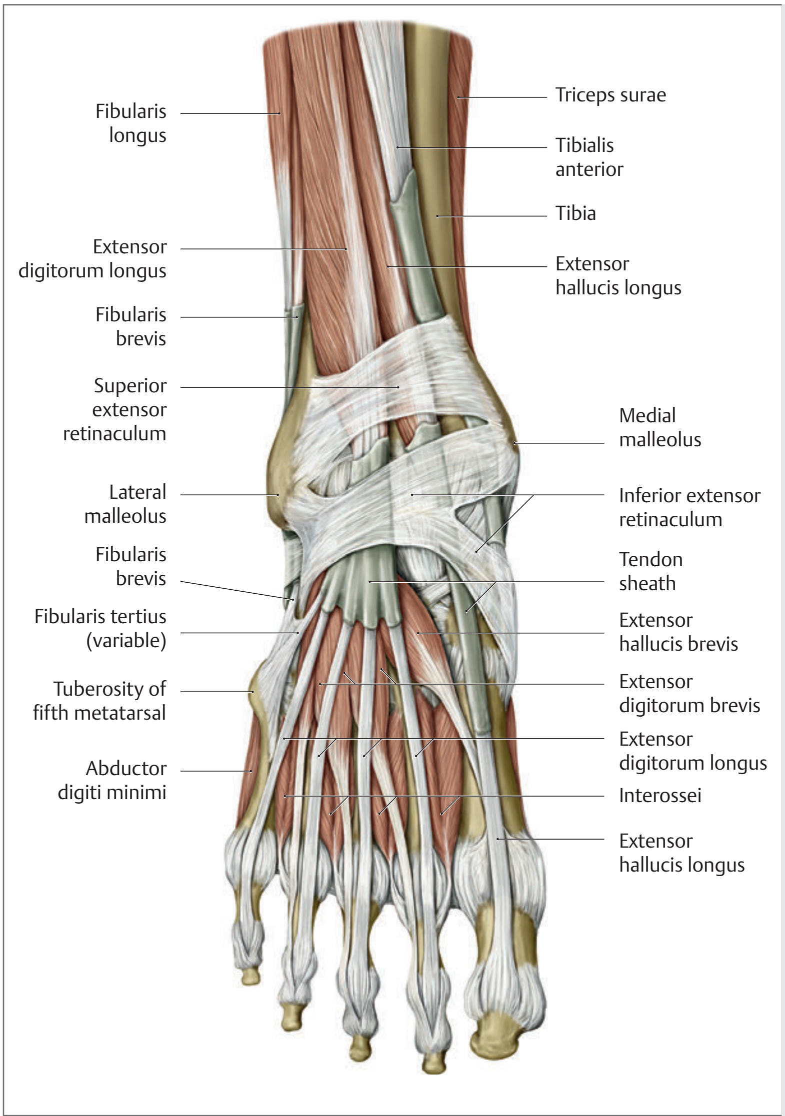

Fig. 12.6 Coronal view of the anterior aspect of the ankle and foot demonstrating the tendon sheaths and retinacula. From medial to lateral the order of tendons is tibialis anterior, flexor hallucis longus, and flexor digitorum longus. The superior extensor retinaculum binds down the tendons of extensor digitorum longus, extensor hallucis longus, fibularis tertius (also known as peroneus tertius), and tibialis anterior as they descend on the front of the tibia and fibula. Under it are also found the anterior tibial vessels and deep peroneal nerve.
The inferior extensor retinaculum is a Y-shaped structure placed in front of the ankle joint. The stem of the Y is attached laterally to the upper surface of the calcaneum anterior to interosseous talocalcaneal ligament. It is directed medially as a double layer with one lamina passing in front of and the other behind the tendons of the peroneus tertius and extensor digitorum longus. At the medial border of the tendon of extensor digitorum longus the two layers join together forming a compartment in which the tendons are enclosed. From the medial edge of the extensor digitorum longus tendon the two limbs of the Y diverge. One is directed proximally and medially to be attached to the medial malleolus, passing over the extensor hallucis longus but enclosing the tibialis anterior by splitting of its fibers. The second limb of the Y extends distally and medially to be attached to the border of the plantar aponeurosis passing over the tendons of the extensor hallucis longus and tibialis anterior. (Reproduced from Schuenke, Schulte, and Schumacher, Atlas of Anatomy, 2nd edition, ©2014, Thieme Publishers, New York. Illustration by Karl Wesker/Markus Voll.)

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Anterior Midfoot: Longitudinal Scan

The patient is positioned in supine with the knee flexed to approximately 90 degrees of flexion and the foot placed on the couch so that it lies in a plantar flexed position. This facilitates a better visualization of the midfoot region and fixes the foot in a stable position. The probe is initially placed in the anatomical sagittal plane so that it lies over the dorsum of talonavicular and navicular cuneiform joints. Moving the probe from medial to lateral allows visualization of the medial, middle, and lateral cuneiform bones and their articulation with the navicular. If the probe is moved distally, the tarsometatarsal joints may be seen (▶Fig. 12.7, ▶Fig. 12.8, ▶Fig. 12.9).

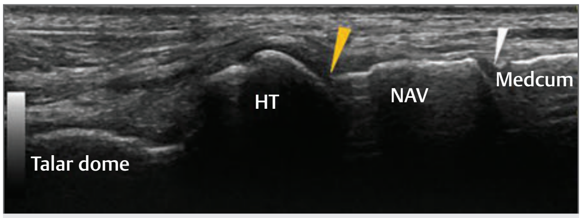

Fig. 12.7 Longitudinal image of the medial aspect of the midfoot. The talar dome may be seen to the left of the image. The head of the talus (HT) articulates with the navicular (NAV) at the talonavicular joint (*yellow arrowhead*). The navicular may be seen to articulate with the medial cuneiform (Medcun) to the right of the image (*white arrowhead*).

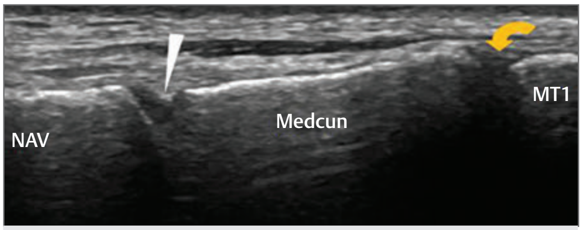

Fig. 12.8 Longitudinal image of the medial aspect of the midfoot. In this image the probe has been moved distally from the image outlined in ▶Fig. 12.7. The navicular (NAV) may be seen to the left of the image. The white arrowhead indicates the navicular medial cuneiform joint. The medial cuneiform (Medcun) may be seen to articulate with the base of the first metatarsal (MT1) at the first tarsometatarsal joint (*curved yellow arrow*).

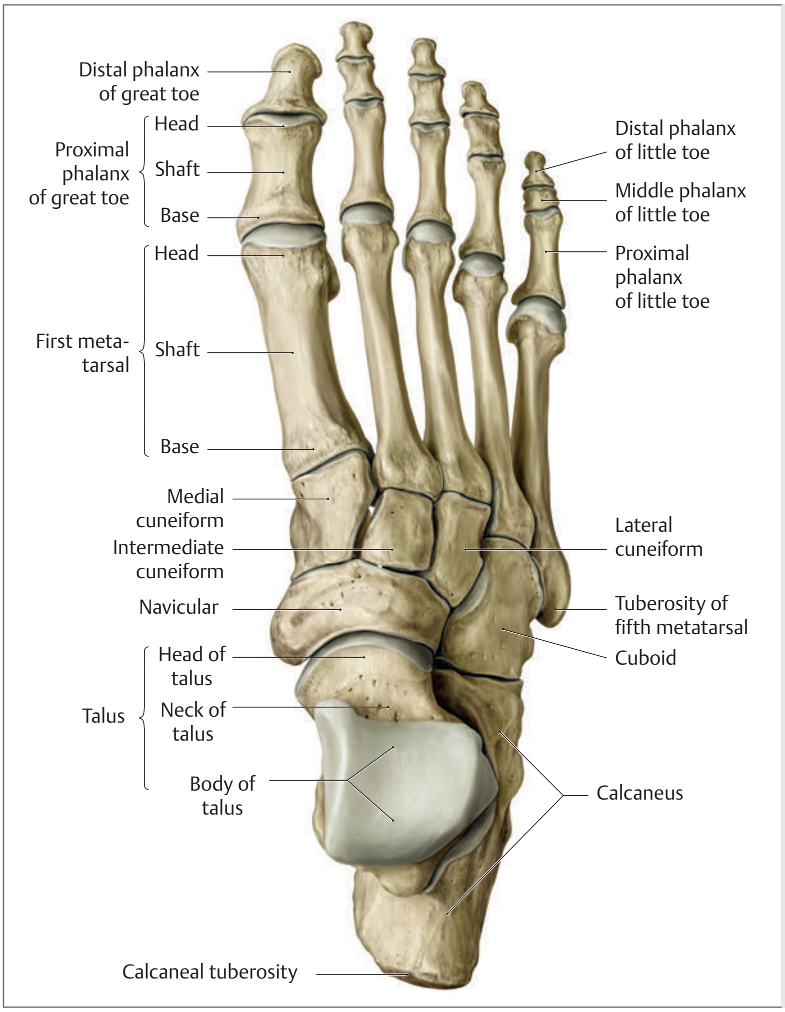

Fig. 12.9 Transverse view of the superior aspect of the bones of the right foot and ankle. The midfoot is composed of five of the seven tarsal bones, the navicular, cuboid, and the three cuneiform bones. These can be thought of as being arranged in two irregular rows with the cuboid occupying space in both rows. The proximal row contains the navicular (on the medial side of the foot) and the cuboid (on the lateral side). The distal row contains the three cuneiforms (medial, intermediate, and lateral) and the cuboid (lateral to the lateral cuneiform). The boundary between the midfoot and forefoot consists of the five tarsometatarsal joints. The medial, intermediate, and lateral cuneiforms articulate with the first, second, and third metatarsals, respectively. The cuboid articulates with the fourth and fifth metatarsals. In addition, there are also multiple joints within the midfoot itself. The distal row of the midfoot has two intercuneiform joints (between adjacent cuneiforms) and a cuneocuboid joint (between the lateral cuneiform and the cuboid). Proximally the three cuneiforms articulate with the navicular bone (the cuneonavicular joints). In some individuals, there is also a small articulation between the cuboid and navicular. (Reproduced from Schuenke, Schulte, and Schumacher, Atlas of Anatomy, 2nd edition, ©2014, Thieme Publishers, New York. Illustration by Karl Wesker/Markus Voll.)

Anterior Ankle: Anterior Tibiofibular Ligament

The patient is positioned in supine with the foot over the edge of the couch. This allows the clinician to move the foot to stress the ligament and assess for patency. The probe is placed in the anatomical transverse oblique plane so that it lies longitudinally over the anterior aspect of the lateral malleolus and anterior distal tibia. The ligament may be assessed dynamically by maintaining the probe position while the patient's foot is passively dorsiflexed placing stress through the ligament as the wider anterior talar dome enters the ankle mortise (▶Fig. 12.10, ▶Fig. 12.11).

Fig. 12.10 Longitudinal scan of the anterior tibiofibular ligament of the ankle. The probe is placed in the anatomical transverse oblique plane so that its lateral edge is over the anterior aspect of the lateral malleolus. The more medial edge of the probe is angled so that it is in a more superior position.

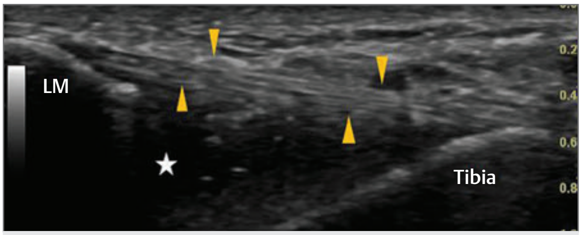

Fig. 12.11 Longitudinal image the anterior tibiofibular ligament of the ankle. The ligament (*yellow arrowheads*) may be seen as an echogenic band of fibrillar pattern extending from the lateral malleolus (LM) medially to the anterior aspect of the distal tibia. In this image the foot has been placed in dorsiflexion to place stress through the ligament which appears taught. Some fluid (*white star*) is noted deep to the ligament in this patient who had recently twisted the ankle LM, anterior aspect of the lateral malleolus; white star, fluid deep to ligament; yellow arrowhead, anterior tibiofibular ligament of the ankle.

Anterior Ankle Joint and Foot: Pathology

See ▶Fig. 12.12, ▶Fig. 12.13, ▶Fig. 12.14a–c; ▶Fig. 12.15a,b; ▶Fig. 12.16a–c.

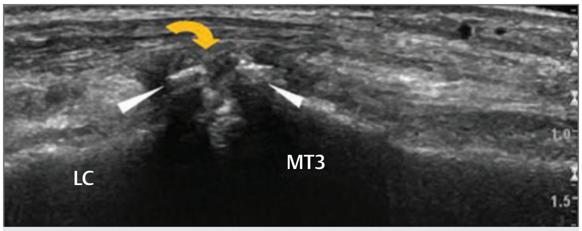

Fig. 12.12 Longitudinal image of the midfoot and the lateral cuneiform (LC) and third metatarsal (MT3) joint. The image demonstrates marked cortical irregularity of both the cuneiform and base of the third metatarsal in keeping with osteophytosis (*white arrowheads*). In addition, there appears to be some soft tissue hypertrophy of the joint (*curved arrow*). These findings are in keeping with marked osteoarthritic change of the joint.

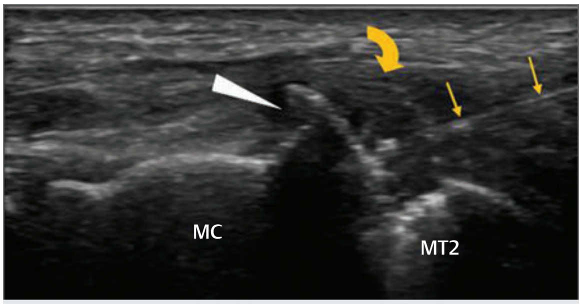

Fig. 12.13 Longitudinal image of the midfoot and middle cuneiform (MC) and second metatarsal (MT2) joint. There is a significant degenerative change within the joint with an associated soft tissue hypertrophy (*curved arrow*) and osteophyte (*white arrowhead*). The image demonstrates a guided injection into the joint with the needle being advanced from distally to proximal from the right side (*yellow arrows*). Yellow arrows indicate the needle.

12

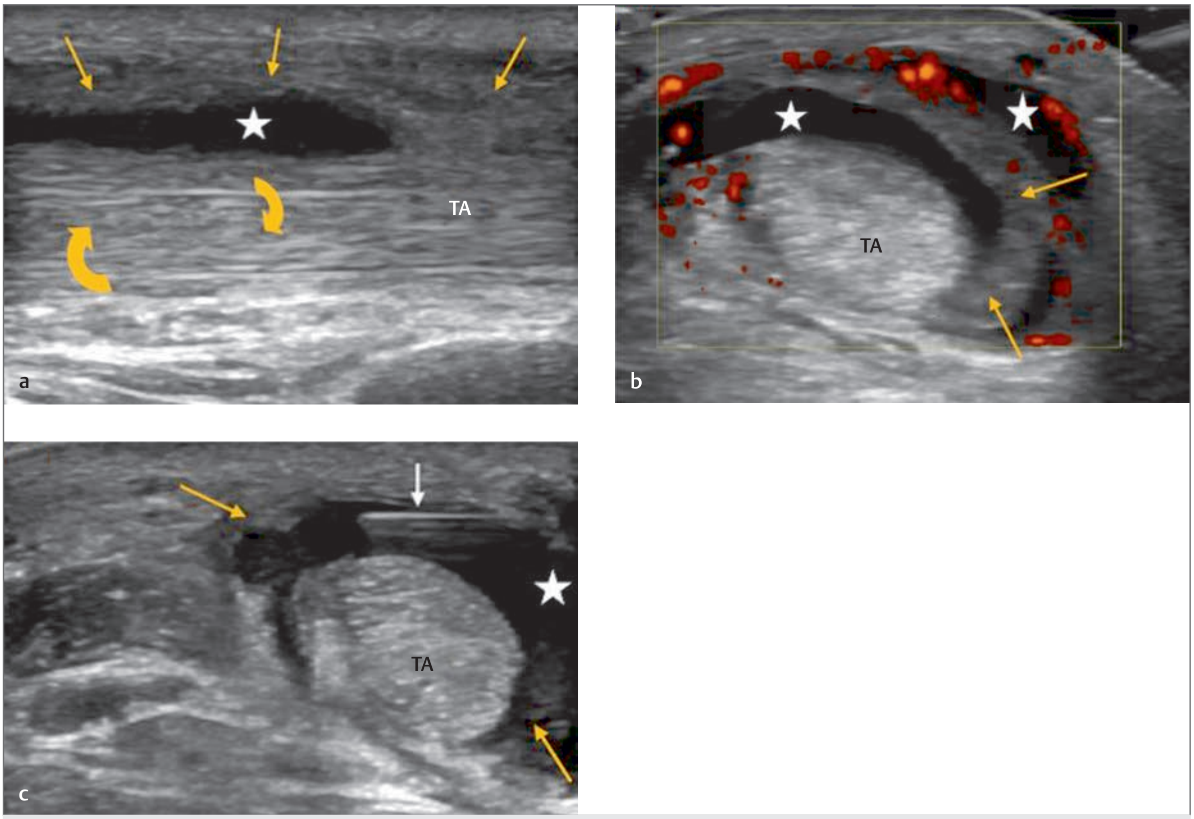

Fig. 12.14 (a) Longitudinal image of the tendon of tibialis anterior (TA) over the anterior aspect of the ankle joint. The tendon is of good fibrillar pattern and appears echogenic other than a longitudinal intrasubstance region (*curved arrow*) suggestive of a possible intrasubstance tear. There is, however, both an effusion (*white star*) and synovial thickening (*yellow arrows*) within the tendon sheath in keeping with a tenosynovitis. **(b)**Transverse image of the tendon of tibialis anterior (TA) demonstrated in part (a). The tendon in this image appears intact with no evidence of intrasubstance pathology. There is, however, significant effusion around the tendon (*white star*) and synovial thickening (*yellow arrows*). In addition, in this image Power Doppler demonstrates an active synovitis in keeping with tenosynovitis. **(c)** Transverse image of the tendon of tibialis anterior (TA) as demonstrated in parts (a) and (b). In this image a needle has been introduced into the tendon sheath in short axis (*white arrow*) prior to injection of corticosteroid into the sheath. Curved arrow, loss of normal intrasubstance fibrillar pattern; white arrow, needle; white star, fluid within tendon sheath; yellow arrows, synovial thickening.

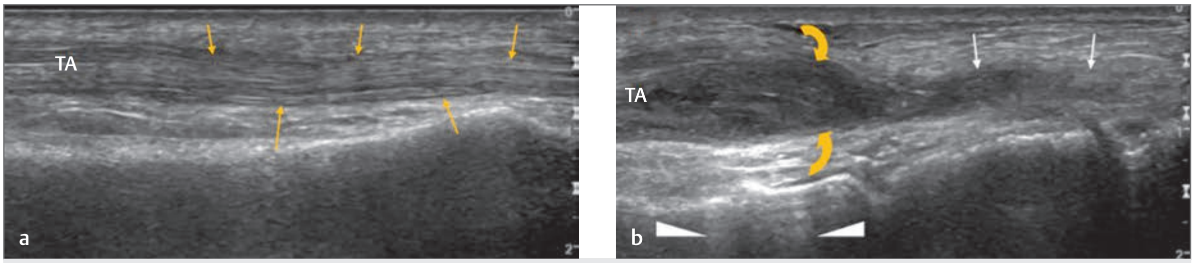

Fig. 12.15 (**a**) Longitudinal image of the tendon of tibialis anterior (TA) over the anteromedial aspect of the ankle. The tendon appears intact at this level; however, it has a "wavy-like" appearance despite the tendon being placed in a stretched position (*yellow arrows*). This is strongly suggestive of a rupture more distally (see part[b]). (**b**) Longitudinal image of the tendon of tibialis anterior (TA) over its distal portion close to its insertion onto the navicular tubercle and medial cuneiform. The image is of the same tendon as in part (a). There appears significant discontinuity within the tendon with retraction and bunching of the tendon proximally (*curved arrows*). In addition, there appears posterior enhancement behind the retracted tendon (*white arrowheads*) indicating a loss of tendon density. Distally there is a loss of normal tendon architecture (*white arrows*). The image is in keeping with a rupture of tibialis anterior toward its insertion.

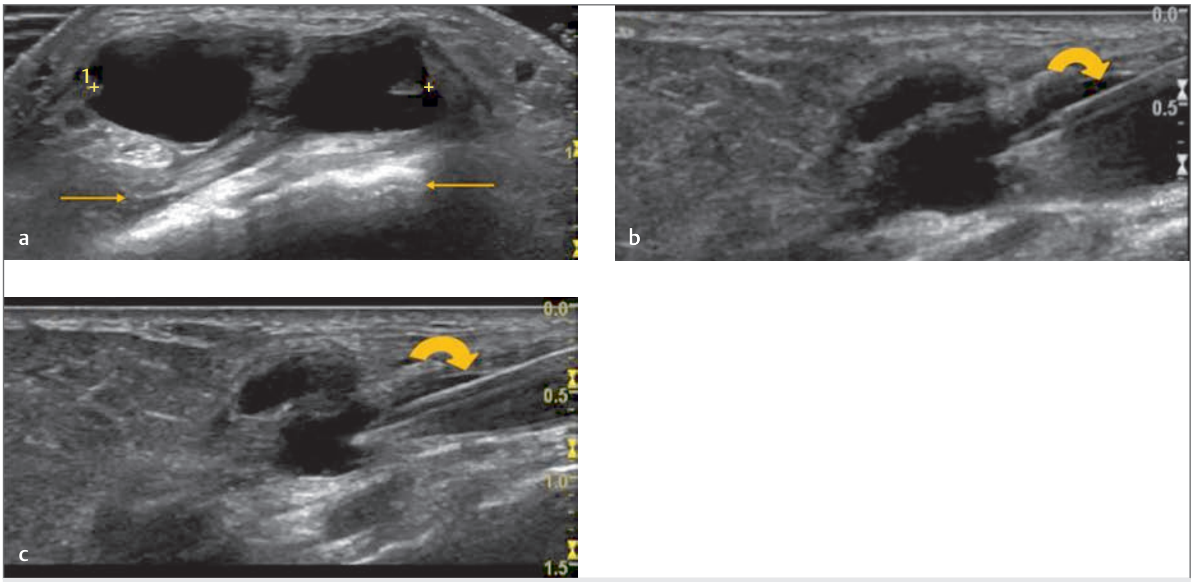

Fig. 12.16 (**a**) Transverse image of the dorsal aspect of the midfoot region. The image demonstrates a lobulated anechoic swelling measuring approximately 4 cm transversely. Note the posterior enhancement (*yellow arrows*). These findings are typical of an arthrosynovial cyst/ganglion. (**b**) Transverse image of the dorsal aspect of the midfoot. The image is the same as demonstrated in part (a). A needle may be seen within the ganglion which is being aspirated (*curved arrow*). (**c**) Transverse image of the dorsal aspect of the midfoot. The image is the same as demonstrated in parts (a) and (b). The image shows the ganglion decreasing in size as aspiration continues (*curved arrow*). Curved arrow, needle being used to aspirate ganglion.

12

12.1.2 Medial

Medial Ankle Joint: Transverse Scan

The patient is positioned in supine with the leg placed in external rotation to allow visualization of the structures laying immediately posterior to the medial malleolus. The probe is placed in the transverse plane behind the malleolus. The anterior edge of the probe should lay on the malleolus with the posterior edge of the probe reaching toward the Achilles tendon. A small cushion placed under the ankle and foot may allow for an improved contact of the probe with the patient (▶Fig. 12.17, ▶Fig. 12.18, ▶Fig. 12.19).

Fig. 12.17 Transverse image of the medial aspect of the ankle. The probe is positioned in the transverse plane behind the medial malleolus to view the structures within the tarsal tunnel.

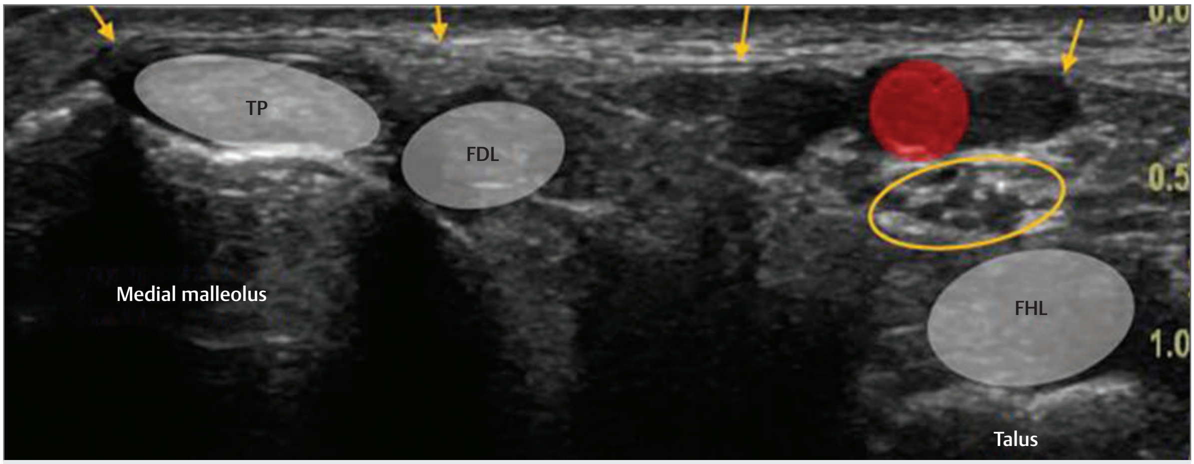

Fig. 12.18 Transverse image of the tarsal tunnel posterior to the medial malleolus. The first tendon seen is that of tibialis posterior (TP). Immediately posterior to this is the tendon of flexor digitorum longus (FDL). More posterior and deeper lying between the posterior medial and lateral talar tubercles is the tendon of flexor hallucis longus (FHL). This arrangement of tibialis posterior, flexor digitorum longus, and flexor hallucis longus affords the mnemonic Tom, Dick, and Harry. Immediately above the tendon of flexor hallucis longus can be seen the tibial nerve prior to it splitting into the medial and lateral plantar nerves (*yellow oval*). Above this the tibial artery (*red circle*) may be seen accompanied by a vein on either side. Red circle, posterior tibial artery; yellow arrows, flexor retinaculum; yellow oval, tibial nerve.

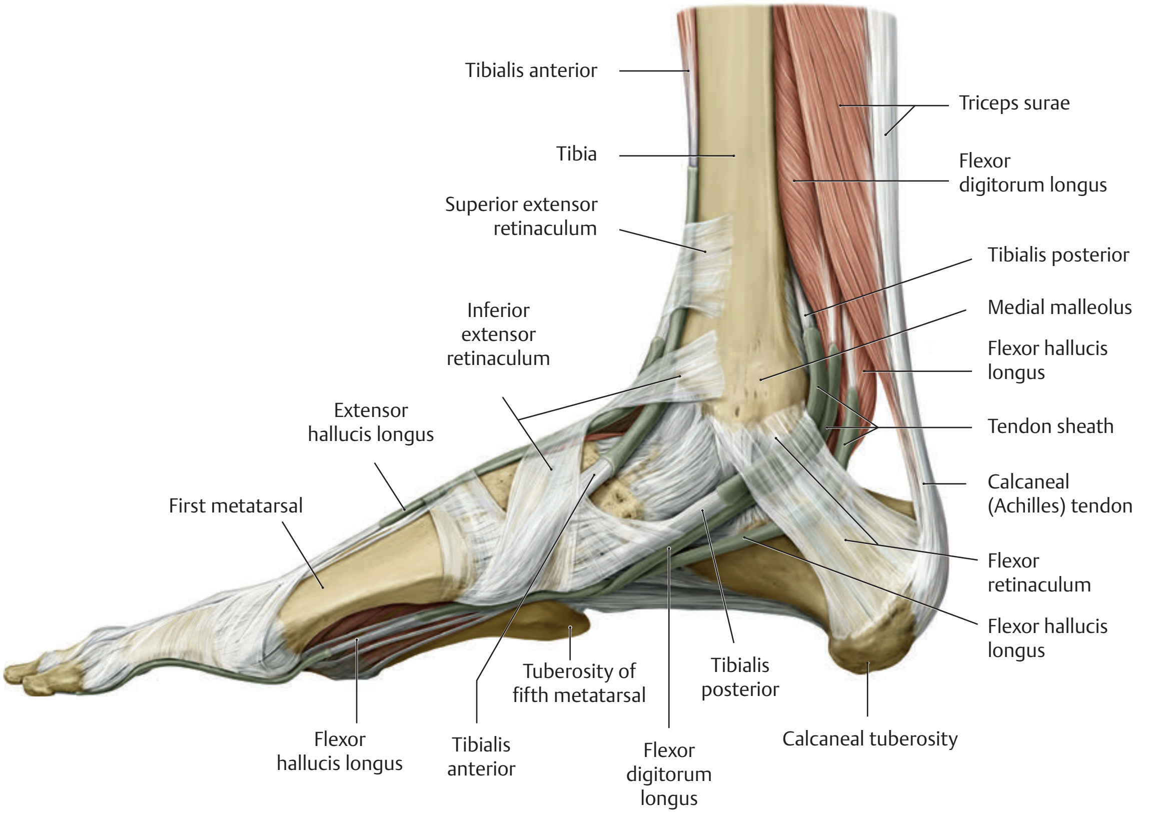

Fig. 12.19 Sagittal view of the medial aspect of the right ankle illustrating the tendon sheaths and retinacula. The tarsal tunnel is the fibro-osseous canal found posterior and inferior to the medial malleolus. The roof of the tarsal tunnel is formed by the flexor retinaculum which extends from the medial malleolus posteriorly and obliquely downward to insert onto the medial aspect of the calcaneum. The floor of the tunnel is formed by the medial surfaces of both the talus and calcaneum. From anterior to posterior the contents of the tarsal tunnel are the tibialis posterior tendon, the flexor digitorum longus tendon, the neurovascular bundle consisting of the posterior tibial artery, vein, and tibial nerve, and most posteriorly situated between the posterior medial and lateral talar tubercles the tendon of flexor hallucis longus. The tibial nerve may be seen to split into the medial and lateral plantar nerves within the tarsal tunnel. A useful mnemonic to remember the order of structures in the tarsal tunnel is Tom, Dick, and A Very Nervous Harry. (Reproduced from Schuenke, Schulte, and Schumacher, Atlas of Anatomy, 2nd edition, ©2014, Thieme Publishers, New York. Illustration by Karl Wesker/Markus Voll.)

12

Medial Ankle Joint: Longitudinal Scan

With the patient's ankle and foot in the same position as for a transverse scan of the medial ankle the probe is turned through 90 degrees so that it lies in the transverse oblique plane to view the structures within the tarsal tunnel. With the probe more anteriorly placed, the tendon of tibialis posterior may be seen. As the probe is moved posteriorly over the tarsal tunnel, the tendon of flexor digitorum longus is next visualized followed by the tibial nerve, posterior tibial artery, and the deeply placed tendon of flexor hallucis longus (▶Fig. 12.20a,b).

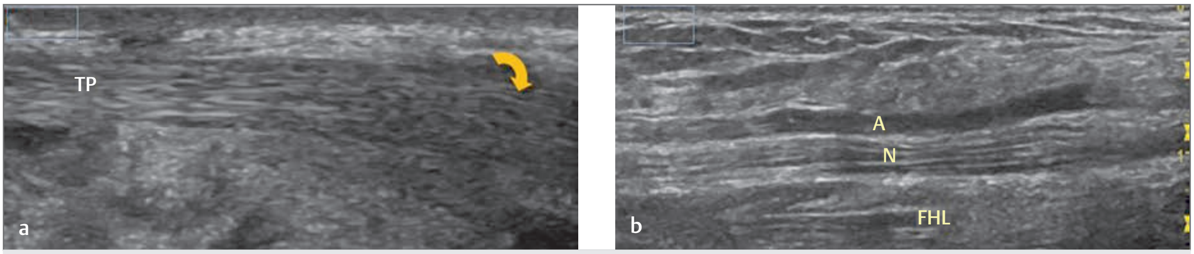

Fig. 12.20 (**a**) Longitudinal image of the tibialis posterior tendon (TP) as it passes posteriorly and then inferiorly to the medial malleolus. The tendon becomes anisotropic as it curves around the malleolus (*curved arrow*). (**b**) Longitudinal image of the tarsal tunnel at the ankle. The probe has been placed more posteriorly over the tarsal tunnel allowing visualization of the posterior tibial artery (A), tibial nerve (N), and more deeply to these two structures the tendon of flexor hallucis longus (FHL) lying between the posterior medial and lateral talar tubercles.

Medial Foot Joint: Longitudinal Scan

Having viewed the tendon of tibialis posterior around the posterior aspect of the medial malleolus as it passes through the tarsal tunnel, the tendon may be followed distally to its insertion onto the tuberosity of the navicular and medial cuneiform (▶Fig. 12.21, ▶Fig. 12.22a,b).

Fig. 12.21 Longitudinal scan of the medial aspect of the foot and the tendon of tibialis posterior. The tendon may be seen down to its insertion onto the navicular and medial cuneiform.

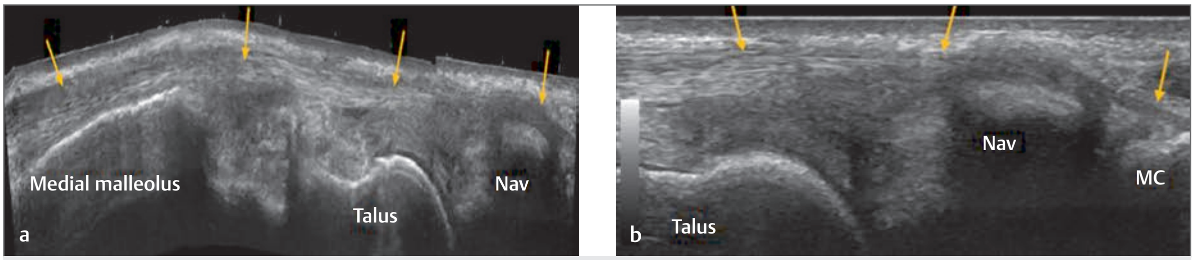

Fig. 12.22 (**a**) Longitudinal image of the tendon of tibialis posterior (*yellow arrows*). In this extended field of view image the tendon may be seen to pass behind the medial malleolus and distally over the talus toward its insertion onto the navicular (Nav) and medial cuneiform. Note the anisotropy exhibited within the tendon as it curves around the navicular. (**b**) Longitudinal image of the distal tibialis posterior tendon (*yellow arrows*). The tendon may be seen to extend beyond the navicular (Nav) distally to insert onto the medial cuneiform (MC).

Medial Ankle and Foot: Pathology

See ▶Fig. 12.23a–c; ▶Fig. 12.24a,b; ▶Fig. 12.25a,b; ▶Fig. 12.26, ▶Fig. 12.27, ▶Fig. 12.28, ▶Fig. 12.29).

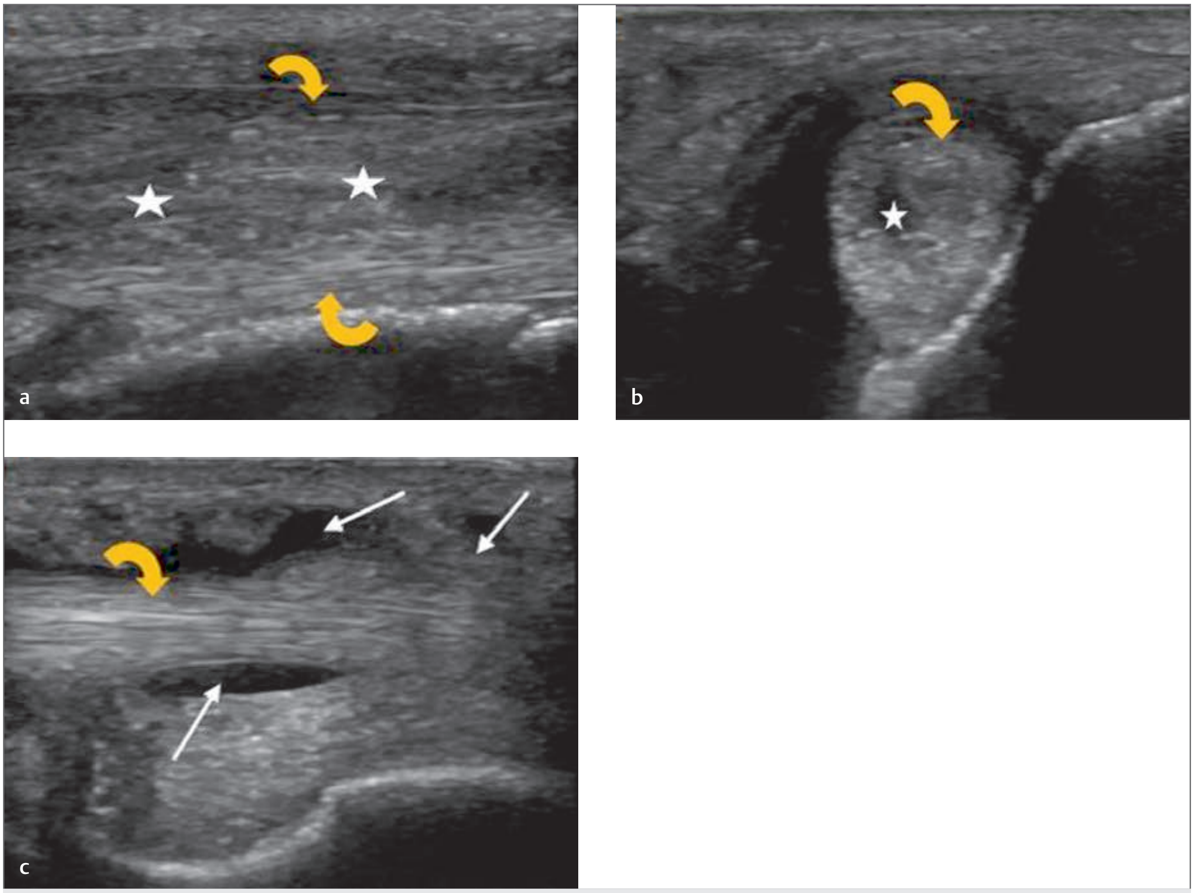

Fig. 12.23 (**a,b**) Images of the tendon of tibialis posterior within the tarsal tunnel. The images demonstrate evidence of an intrasubstance tear within the tendon (*white stars*). The tendon around the tear appears intact (*curved arrow*). (**c**) More distally below the medial malleolus the tendon appears intact, but there is evidence of a significant tenosynovitis with effusion and synovial thickening throughout the tendon sheath (*white arrows*).

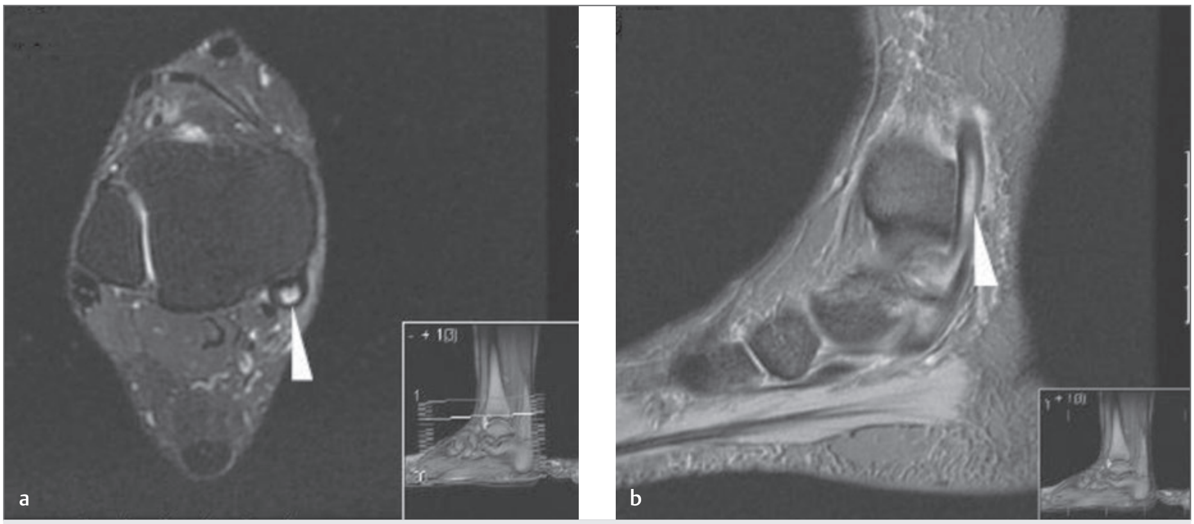

Fig. 12.24 (**a,b**) MRI of the ankle. Axial STIR and sagittal T2, respectively, demonstrate expansion of the tibialis posterior tendon with intrasubstance high signal in keeping with a tear (*white arrowhead*). The images are of the same patient as demonstrated in ▶Fig. 12.23a–c.

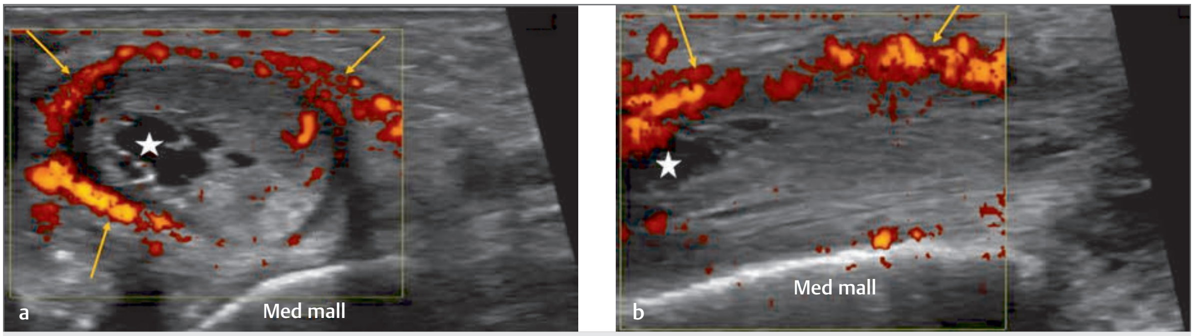

Fig. 12.25 (**a,b**) Transverse and longitudinal scan, respectively, of the tendon of tibialis posterior demonstrating a marked tendinopathy with a central anechoic region within the tendon indicating an intrasubstance tear (*white stars*). In addition, there is a marked tenosynovitis noted within the tendon sheath (*yellow arrows*) which is further highlighted with Power Doppler imaging. Med Mall, medial malleolus; white star, anechoic tear within the substance of tibialis posterior tendon; yellow arrows, evidence of a tenosynovitis within the tendon sheath.

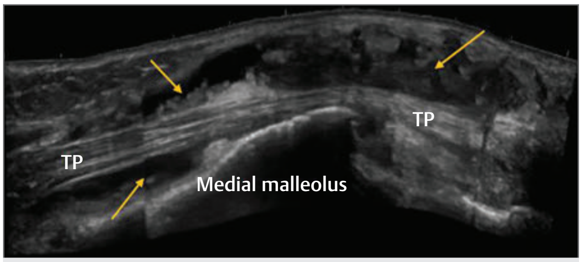

Fig. 12.26 Longitudinal image of the tendon of tibialis posterior (TP). In this extended field of view the tendon may be seen passing posteriorly and inferiorly to the medial malleolus. The tendon itself appears intact. However, there is a marked synovial thickening and fluid within the tendon sheath (*yellow arrows*). These findings are in keeping with a chronic tenosynovitis.

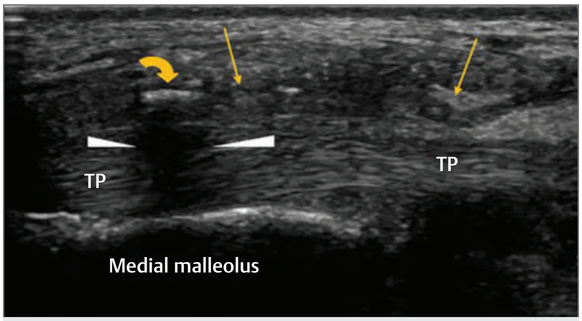

Fig. 12.27 Longitudinal image of the tendon of tibialis posterior. The tendon appears intact; however, some thickening is noted within the tendon sheath (*yellow arrows*). In addition, calcific foci are seen within the sheath (*curved arrow*). Note the posterior shadowing behind the calcific foci (*white arrowheads*). These findings are in keeping with a chronic tenosynovitis.

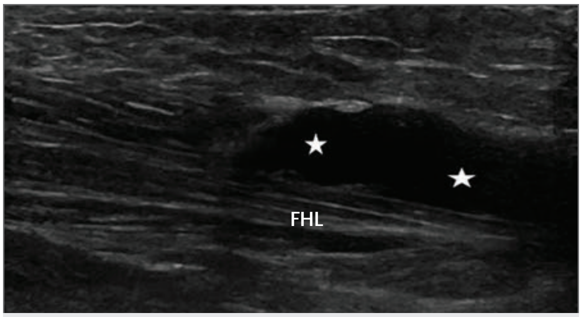

Fig. 12.28 Longitudinal image of the tendon of flexor hallucis longus (FHL) at the posterior aspect of the talus. The tendon appears intact. However, fluid is noted around the tendon (*white stars*). This may indicate a tenosynovitis of the tendon sheath or pathology in the ankle joint itself with secondary posterior effusion.

Fig. 12.29 Longitudinal image of the insertion of the tendon of tibialis posterior (TP). The tendon may be seen to insert onto the medial aspect of the navicular. Within the tendon there appears to be a well-corticated bony fragment. The image is in keeping with an os navicularis. Although this is an incidental finding, it may predispose to an insertional tendinopathy and ultrasound findings need to be considered in light of the clinical presentation. Yellow star indicates the os navicularis.

12.1.3 Lateral

Lateral Ankle Joint—Proximal Peroneal Tendons: Transverse Scan

The patient is positioned in supine with the leg internally rotated to allow visualization of the peroneal tendons and peroneus brevis muscle laying immediately posterior to the lateral malleolus. The probe is in the transverse oblique plane behind the lateral malleolus. The anterior edge of the probe should lay on the lateral malleolus with the posterior edge of the probe reaching toward the Achilles tendon. The probe should be moved in a distal direction to visualize both peroneal tendons as far as the peroneal tubercle at the lateral aspect of the calcaneum and peroneus brevis to the base of the fifth metatarsal (▶Fig. 12.30, ▶Fig. 12.31, ▶Fig. 12.32).

Lateral Ankle Joint—Distal Peroneal Tendons: Transverse Scan

The patient is positioned as for scanning the proximal peroneal tendons. The probe is moved distally while keeping its anterior edge over the lateral malleolus its posterior edge is swung through 90 degrees to lie in the coronal plane. In this way both peroneal tendons may be seen down to their separation at the peroneal tubercle on the lateral aspect of the calcaneum with peroneus brevis being scanned down to its insertion onto the base of the fifth metatarsal (▶Fig. 12.33, ▶Fig. 12.34).

Fig. 12.30 Transverse scan of the proximal peroneal tendons and peroneus brevis muscle. The probe is positioned so that its anterior edge is over the lateral malleolus with its posterior edge reaching toward the Achilles tendon. The probe should be turned in an anticlockwise direction with the lateral malleolus at the fulcrum so that it moves distally over the peroneal tendons from the transverse to coronal planes.

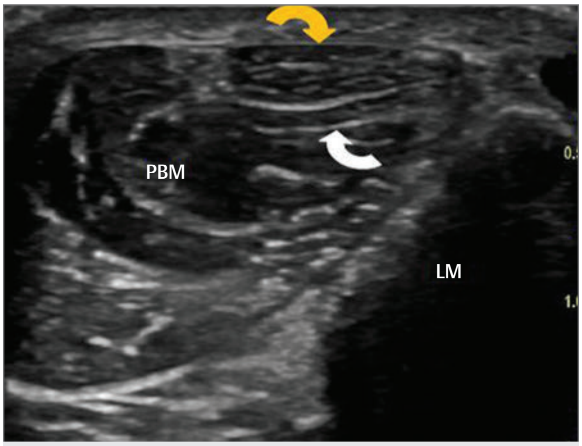

Fig. 12.31 Transverse image of the peroneal tendons around the posterior aspect of the lateral malleolus (LM). The tendon of peroneus longus (*yellow curved arrow*) is positioned more superficially. Deep to the peroneus longus tendon can be seen the tendon of peroneus brevis (*white curved arrow*). At this level the peroneus muscle can still be seen (PBM). PBM, peroneus brevis muscle.

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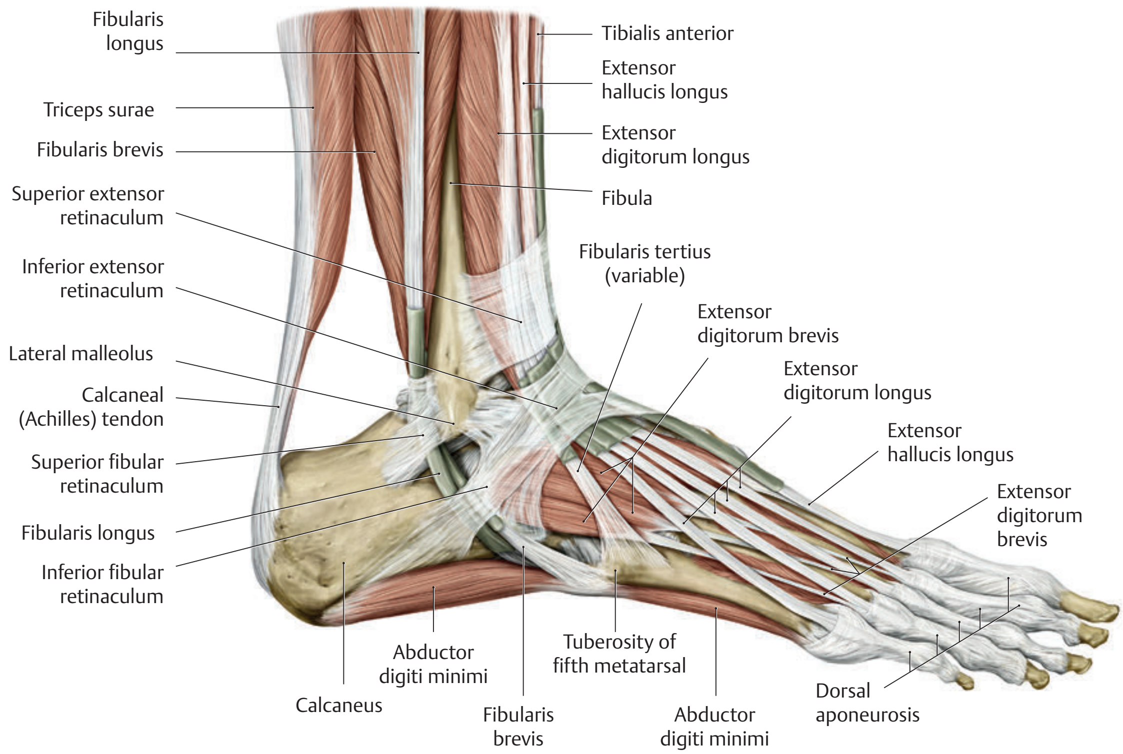

Fig. 12.32 Sagittal view of the lateral aspect of the right ankle illustrating the tendon sheaths and retinacula. The peroneus or fibularis longus arises from the head and upper two-thirds of the lateral surface of the body of the fibula from the deep surface of the fascia, and from the intermuscular septa between it and the muscles on the anterior and posterior of the leg. Between its attachments to the head and to the body of the fibula there is a gap through which the common fibular nerve passes to the front of the leg. It ends in a long tendon which runs behind the lateral malleolus in a groove common to it and the tendon of the peroneus or fibularis brevis. The groove is converted into a canal by the superior fibular retinaculum and the tendons in it are contained in a common sheath. The tendon then extends obliquely forward across the lateral side of the calcaneus, below the peroneal tubercle with the tendon of the peroneus brevis under cover of the inferior fibular retinaculum. It crosses the lateral side of the cuboid, and then runs on the undersurface of that bone in a groove which is converted into a canal by the long plantar ligament. The tendon then crosses the sole of the foot obliquely and is inserted into the lateral side of the base of the first metatarsal bone and the lateral side of the medial cuneiform. The peroneus or fibularis brevis arises from the lower two-thirds of the lateral surface of the body of the fibula medial to the peroneus longus and from the intermuscular septa. The fibers pass downward and end in a tendon which runs behind the lateral malleolus along with but anterior and superior to the peroneus longus tendon. The two peroneal tendons are enclosed in the same tendon sheath. From the level of the peroneal tubercle the tendon runs forward and obliquely downward to insert onto the base of the fifth metatarsal on its lateral side. The fibularis or peroneus tertius muscle arises from the lower third of the anterior surface of the fibula the lower part of the interosseous membrane and from an intermuscular septum between it and the peroneus brevis muscle in the anterior compartment of leg. The septum is sometimes called the intermuscular septum of Otto. The tendon after passing under the superior extensor and inferior retinaculum of the foot in the same canal as the extensor digitorum longus is inserted into the dorsal surface of the base of the fifth metatarsal. The peroneus tertius muscle is seldom found in other primates a fact that has linked its function to efficient terrestrial bipedalism. (Reproduced from Schuenke, Schulte, and Schumacher, Atlas of Anatomy, 2nd edition, ©2014, Thieme Publishers, New York. Illustration by Karl Wesker/Markus Voll.)

Fig. 12.33 Transverse scan of the distal peroneal tendons. The probe has been moved from the transverse plane used to image the tendons proximally to a more coronal plane. As the probe is moved distally toward the little toe, the coronal plane should be maintained. In this way both peroneal tendons may be seen down to the peroneal tubercle on the lateral calcaneum. The tendon of peroneus brevis may be seen down to its insertion at the base of the fifth metatarsal.

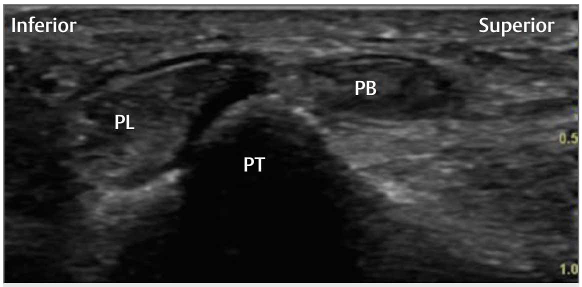

Fig. 12.34 Transverse image of the peroneal tendons at the level of the peroneal tubercle (PT) below the lateral malleolus. At this level the two peroneal tendons separate with the tendon of peroneus brevis (PB) laying superior to the tubercle and the tendon of peroneus longus (PL) lying below the tubercle.

Lateral Ankle Joint—Proximal Peroneal Tendons: Longitudinal Scan

The patient is positioned as for scanning the peroneal tendons in the transverse plane. The probe is placed in the coronal plane directly behind the distal fibula and lateral malleolus. The tendons should be followed distally with the probe moving from a coronal to transverse plane. The tendon of peroneus brevis may be visualized down to its insertion onto the base of the fifth metatarsal. The tendon of peroneus longus may be seen just distal to the peroneal tubercle on the lateral aspect of the calcaneum before it dives under the lateral border of the foot (▶Fig. 12.35, ▶Fig. 12.36).

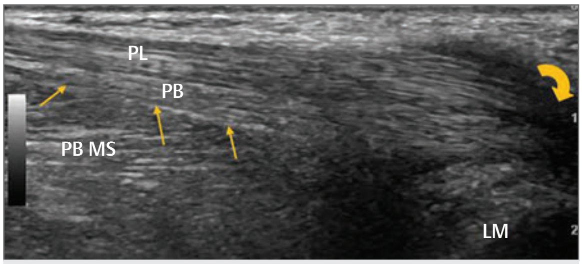

Fig. 12.35 Longitudinal image of the proximal peroneal tendons. The peroneus longus (PL) can be seen to be superficial with peroneus brevis (PB) below. The muscle of peroneus brevis (PBMS) can be seen deep to the tendon of peroneus brevis. The musculotendinous junction being demonstrated by the yellow arrows. To the right of the image the tendons may be seen to appear anisotropic (*curved yellow arrow*) as they pass around the lateral malleolus (LM).

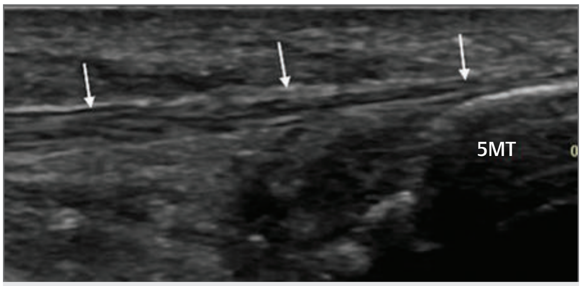

Fig. 12.36 Longitudinal image of the peroneus brevis tendon (*white arrows*) at its insertion onto the base of the fifth metatarsal (5MT).

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Lateral Ankle Joint—Peroneal Tendons: Pathology

See ▶Fig. 12.37a,b.

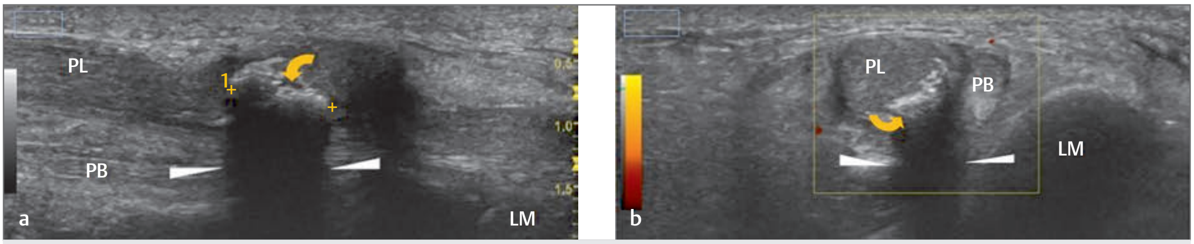

Fig. 12.37 (**a**) Longitudinal image of the peroneal tendons around the posterior aspect of the lateral malleolus. The large calcific foci (*curved arrow*) is seen within the peroneus longus tendon (PL) measuring approximately 9 mm. This appears to indent on the underlying peroneus brevis tendon (PB). The foci exhibit a clear posterior shadowing (*white arrowheads*). (**b**) The image is of the same patient as in part (a). Transverse image of the peroneal tendons around the posterior aspect of the lateral malleolus (LM). The calcific foci may be seen within peroneus longus (PL). The tendon of peroneus brevis (PB) appears to be forced to the right. The foci exhibit a clear posterior shadowing (*white arrowheads*). There is no evidence of neovascularity or tenosynovitis.

Lateral Ankle Joint: Anterior Talofibular Ligament

The patient is positioned in supine with the leg internally rotated and the foot hanging off the couch. The probe is placed so that its posterior edge lies over the lateral malleolus and its anterior edge is over the lateral talus. This position allows the clinician to move the foot into a plantar flexed and inverted position placing a stress through the anterior talofibular ligament to assess dynamically for stability—the sonographic draw test (▶Fig. 12.38, ▶Fig. 12.39, ▶Fig. 12.40).

Fig. 12.38 Longitudinal scan of the anterior talofibular ligament. The probe is placed so that its posterior edge lies over the lateral malleolus and its anterior edge over the lateral talus. The clinician should start the scan with the foot in a neutral position. However, to fully assess the ligament the foot should then be passively moved into plantar flexion and inversion to dynamically assess the ligament.

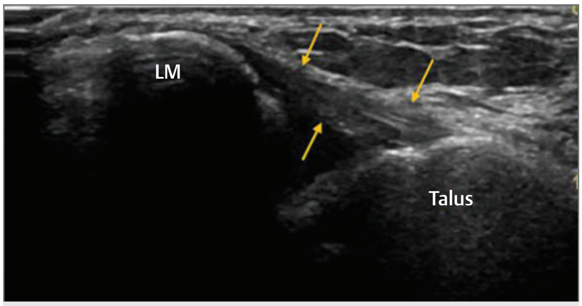

Fig. 12.39 Longitudinal image of the anterior talofibular ligament. In this image the foot has been placed into a plantar flexed and inverted position to stress the ligament which appears as a taught band extending from the lateral malleolus to the lateral talus (*yellow arrows*). LM, lateral malleolus; yellow arrows, anterior talofibular ligament.

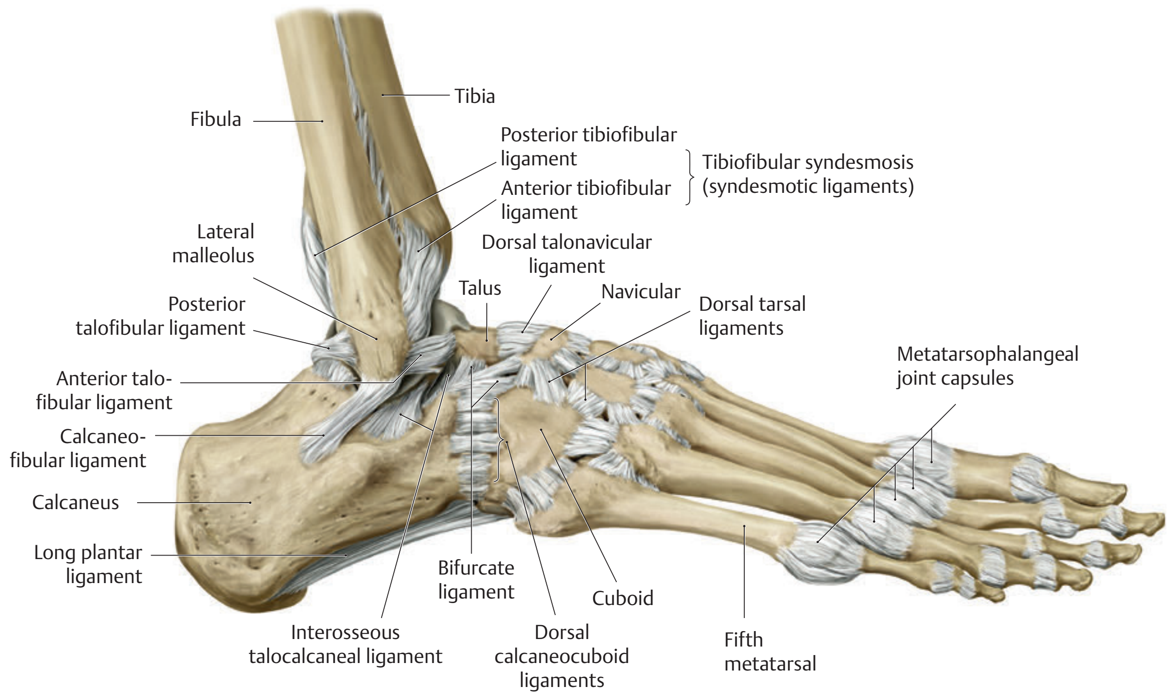

Fig. 12.40 Sagittal view of the lateral aspect of the right ankle and foot demonstrating the bones and associated ligaments. The lateral ligaments of the ankle include the posterior and anterior tibiofibular ligaments (the syndesmotic ligaments), the anterior talofibular ligament, the posterior talofibular ligament, and the calcaneofibular ligament. The anterior tibiofibular ligament is a flat triangular band of fibers, broader below than above, which extends obliquely downward and laterally between the adjacent margins of the tibia and fibula on the front aspect of the syndesmosis. The posterior tibiofibular ligament is smaller than the anterior ligament but is disposed in a similar manner on the posterior surface of the syndesmosis. The anterior talofibular ligament passes from the anterior margin of the lateral malleolus in an anteromedial direction to attach onto the talus in front of its lateral articular facet. The calcaneofibular ligament is a narrow rounded band running from the tip of the lateral malleolus inferiorly and slightly backward to a tubercle on the lateral surface of the calcaneus. It is covered by the tendons of the peroneus longus and brevis. The posterior talofibular ligament runs almost horizontally from the lateral malleolus to a prominent tubercle on the posterior surface of the talus immediately lateral to the groove for the tendon of the flexor hallucis longus. (Reproduced from Schuenke, Schulte, and Schumacher, Atlas of Anatomy, 2nd edition, ©2014, Thieme Publishers, New York. Illustration by Karl Wesker/Markus Voll.)

Lateral Ankle Joint—Anterior Talofibular Ligament: Pathology

See ▶Fig. 12.41, ▶Fig. 12.42, ▶Fig. 12.43, ▶Fig. 12.44.

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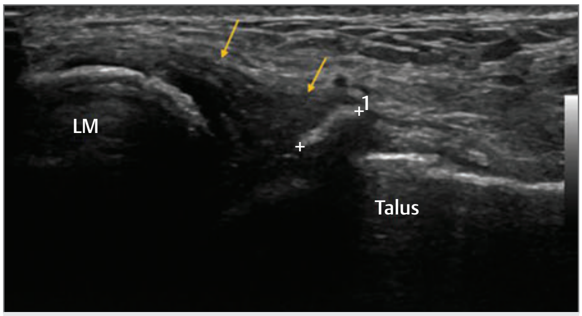

Fig. 12.41 Longitudinal image of the anterior talofibular ligament (*yellow arrows*). The image demonstrates thickening of the ligament which is of poor echogenicity. In addition, there appears to be a bony fragment (*white crosses*) to the left of the talus measuring approximately 5 mm. Dynamic stressing of the ligament demonstrated a negative sonographic draw. These findings are in keeping with a partial tear of the anterior talofibular ligament with associated avulsion fragment from the talus.

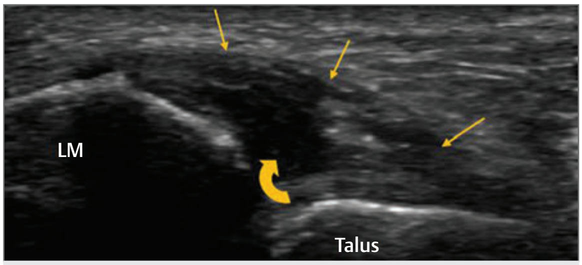

Fig. 12.42 Longitudinal image of the anterior talofibular ligament (*yellow arrows*). The image demonstrates marked thickening and loss of normal echogenicity. In addition, there appears to be a specific anechoic region deep within the ligament. There was a negative sonographic draw. The image is in keeping with a partial tear of the articular side of the anterior talofibular ligament. Curved arrow, partial tear within the deep portion of the ligament; LM, lateral malleolus; yellow arrows, anterior talofibular ligament.

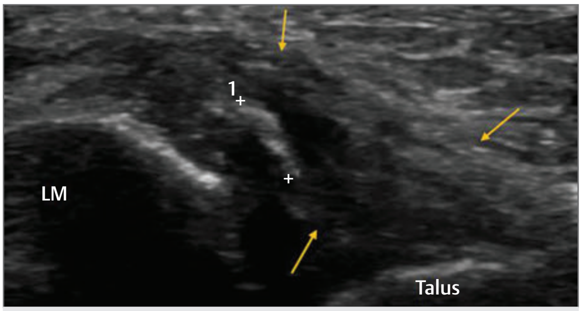

Fig. 12.43 Longitudinal image of the anterior talofibular ligament (*yellow arrows*). The image demonstrates a loss of normal ligament structure and marked soft tissue thickening. In addition, there appears to be a bony fragment (*white crosses*) to the right of the lateral malleolus (LM). Dynamic stressing of the ligament demonstrated a positive sonographic draw. Findings in keeping with a rupture of the anterior talofibular ligament with associated avulsion fragment.

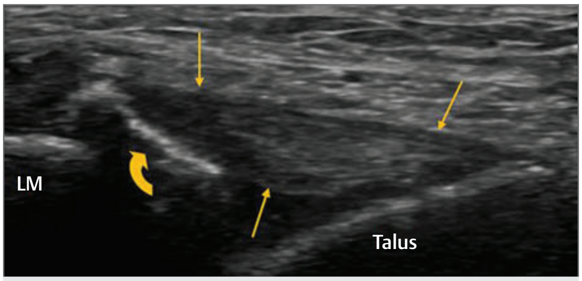

Fig. 12.44 Longitudinal image of the anterior talofibular ligament (*yellow arrows*). The image demonstrates no significant thickening and a good fibrillar pattern. The ligament appears taught in this stressed view and dynamic stressing demonstrated a negative sonographic draw However, there appear to be a bony fragment (*curved arrow*) to the right of the lateral malleolus (LM). Findings are in keeping with an avulsion fragment but intact anterior talofibular ligament.

Lateral Ankle Joint: Calcaneofibular Ligament

The patient is positioned in supine with the leg internally rotated and the foot hanging off the couch. The probe is placed so that its superior edge lies over the lateral malleolus and angled a few degrees posteriorly toward the heel. This position permits the clinician to move the foot into an inverted position which allows better visualization of the calcaneofibular ligament and to place a stress through the ligament to assess dynamically for stability (▶Fig. 12.45, ▶Fig. 12.46a,b).

Fig. 12.45 Longitudinal scan of the calcaneofibular ligament. The superior edge of the probe is placed over the lateral malleolus while the inferior edge is angled a few degrees posteriorly toward the heel. With the patient's foot positioned off the bed, the clinician is able to invert the foot which allows better visualization of the ligament and tests for integrity.

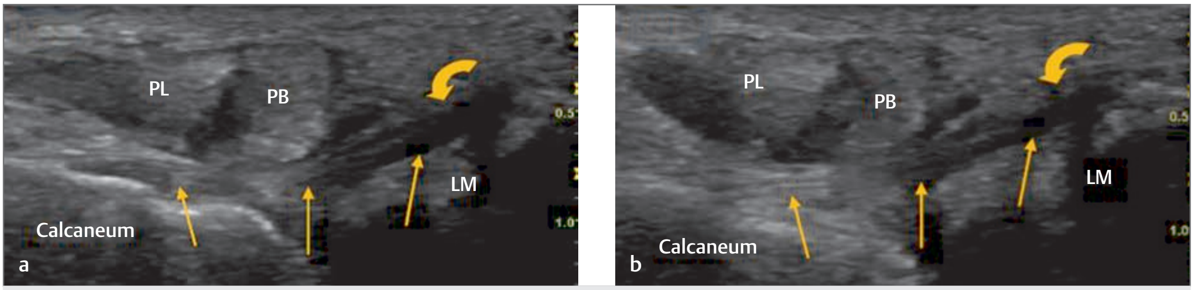

Fig. 12.46 (**a**) Longitudinal image of the calcaneofibular ligament (*yellow arrows*). In this view the foot is in neutral. The ligament may be seen to "bow" downward below the tendons of peroneus longus (PL) and brevis (PB). Note anisotropy of the ligament toward its insertion onto the lateral malleolus (*curved arrow*). (**b**) Longitudinal image of the calcaneofibular ligament (*yellow arrows*). In this view the foot is in an inverted position to stress the ligament. The ligament appears less bowed and has lifted the tendons of PL and PB. This has resulted in a decrease in anisotropy (*curved arrow*). LM, lateral malleolus.

Lateral Ankle Joint: Calcaneocuboid Joint

The patient is positioned in supine with the leg internally rotated and the foot resting on the couch. The probe is placed immediately below and slightly anterior to the lateral malleolus in the transverse plane to lie over the lateral aspect of the calcaneocuboid joint. From this position the probe may be moved in a proximal direction to view the superior aspect of the joint and the overlying dorsal calcaneocuboid ligament (▶Fig. 12.47, ▶Fig. 12.48, ▶Fig. 12.49).

Fig. 12.47 Longitudinal scan of the lateral aspect of the calcaneocuboid joint. The probe is placed below and slightly anterior to the lateral malleolus in the transverse plane to view the calcaneocuboid joint and overlying calcaneocuboid ligament.

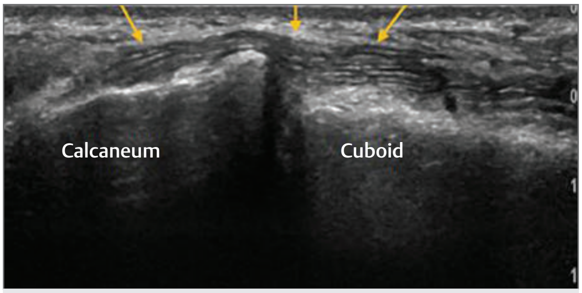

Fig. 12.48 Longitudinal image of the lateral aspect of the calcaneocuboid joint. The calcaneum is normally seen to be slightly higher than the cuboid. The calcaneocuboid ligament (*yellow arrows*) appears as a fibrillar structure spanning the joint.

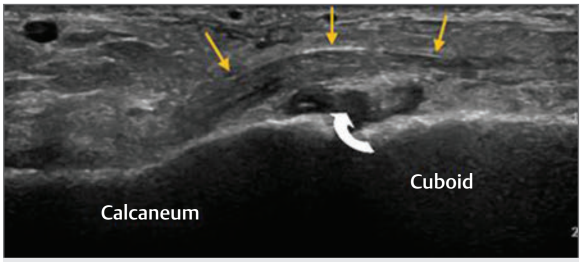

Fig. 12.49 Longitudinal image of the lateral aspect of the calcaneocuboid joint. There appears to be an effusion extending out from the joint (*curved arrow*). The overlying calcaneocuboid ligament appears to be elevated due to this swelling but is of normal appearance (*yellow arrows*).

12.1.4 Posterior

Posterior—Achilles Tendon and Calf: Longitudinal Scan

The patient is positioned in prone with the foot hanging off the end of the couch. The probe is placed in the anatomical sagittal plane with its distal edge over the posterior calcaneum. From this position the probe should be moved proximally to visualize up to the musculotendinous junction of the Achilles tendon and soleus and gastrocnemius muscles. The clinician should position the patients so that they are able to move the foot passively which facilitates both a better visualization of the posterior structures of the ankle and allows the Achilles tendon and calf to be stressed (▶Fig. 12.50, ▶Fig. 12.51, ▶Fig. 12.52).

Fig. 12.50 Longitudinal scan of the Achilles tendon and calf. The probe is placed in the anatomical sagittal plane with its distal edge over the posterior aspect of the calcaneum to first image the insertion of the Achilles tendon. Following this the probe should be moved proximally up the musculotendinous junctions of the soleus and gastrocnemius muscles.

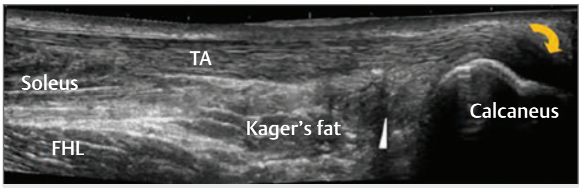

Fig. 12.51 Longitudinal image of the Achilles tendon (TA) insertion and musculotendinous junction with soleus. The Achilles appears normal and of good fibrillar pattern. The posterior aspect of the calcaneum appears intact with no cortical irregularity. The soleus muscle may be seen attaching onto the deep aspect of the Achilles. Deep to the soleus flexor hallucis longus may be seen. Superior to the upper aspect of the calcaneum Kager's fat may be seen. The curved arrow demonstrates anisotropy at the insertion of the Achilles as it wraps around the posterior calcaneum. White arrowhead, positon of retrocalcaneal bursa; yellow curved arrow, anisotropy.

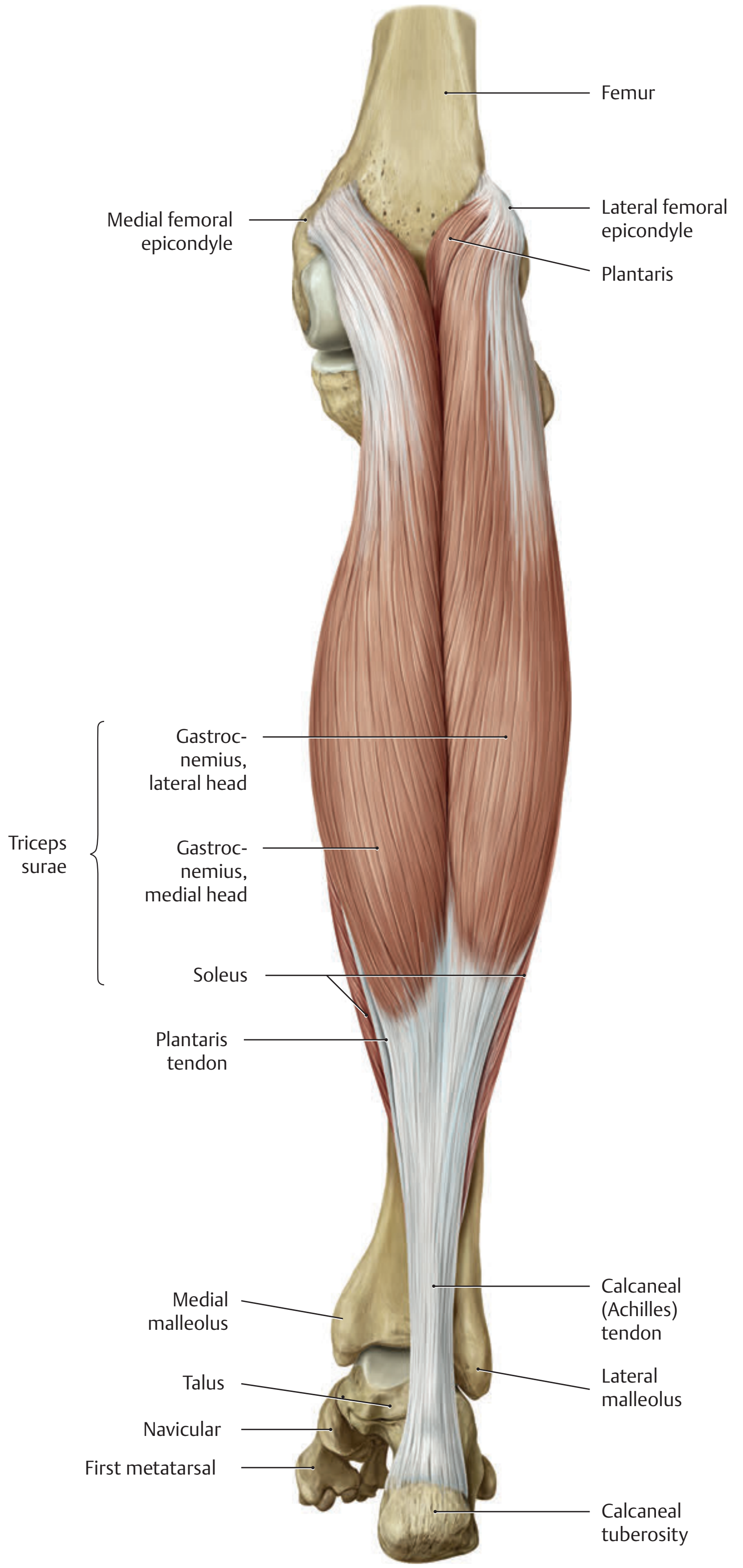

Fig. 12.52 Coronal view of the posterior superficial compartment of the leg. The leg is separated into anterior, lateral, superficial posterior, and deep posterior compartments by intermuscular septa and surrounded by the deep fascia of the leg. The transverse intermuscular septum divides the superficial and deep posterior compartments. The superficial posterior compartment contains the medial and lateral gastrocnemius, soleus, and plantaris muscles. (Reproduced from Schuenke, Schulte, and Schumacher, Atlas of Anatomy, 2nd edition, ©2014, Thieme Publishers, New York. Illustration by Karl Wesker/Markus Voll.)

Posterior: Musculotendinous Junction Achilles and Calf

The patient is positioned in prone with the foot hanging off the end of the couch. The clinician should position the patients so that they are able to move the foot passively allowing both the muscles and musculotendinous junctions to be stressed, both the medial and lateral heads of the gastrocnemius should be assessed (▶Fig. 12.53, ▶Fig. 12.54).

Fig. 12.53 Longitudinal image of the medial gastrocnemius muscle and musculotendinous junction of the calf. The probe is placed in a sagittal oblique plane to lie longitudinally over the medial and lateral head of the gastrocnemius as clinically indicated.

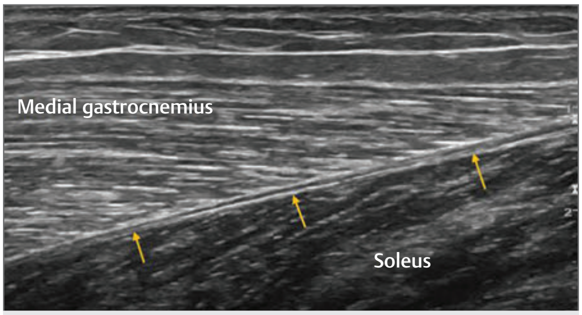

Fig. 12.54 Longitudinal image of the medial gastrocnemius and soleus muscles as they join onto the medial aponeurosis (*yellow arrows*) in the midcalf region. Yellow arrows, medial gastrocnemius aponeurosis (distally this will join with the lateral aponeurosis to form the Achilles tendon).

Posterior—Achilles Tendon: Transverse Scan

The patient is positioned in prone with the foot hanging off the end of the couch. The probe is placed in the anatomical transverse plane over the posterior aspect of the calcaneum. From this position the probe should be moved proximally to visualize the Achilles tendon as far as its musculotendinous junction with the muscles of gastrocnemius and soleus (▶Fig. 12.55, ▶Fig. 12.56, ▶Fig. 12.57).

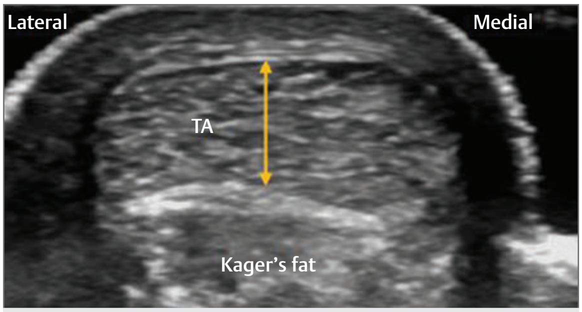

Fig. 12.55 Transverse image of the midsubstance of the Achilles tendon (TA). The tendon appears intact. Kager's fat may be seen anterior to the tendon. The tendon is seen to be slightly wider medially which is normal. A normal AP diameter through the middle of the tendon is considered to be 6 mm (*yellow double-headed arrow*).

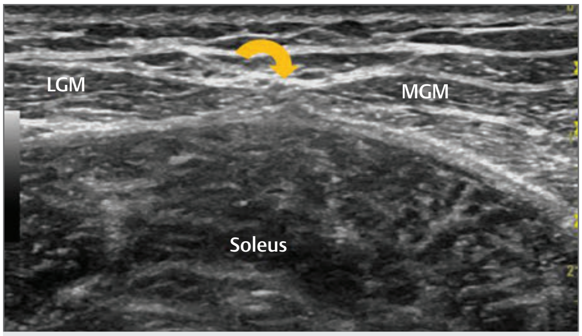

Fig. 12.56 Transverse image of the Achilles tendon (TA) at its musculotendinous junction (*curved yellow arrow*) with the medial (MGM) and lateral (LGM) gastrocnemius muscles. The soleus muscle may be seen deep to the gastrocnemius muscle.

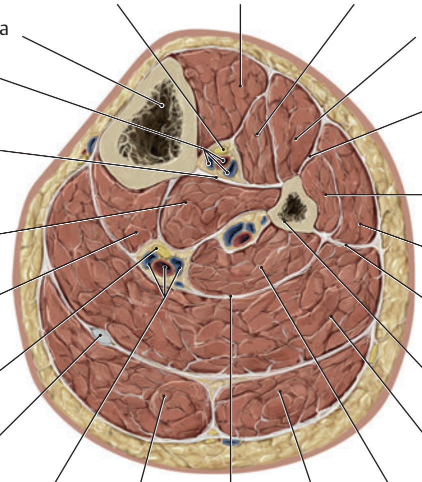

Fig. 12.57 Transverse section of the lower leg. The lower leg is divided into four compartments by the interosseous membrane, the anterior intermuscular septum, the transverse intermuscular septum and the posterior intermuscular septum. The anterior compartment contains the tibialis anterior, extensor hallucis longus, extensor digitorum longus, and peroneus tertius muscles and the deep fibular (peroneal) nerve and anterior tibial vessels. The lateral compartment contains the peroneus (fibularis) longus and brevis and the superficial fibular nerve. The deep posterior compartment contains the tibialis posterior, flexor hallucis longus, flexor digitorum longus and popliteus muscles, the tibial nerve, the posterior tibial artery and vein, and the peroneal (fibular) artery and vein. The superficial posterior compartment contains the gastrocnemius, soleus, and plantaris muscles and the medial sural cutaneous nerve. (Reproduced from Schuenke, Schulte, and Schumacher, Atlas of Anatomy, 2nd edition, ©2014, Thieme Publishers, New York. Illustration by Karl Wesker/Markus Voll.)

Posterior: Achilles Tendon and Plantaris

The plantaris muscle arises from the lateral supracondylar line of the femur just superior to the lateral head of the gastrocnemius. It may also take origin from the oblique popliteal ligament. The muscle belly is small and gives way to a long thin tendon which passes inferomedially to run between the medial head of the gastrocnemius and soleus muscles. The tendon then continues along the medial aspect of the Achilles tendon onto which it inserts. In some patients the tendon may remain independent of the Achilles to insert directly onto the calcaneum. It should be noted that up to 10% of people do not have a plantaris (▶Fig. 12.58, ▶Fig. 12.59, ▶Fig. 12.60).

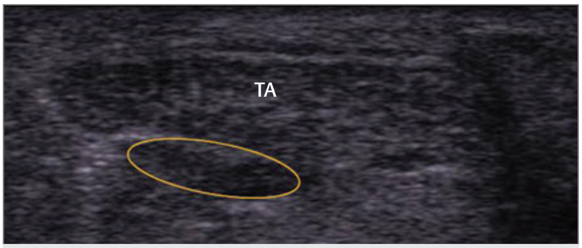

Fig. 12.58 Transverse image of the midsubstance of the Achilles tendon (TA). The tendon of plantaris may be seen as a separate oval form to the anteromedial aspect of the Achilles (*yellow oval*). It should be noted that the tendon is not always clearly seen as a separate entity.

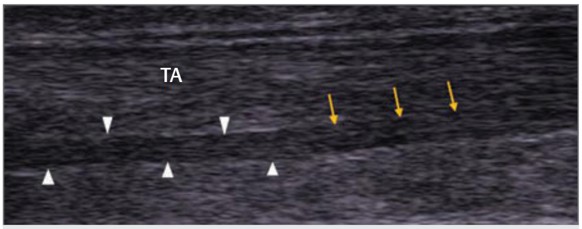

Fig. 12.59 Longitudinal image of the midsubstance of the Achilles tendon (TA). The tendon of plantaris (*white arrowheads*) may be seen as a long thin band running along the anteromedial aspect of the Achilles tendon. In this example, it may be seen to insert onto the mid-substance of the Achilles tendon (*yellow arrows*).

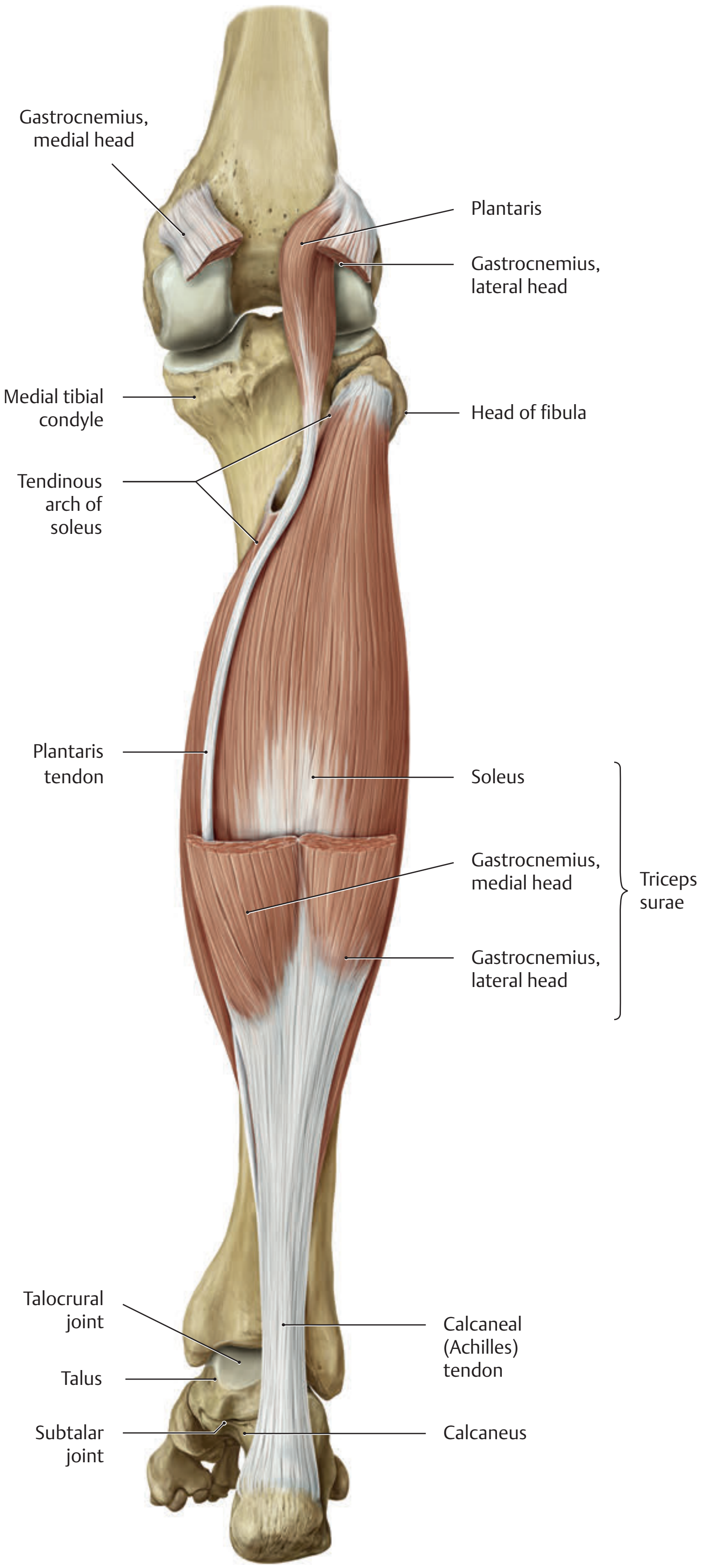

Fig. 12.60 Coronal view of the posterior superficial compartment of the leg. The superficial posterior compartment contains the medial and lateral gastrocnemius, soleus, and plantaris muscles. In this illustration, the medial and lateral gastrocnemius have been removed. The superficial posterior compartment is separated from the deep posterior compartment by the transverse intermuscular septum. (Reproduced from Schuenke, Schulte, and Schumacher, Atlas of Anatomy, 2nd edition, ©2014, Thieme Publishers, New York. Illustration by Karl Wesker/Markus Voll.)

Posterior—Achilles Tendon: Pathology

See ▶ Fig. 12.61 and ▶ Fig. 12.62a–c.

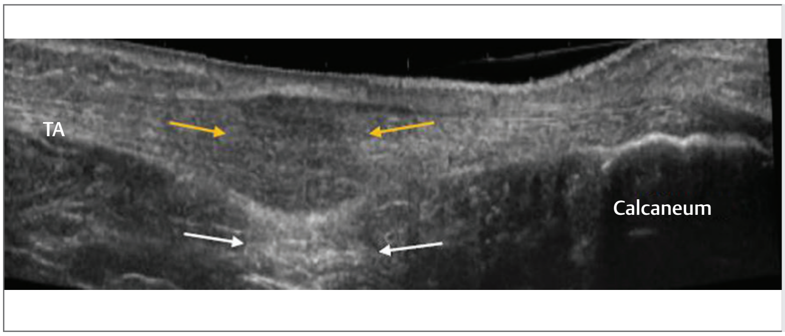

Fig. 12.61 Longitudinal image of the Achilles tendon (TA). The tendon appears intact at its insertion onto the calcaneum. However, there is marked thickening of the midsubstance of the tendon with loss of echogenicity (*yellow arrows*). Note the posterior enhancement associated with this thickening which indicates that although the tendon is thickened it is of a decreased density (*white arrows*). These findings are indicative of a midsubstance tendinopathy.

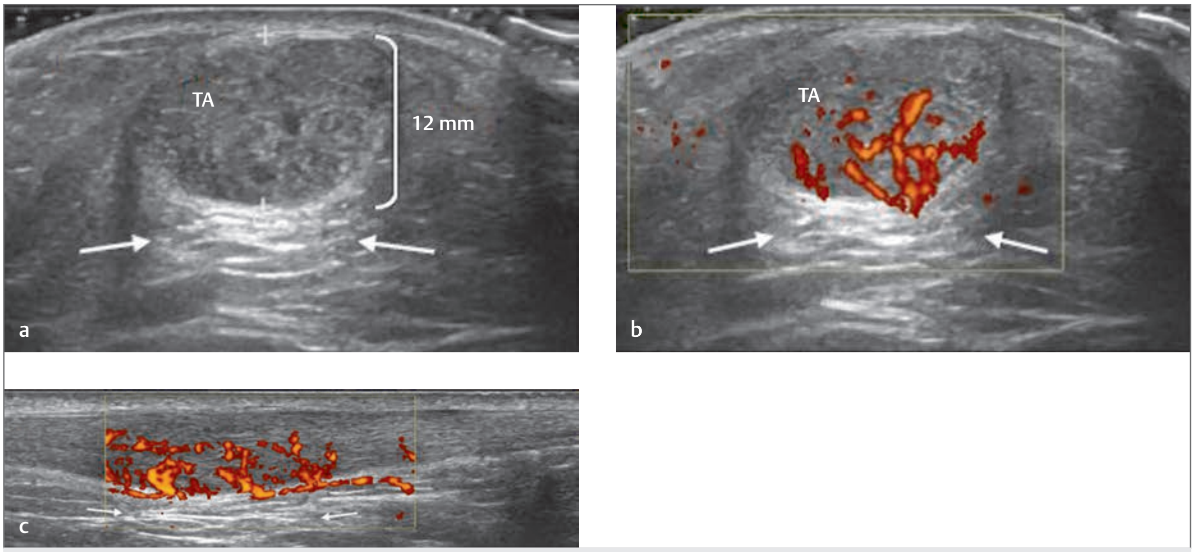

Fig. 12.62 (**a,b**) Transverse images of the midsubstance of an Achilles tendon (TA). The tendon appears thickened at over 12 mm. In addition, there is marked posterior enhancement indicating lack of normal tendon density (*white arrows*). In part (**b**) Power Doppler demonstrates a marked neovascularity. (**c**) Longitudinal image of the same tendon as in parts (a) and (b) clearly demonstrating the spindle-shaped swelling of the tendon and a diffuse neovascularity. These findings are indicative of a midsubstance tendinopathy. White bracket, maximum tendon diameter (AP).

Posterior—Retrocalcaneal: Pathology

See ▶ Fig. 12.63a,b.

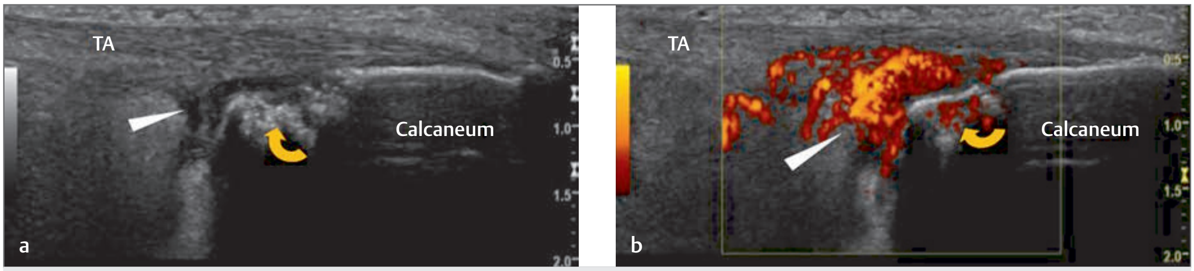

Fig. 12.63 (**a,b**) Longitudinal image of the posterior aspect of the insertion of the Achilles tendon (TA) and retrocalcaneal area. The Achilles tendon appears intact with no evidence of thickening or insertional change. However, there appears to be a large diffuse and inflamed retrocalcaneal bursa (*white arrowhead*). In addition, the superoposterior aspect of the calcaneum demonstrates significant cortical irregularity in keeping with erosive change (*curved arrow*).

Posterior—Musculotendinous Junction of the Calf: Pathology

See ▶ Fig. 12.64, ▶ Fig. 12.65, and ▶ Fig. 12.66a,b.

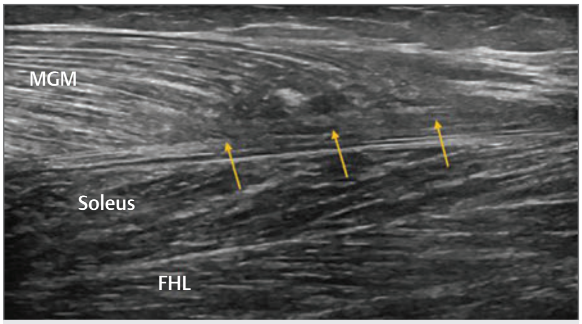

Fig. 12.64 Longitudinal image of the medial calf. The medial head of the gastrocnemius muscle (MGM) demonstrates a loss of normal fibrillar pattern toward its distal insertion onto the medial aponeurosis (*yellow arrows*). The deeper soleus and flexor hallucis longus (FHL) muscles appear intact. The image is in keeping with a tear of the medial gastrocnemius.

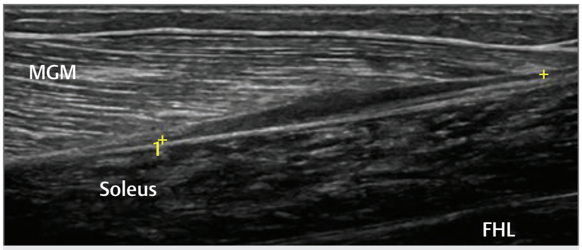

Fig. 12.65 Longitudinal image of the medial head of the gastrocnemius muscle (MGM). The image demonstrates a spindle-shaped low echo region within the deeper aspect of the muscle at its insertion onto the medial aponeurosis measuring 3.5 cm (*yellow crosses*). The image is in keeping with a chronic scar within the muscle subsequent to previous tear. FHL, flexor hallucis longus muscle; yellow crosses, scar tissue within medial gastrocnemius muscle.

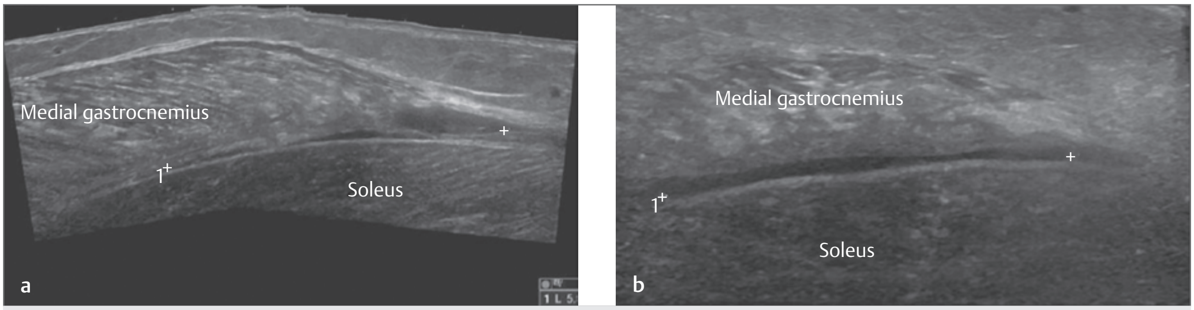

Fig. 12.66 (**a**) Longitudinal image of the medial head of the gastrocnemius muscle. The image demonstrates a large tear measuring approximately 6 cm longitudinally at the insertion of the muscle belly onto the Achilles aponeurosis (*white crosses*). The torn ends appear in close approximation. (**b**) Transverse image of the medial gastrocnemius muscle. The image demonstrates a large tear measuring approximately 3.6 cm transversely through the insertion of the muscle belly onto the Achilles aponeurosis (*white crosses*). The torn ends appear in close approximation. White crosses, calipers measuring extent of tear between medial gastrocnemius and Achilles aponeurosis.

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Posterior—Pathology: Achilles Tendon Rupture

See ▶Fig. 12.67 and ▶Fig. 12.68.

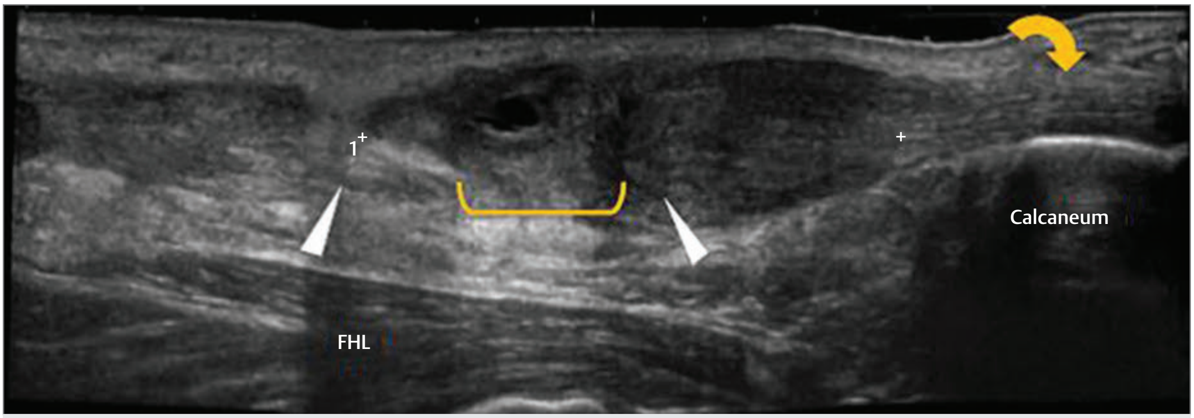

Fig. 12.67 Longitudinal image of the Achilles tendon. The image demonstrates a normal appearance of the distal tendon at its insertion onto the posterior aspect of the calcaneum (*curved arrow*). However, there is a 4.5-cm loss of normal tendon architecture within the midsubstance of the tendon (*white crosses*) with retraction of both the distal and proximal ends of the tendon (*white arrowheads*). The gap between the retracted ends of the tendon measures approximately 3 cm and appears to be filled with fibrous tissue (*yellow bracket*). Clinically, squeezing the calf muscle proximally produced no movement of the tendon although the foot itself did plantar flex due to activity within the flexor hallucis longus (FHL) muscle deep to the tendon. Findings are in keeping with a complete rupture of the Achilles tendon within its midsubstance. Curved arrow, normal Achilles tendon; white arrowheads, retracted tendon; white crosses, loss of normal tendon architecture; yellow bracket, gap within tendon.

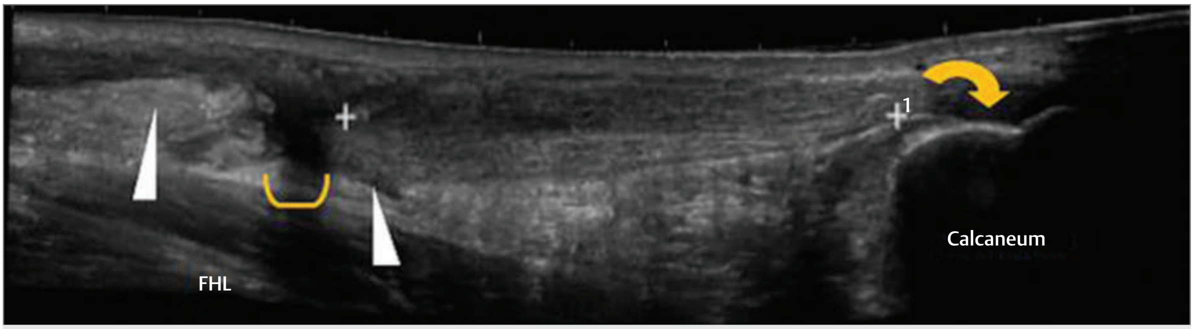

Fig. 12.68 Longitudinal image of the Achilles tendon. The distal tendon at its insertion onto the calcaneum appears intact (*curved arrow*). The lower half of the tendon also appears intact although thickened in keeping with tendinopathy (*white crosses*). There is a clear 1-cm gap within the tendon approximately 6 cm proximally from the upper edge of the calcaneum in keeping with complete rupture (*yellow bracket*). The tendon on either side of this gap may be seen to be retracted (*white arrowheads*). Curved arrow, normal Achilles tendon; FHL, flexor hallucis longus; white arrowheads, retracted tendon; white crosses, intact but thickened tendon; yellow bracket, gap within tendon.

12

12.1.5 Inferior

Plantar Aspect of the Heel—Plantar Fascia: Longitudinal Scan

The patient is positioned in supine with the leg in external rotation. The clinician should position themselves so that they are able to move the foot passively allowing a stress to be placed through the plantar fascia to assess for patency. The probe is placed in the anatomical sagittal plane with its posterior edge over the anterior medial calcaneal tubercle and its anterior edge extending into the medial longitudinal arch (▶Fig. 12.69, ▶Fig. 12.70a,b).

Fig. 12.69 Longitudinal scan of the plantar fascia at its origin on the anterior medial calcaneal tubercle. The probe is placed in the anatomical sagittal plane to view the proximal fascia.

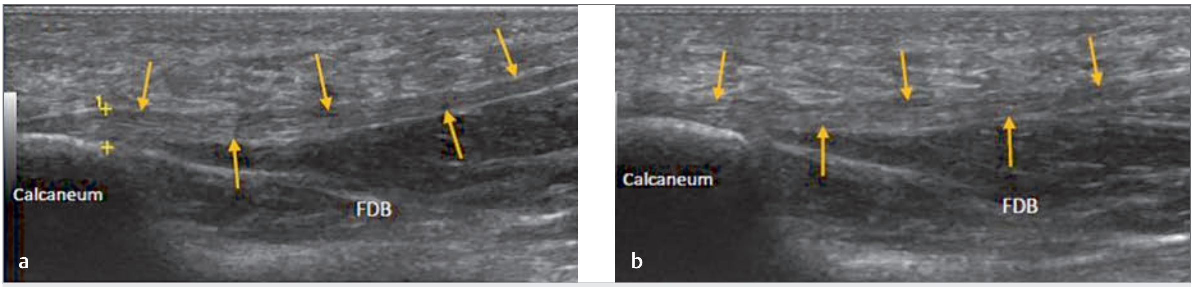

Fig. 12.70 (**a,b**) Longitudinal image of the plantar fascia at its origin on the anterior medial calcaneal tubercle. The fascia may be seen as band extending from the tubercle distally within the medial longitudinal arch of the foot (*yellow arrows*). In these images the fascia does not appear thickened measuring 4 mm at the tubercle (*yellow crosses*). In part (a), the foot is relaxed and the fascia may be seen to bow downward slightly. In part (b), stress has been placed through the fascia by elevating the first metatarsal head and the fascia appears less bowed. FDB, flexor digitorum brevis muscle; yellow arrows, plantar fascia; yellow crosses, calliper measurement of the plantar fascia at the anterior medial calcaneal tubercle (4 mm is an average thickness).

Plantar Aspect of the Heel—Plantar Fascia: Transverse Scan

The patient is positioned in supine with the leg in external rotation. The probe is placed in the anatomical coronal plane over the plantar fascia at its origin on the anterior medial calcaneal tubercle (▶Fig. 12.71, ▶Fig. 12.72).

Fig. 12.71 Transverse scan of plantar fascia at its origin on the anterior medial calcaneal tubercle. The probe is placed in the anatomical coronal plane.

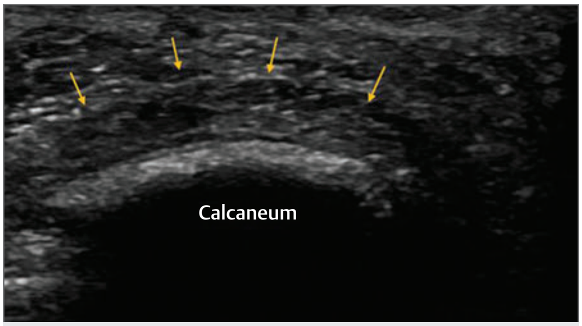

Fig. 12.72 Transverse image of the plantar fascia at the anterior medial calcaneal tubercle. The plantar fascia appears as an echogenic layer lying parallel to the calcaneum (*yellow arrows*).

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Plantar Aspect of Heel—Plantar Fascia: Pathology

See ▶ Fig. 12.73, ▶ Fig. 12.74, ▶ Fig. 12.75, and ▶ Fig. 12.76.

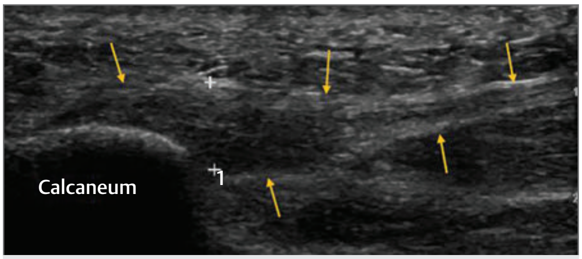

Fig. 12.73 Longitudinal image of the plantar fascia at its proximal attachment onto the anterior medial calcaneal tubercle (*yellow arrows*). The calcaneum appears intact with no evidence of spurring. The fascia is however thickened and of poor echogenicity within its proximal attachment measuring 8 mm in thickness (normal 4 mm) (*crosses*). These findings are indicative of a plantar fasciosis.

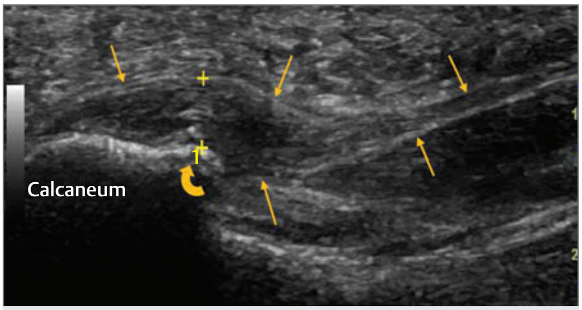

Fig. 12.74 Longitudinal image of the plantar fascia at its proximal attachment onto the anterior medial calcaneal tubercle (*yellow arrows*). The fascia is thickened at 7 mm (crosses). In addition, there is a heel spur (*curved arrow*). These findings are indicative of a plantar fasciosis and associated heel spur. Crosses, calipers measuring thickness of plantar fascia; curved arrow, calcaneal heel spur; yellow arrows, plantar fascia.

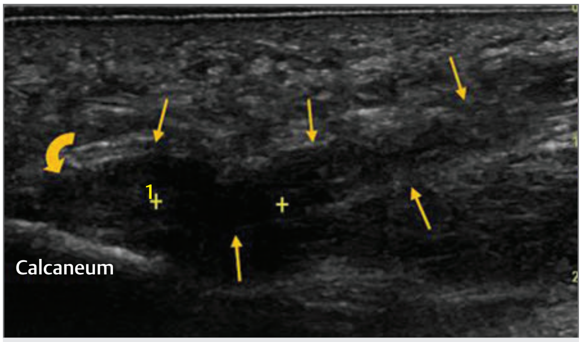

Fig. 12.75 Longitudinal image of the plantar fascia at its insertion onto the anterior medial calcaneal tubercle (*yellow arrows*). In addition to the fascia being thickened over the calcaneum (*curved arrow*), there is a 10-mm anechoic "gap" in the fascia (*yellow crosses*). These findings are in keeping with a rupture of the proximal fascia.

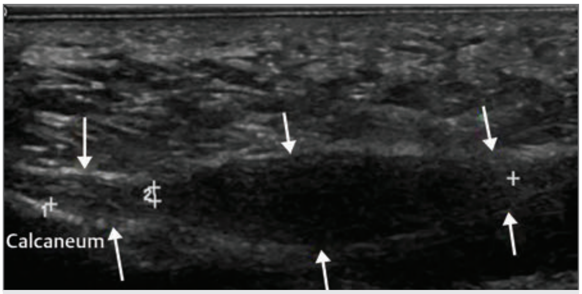

Fig. 12.76 Longitudinal image of the proximal third of the plantar fascia (*yellow arrows*). The fascia appears of normal echogenicity and thickness at its proximal insertion onto the anterior medial calcaneal tubercle. However, approximately 1 cm distal to the tubercle is an area of thickening and low echogenicity within the plantar fascia measuring approximately 3 cm longitudinally (two sets of *white crosses*). Stressing the plantar fascia did not demonstrate a complete rupture. These findings are likely to represent a partial tear of the fascia at this level as the patient described a trauma to the foot and sudden onset of discomfort. In the absence of any such trauma a diagnosis of a plantar fibroma would be likely. White crosses, calipers indicating measurement of low echo thickening within the fascia and distance of thickening from the calcaneum; yellow crosses, calipers measuring rupture within fascia.

12.1.6 Interdigital

Interdigital—Metatarsal Heads: Transverse Scan

The patient is positioned in supine with the ankle in dorsiflexion. The probe is placed in the anatomical coronal oblique plane to view the metatarsal heads. The slight oblique angle from the true coronal plane should result in the lateral edge of the probe being slightly posterior in orientation relative to the medial edge. This obliquity allows for the difference in length of the metatarsals. If scanning is to detect a possible Morton's neuroma, then a transverse pressure should be applied through the metatarsal heads forcing the neuroma in a plantar direction where it can be visualized (▶Fig. 12.77 and ▶Fig. 12.78).

Fig. 12.77 Transverse scan of the metatarsal heads and interdigital spaces. With the probe in this position a transverse pressure may be applied across the metatarsal heads—the "Mulder's click" test.

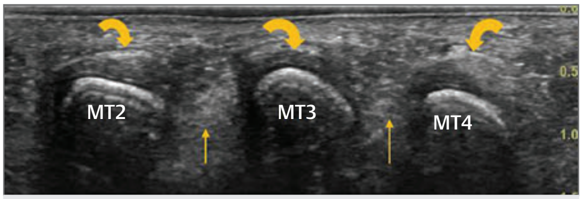

Fig. 12.78 Transverse image of the second to fourth metatarsal heads (MT2, MT3, MT4). The tendons of flexor digitorum longus below the metatarsal heads appear intact (*curved arrows*) and the fatty tissue between the metatarsal heads appears of normal echogenicity (*straight arrows*). Yellow arrows, normal interdigital fatty tissue.

12

Interdigital—Metatarsal Heads: Pathology

See ▶ Fig. 12.79a,b and ▶ Fig. 12.80a,b.

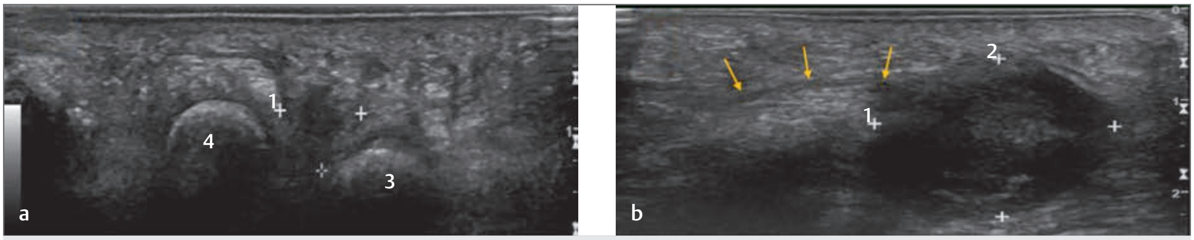

Fig. 12.79 (**a**) Transverse image of the fourth and third metatarsal heads. A transverse pressure has been applied across the metatarsal heads (the Mulder's click test) and the low echo foci has been forced in a plantar direction from between the fourth and third metatarsal heads as outlined by the white crosses indicating a Morton's neuroma. (**b**) Longitudinal image of the fourth or third interspace in the same patient as part (a). In the longitudinal view there is no need to apply a transverse pressure to the metatarsal heads. The large low echo foci may be seen within the interspace (*white crosses*). A thin linear structure of low echogenicity may be seen entering the foci from the left of the screen (*yellow arrows*) representing the interdigital nerve from which the neuroma has formed. White crosses, Morton's neuroma; yellow arrows, inter digital nerve.

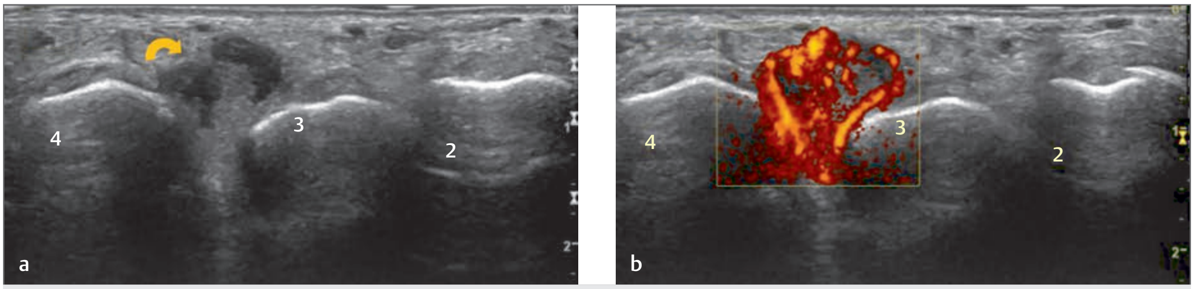

Fig. 12.80 (**a**) Transverse image of the second, third, and fourth metatarsal heads. No transverse pressure has been applied to the metatarsal heads but a low echo foci may be seen to extend from between the fourth and third metatarsal heads (*curved arrow*). (**b**) With Power Doppler imaging the low echo foci demonstrates a marked internal vascularity. Both images are in keeping with an intermetatarsal bursa. 4, 3, 2, fourth, third, and second metatarsal head; curved arrows, intermetatarsal bursa.

12

12.1.7 Digital

Digital—Dorsal Aspect Metatarsophalangeal and Interphalangeal Joints: Longitudinal Scan

The patient is positioned in supine with the knee flexed and the foot resting on the couch in a plantar flexed position. The probe is placed in the anatomical sagittal plane over the metatarsophalangeal or interphalangeal joint to be scanned. In ▶Fig. 12.81 the first metatarsophalangeal joint is being scanned (▶Fig. 12.82, ▶Fig. 12.83).

Fig. 12.81 Longitudinal scan of the dorsal aspect of the first metatarsophalangeal joint. The probe is positioned in the anatomical sagittal plane over the joint. To image the interphalangeal joint the probe should be kept in the sagittal plane and moved distally.

Digital—Plantar Aspect First Metatarsophalangeal Joint: Transverse and Longitudinal Scans

The patient is positioned in supine with the leg and foot resting on a couch. The clinician should position themselves so that they are able to scan the plantar aspect of the foot. The probe is placed in the anatomical coronal plane over the plantar aspect of the first metatarsophalangeal joint (▶Fig. 12.84, ▶Fig. 12.85).

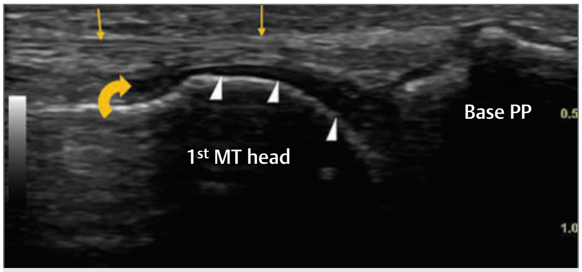

Fig. 12.82 Longitudinal image of the dorsal aspect of the first metatarsophalangeal joint. Superficially the tendon of extensor hallucis longus may be seen as a fibrillar band (*yellow arrows*). The anechoic layer seen over the metatarsal head (1st MT head) represents articular cartilage. The metatarsal recess is demonstrated by the curved arrow. Base PP, base of the proximal phalanx; curved arrow, metatarsal recess; white arrowheads, articular cartilage over the metatarsal head.

12

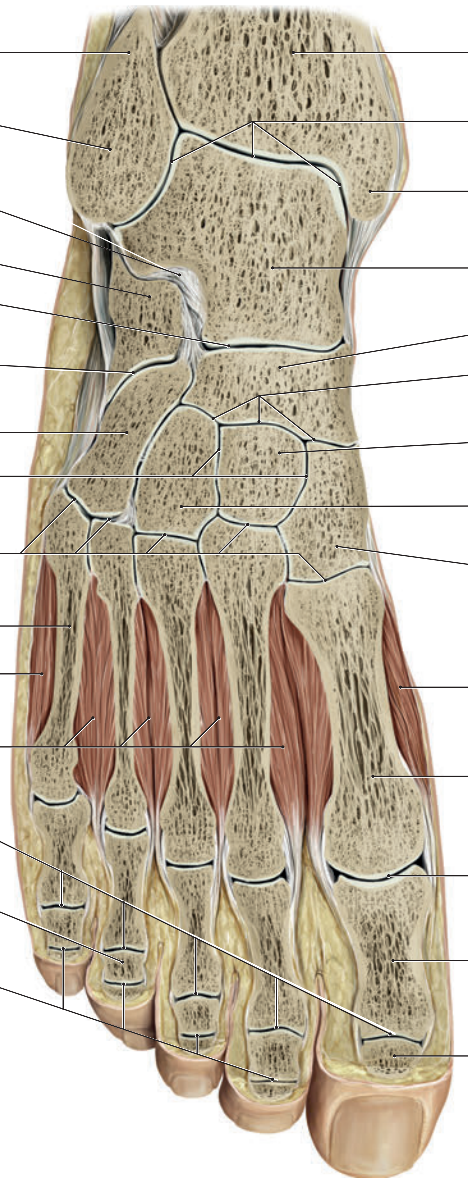

Fig. 12.83 Transverse section of the right ankle and foot. The hindfoot is composed of the talus and the calcaneum. While the tibia and fibula are connected to the superior part of the talus to form the talocrural joint, the talus is connected inferiorly with the calcaneum forming the subtalar joint. The five irregular bones of the midfoot, the cuboid, navicular, and three cuneiform form the arches of the foot. The midfoot may be considered to begin with the calcaneocuboid joint and end where the metatarsals begin. The midfoot joints also known as the Lisfranc joint are composed of the five tarsometatarsal joints in which the first through third metatarsals articulate with their corresponding medial, middle, and lateral cuneiforms, whereas the fourth and fifth metatarsals articulate with the cuboid. Functionally, the Lisfranc joint can be divided longitudinally into three columns:
Medial column—or first ray consisting of the first tarsometatarsal joint.
Middle column—consisting of the second and third tarsometatarsal joints.
Lateral column—consisting of the fourth and fifth tarsometatarsal joints.
A transverse line through these joints is not straight but demonstrates a recess termed the keystone which is formed by the second tarsometatarsal joint. This joint lies approximately 1 cm proximal to the first tarsometatarsal joint line and 0.5 cm proximal to the third tarsometatarsal joint line. The forefoot is composed of five toes and the corresponding five proximal metatarsals. Similar to the fingers of the hand the big toe has two phalanges while the other four toes have three phalanges. (Reproduced from Schuenke, Schulte, and Schumacher, Atlas of Anatomy, 2nd edition, ©2014, Thieme Publishers, New York. Illustration by Karl Wesker/Markus Voll.)

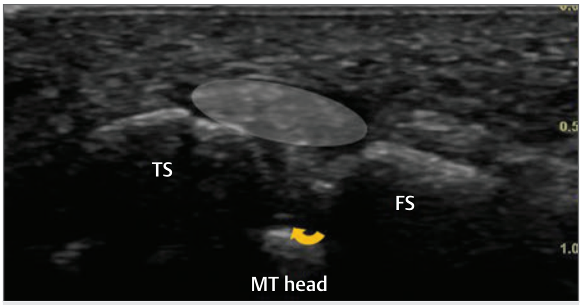

Fig. 12.84 Transverse image of the plantar aspect of the first metatarsophalangeal joint. The image demonstrates the tibial and fibular sesamoid bones (TS and FS, respectively). The anechoic region over the first metatarsal head (*curved arrow*) is articular cartilage. Resting between the two sesamoid bones is the tendon of flexor hallucis longus (*oval*).

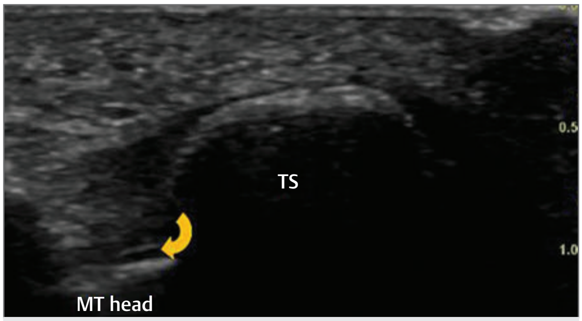

Fig. 12.85 Longitudinal scan of the plantar aspect of the first metatarsophalangeal joint. In this image the probe has been placed over the medial side of the joint to demonstrate the tibial sesamoid (TS). Curved arrow, articular cartilage; MT Head, first metatarsal head.

Digital—Plantar Aspect Second to Fifth Metatarsophalangeal and Interphalangeal Joints: Longitudinal Scan

The patient is positioned in supine with the leg and foot resting on a couch. The position of the clinician should be such that he or she is able to scan the plantar aspect of the foot. The probe is placed in the anatomical sagittal plane over the plantar aspect of the metatarsophalangeal or interphalangeal joint to be scanned. In ▶Fig. 12.86 the second metatarsophalangeal joint is being scanned (▶Fig. 12.87).

Fig. 12.86 Longitudinal scan of the plantar aspect of the second metatarsophalangeal joint. The probe is positioned in the anatomical sagittal plane over the joint. To image the interphalangeal joint the probe should be kept in the sagittal plane and moved distally.

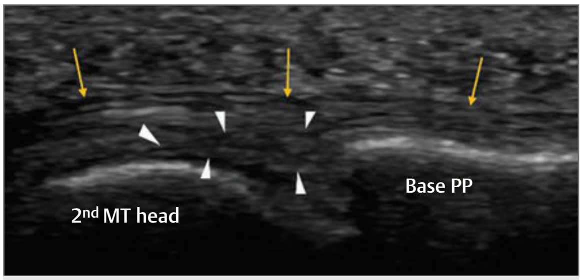

Fig. 12.87 Longitudinal image of the plantar aspect of the second metatarsophalangeal joint. Superficially the tendon of flexor digitorum longus may be seen as a fibrillar band (*yellow arrows*). The echogenic triangular region deep to the tendon is the plantar plate which may be seen to have a wider base attached to the base of the phalanx (*white arrowheads*). 2nd MT Head, second metatarsal head; Base PP, base of proximal phalanx; white arrowheads, plantar plate.

Digital: Pathology

See ▶Fig. 12.88a,b; ▶Fig. 12.89, ▶Fig. 12.90a,b and ▶Fig. 12.91.

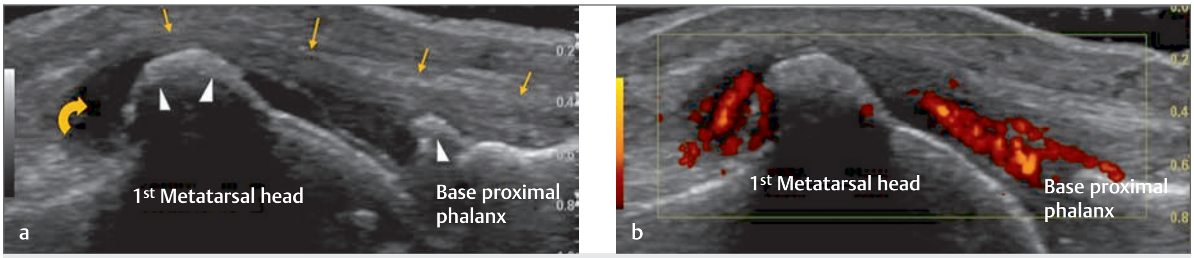

Fig. 12.88 (**a**) Longitudinal image of the first metatarsophalangeal joint of the great toe. The image demonstrates marked degenerative change with bony exostosis at both the head of the metatarsal and at the base of the proximal phalanx (*white arrowheads*). Effusion is noted in the joint and also the metatarsal recess (*curved arrow*). The joint capsule is thickened (*yellow arrows*). (**b**) With Power Doppler the joint may also be seen to exhibit a marked synovitis. These findings are in keeping with a marked osteoarthritis and associated synovitis of the first metatarsophalangeal joint of the great toe. White arrowheads, bony exostosis; yellow arrows, hypertrophy of the joint capsule.

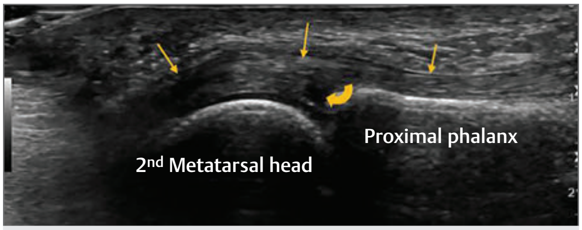

Fig. 12.89 Longitudinal image of the plantar aspect of the second metatarsophalangeal joint. There is the hypoechoic foci within the distal attachment of the plantar plate on the base of the proximal phalanx (*curved arrow*). The patient described a sudden onset of pain in this region following jumping and landing on the foot. The pain was located at the undersurface of the second metatarsal head. Findings would suggest a tear of the plantar plate. Yellow arrows, measurement calipers.

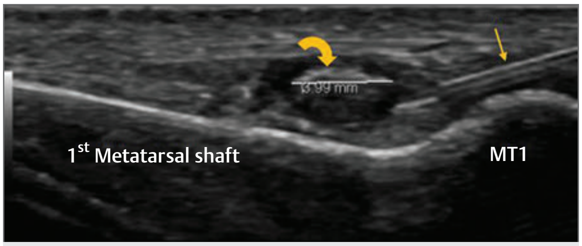

Fig. 12.91 Longitudinal image of the dorsum of the distal shaft of the 1st metatarsal. The metatarsal head (MT1) may be seen to the right of the image. The metatarsal recess contains the well-defined calcific foci measuring 4 mm in diameter in keeping with a loose body (*curved arrow*). The joint is being injected note needle entering the metatarsal recess from the right of the screen (*yellow arrow*).

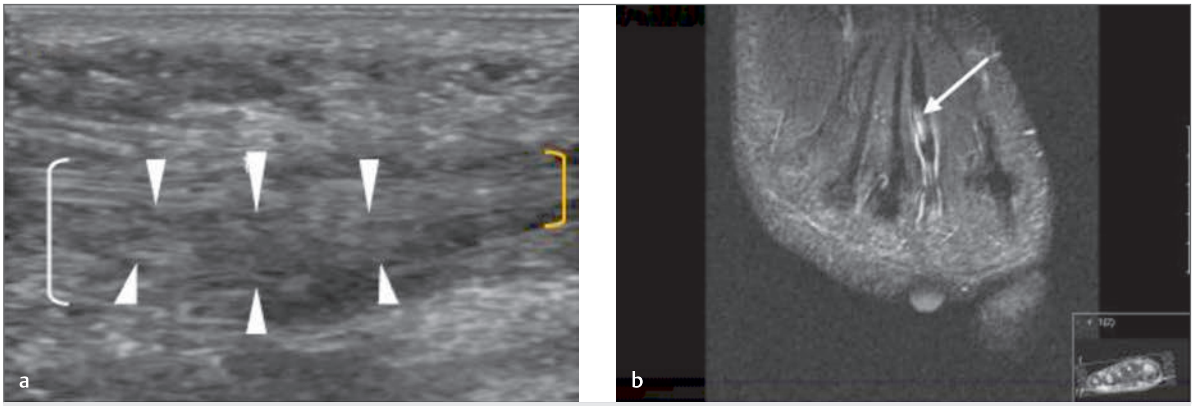

Fig. 12.90 (**a**) Longitudinal image of the plantar aspect of the second toe and associated tendon of flexor digitorum longus. The image demonstrates thickening and a loss of normal fibrillar pattern within the substance of the tendon in keeping with an intrasubstance tear (*white arrowheads*). (**b**) MRI image (T2 axial) of the same area as in part (a). There is a high signal around the tendon of flexor digitorum longus at the second metatarsal. There is a diffuse thickening of the tendon with high signal (*white arrow*). White arrow, high signal within the tendon of flexor digitorum longus at the second metatarsal; white bracket, thickened tendon; yellow bracket, normal tendon diameter.

12

13 The Ankle and Foot: Guided Injection Techniques

Abstract
This chapter outlines commonly used injection techniques around the ankle and foot. The aim of the chapter is to provide details of the position and alignment of the probe and needle to allow accurate placement into the target tissue. In addition, a brief clinical presentation is given for each condition as well as some of the anatomical considerations which should be noted. The drugs, dosages, and volumes given are those used in the author's clinic.

Keywords: talocrural, subtalar, midfoot, forefoot, metatarsophalangeal, anterior talofibular, calcaneofibular, anterior inferior tibiofibular, calcaneocuboid, Achilles, plantar fascia, tibialis posterior, flexor digitorum longus, flexor hallucis

13.1 Ankle Joint (Talocrural Joint) Injection

13.1.1 Cause

- Osteoarthritis.
- Posttrauma.

13.1.2 Presentation

- Pain is described as deep within the anterior aspect of the ankle joint. If osteoarthritis is the cause of pain, then there is often a relatively more limited restriction of plantarflexion than dorsiflexion.
- If pain is due to an impingement, then limitation will be related to the site of the impingement either anterior or posterior.

13.1.3 Equipment

See ▶Table 13.1.

Table 13.1 Equipment needed for ankle joint (talocrural joint) injection

Syringe	Needle	Corticosteroid	Local anesthetic	Transducer
5 mL	23 gauge	20-mg Depo-Medrone	2-mL 1%	Large linear or hockey stick

13.1.4 Anatomical Considerations

The most convenient point of entry to the talocrural joint is immediately distal to the anterior edge of the tibia just above the talar dome. The deep peroneal nerve and dorsalis pedis artery and vein should be visualized prior to injection.

13.1.5 Procedure

- The patient is positioned supine with the knee bent to approximately 90 degrees and the foot flat on the couch. This places the foot in a plantar flexed position allowing for easier needle entry into the joint.
- The transducer is placed in the anatomical sagittal plane between the tendons of tibialis anterior and extensor hallucis longus.
- The needle is introduced in the longitudinal plane of the transducer from an inferior to superior direction into the talocrural joint.
- The dome of the talus gives the clinician the needle angle.
- Injection is given as a bolus.

13.1.6 The Injection

See ▶Fig. 13.1 and ▶Fig. 13.2.

Fig. 13.1 Ankle joint injection. The probe is placed in the anatomical sagittal plane between the tendons of tibialis anterior and extensor hallucis longus. The needle is introduced in the longitudinal plane of the probe from an inferior to superior direction into the talocrural joint. The dome of the talus gives the clinician the needle angle.

13.1.7 Notes

The ankle joint is not a joint commonly affected by osteoarthritis unless this is secondary to previous fracture. Even then problems do not usually develop for a number of years. If osteoarthritis is present, injection can provide a good degree of symptomatic relief and facilitate a programme of rehabilitation.

Injection may also be of diagnostic use particularly if an intra-articular swelling is present secondary to anterior impingement.

Prior to injection the possibility of an osteochondral defect should be considered and may require magnetic resonance imaging (MRI) to fully assess for this possibility particularly if pain is present on weight-bearing and the patient describes a history of inversion-like injury.

13.2 Midtarsal Joint Injection

13.2.1 Cause

- Commonly osteoarthritis of the talonavicular, navicular-cuneiform or cuneiform-metatarsal joints.
- Overuse often associated with either an overpronated or supinated foot.

13.2.2 Presentation

Pain is located over the dorsum of the foot. There may be an associated soft tissue or bony prominence which ultrasound demonstrates to be a bony exostosis associated with degenerative change of the underlying joint or an arthrosynovial cyst.

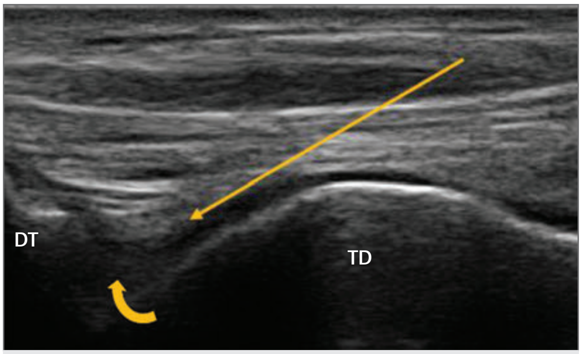

Fig. 13.2 Longitudinal image of the anterior ankle joint. The distal tibia (DT) may be seen to the left of the image and the talar dome (TD) to the right. The joint is demonstrated by the curved arrow. The straight line gives the needle direction. Curved arrow, ankle joint.

Table 13.2 Equipment needed for midtarsal joint injection

Syringe	Needle	Corticosteroid	Local anesthetic	Transducer
2 mL	23 gauge	20-mg Depo-Medrone	1-mL 1%	Linear or hockey stick

13.2.3 Equipment

See ▶Table 13.2.

13.2.4 Anatomical Considerations

There are several joints in the midtarsal region any one of which or a combination of which may be painful. The joint to be injected should be identified using both careful palpation of the region and ultrasound to identify the most symptomatic. Injection may be required at more than one joint and given on separate occasions can be a useful diagnostic tool.

13.2.5 Procedure

- The patient is positioned supine with the knee bent to approximately 90 degrees and the foot flat on the couch, placing the foot in a plantar flexed position allowing for easier needle entry into the joint identified as being the problem.
- The transducer is placed in the anatomical sagittal plane over the joint to be injected.
- The needle is introduced in the longitudinal plane of the transducer from an inferior to superior direction into the joint to be injected.
- Injection is given as a bolus.

13

13.2.6 The Injection

See ▶ Fig. 13.3 and ▶ Fig. 13.4.

13.2.7 Notes

Injection of the midtarsal joints can provide good symptomatic relief in patients with osteoarthritis of this region.

However, the patient's foot position should always be considered and corrected where possible with the appropriate supportive shoe and orthotic. This is also the case of the patient who presents with overuse problems in this area related for example to overpronation of the foot.

Fig. 13.3 Midtarsal joint injection (first metatarsal-cuneiform joint). The probe is placed in the anatomical sagittal plane over the joint to be injected. The needle is introduced in the longitudinal plane of the probe from an inferior to superior direction into the joint to be injected.

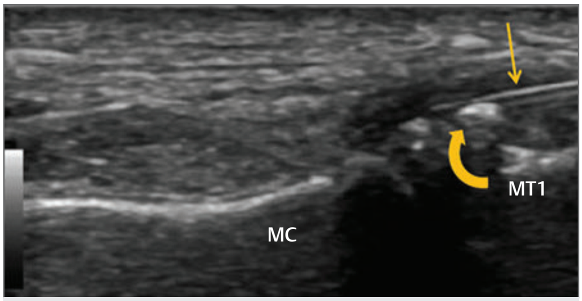

Fig. 13.4 Longitudinal image of the anterior aspect of the midfoot and first metatarsal-cuneiform joint. The base of the first metatarsal (MT1) may be seen to the right of the image with the medial cuneiform to the left (MC). The curved arrow demonstrates cortical irregularity in keeping with osteophytosis. The needle may be seen entering the joint from the left of the image (*straight arrow*). Curved arrow, osteophytosis at base of first metatarsal; straight arrow, needle.

13.3 Peroneal Tendon Sheath Injection

13.3.1 Cause

- Commonly overuse.
- May be related to an acute or chronic inversion injury of the ankle.

13.3.2 Presentation

- Pain is located over the lateral aspect of the ankle posterior and below the lateral malleolus.
- Pain may be reproduced with resisted eversion of the ankle and foot and end-range inversion and plantar flexion.

13.3.3 Equipment

See ▶ Table 13.3.

Table 13.3 Equipment needed for peroneal tendon sheath injection

Syringe	Needle	Corticosteroid	Local anesthetic	Transducer
5 or 10 mL	23 gauge	20-mg Depo-Medrone	2-mL 1% (± 20-mL normal saline)	Linear or hockey stick

13.3.4 Anatomical Considerations

The tendons of peroneus brevis and longus run together within a common synovial sheath behind and then below the lateral malleolus. They then divide at the peroneal tubercle on the lateral aspect of the calcaneum. The tendon of peroneus longus then passes under the foot while peroneus brevis continues laterally to insert onto the base of the fifth metatarsal.

The point at which the tendons divide is a useful entry point for the needle. Clinically, this division can be felt as a "V-shaped" fork between the tendons on the lateral aspect of the calcaneum.

13.3.5 Procedure

- The patient is positioned in side-lying with the symptomatic side uppermost.
- The transducer is placed in an oblique coronal plane longitudinally over the peroneal tendons below and posterior to the lateral malleolus.
- The needle is introduced in the longitudinal plane of the transducer from an anterior and inferior to posterior and superior direction into the space between the two tendons.
- Injection is given as a bolus.
- If the condition is acute and inflamed indicating a fairly acute tenosynovitis, the injection is given as a relatively low-volume bolus typically with 20-mg Depo-Medrone

and 2-mL 1% local anesthetic. However, if the condition is more chronic and if the ultrasound demonstrates significant synovial thickening within the peroneal sheath, a higher-volume injection may be given with 20-mg Depo-Medrone and 2-mL 1%local anesthetic and up to 20-mL normal saline. It is suggested that a connecting tube is used if this procedure is undertaken.

13.3.6 The Injection

See ▶Fig. 13.5 and ▶Fig. 13.6.

Fig. 13.5 Peroneal tendon sheath injection. The probe is placed in an oblique coronal plane longitudinally over the peroneal tendons below and posterior to the lateral malleolus. The needle is introduced in the longitudinal plane of the transducer from an anterior and inferior to posterior and superior direction into the space between the two tendons.

13.3.7 Notes

Careful consideration should be given to the foot position particularly in cases of chronic overuse. Occasionally, the peroneus brevis insertion onto the base of the fifth metatarsal is the problem and ultrasound of this area demonstrates an insertional tendinopathy. If this is the case, an injection may be given here using a fenestration technique.

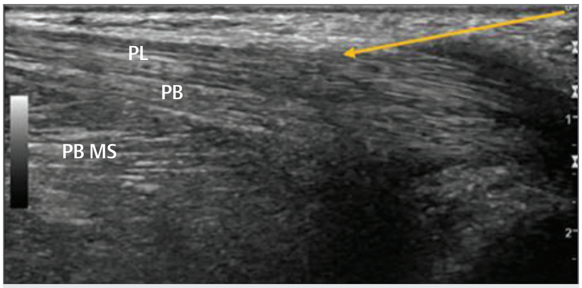

Fig. 13.6 Longitudinal image of the peroneal tendons around the posterior and inferior aspect of the lateral malleolus (LM). The peroneus brevis (PB) tendon may be seen laying deep to the peroneus longus (PL) tendon. The needle direction is given by the yellow arrow. PB MS, peroneus brevis muscle; straight arrow, needle direction.

13.4 Tibialis Posterior Injection

13.4.1 Cause

- Commonly overuse and related to overpronation of the foot in both the athlete and nonathlete.

13.4.2 Presentation

Pain is located around the medial aspect of the ankle posterior and below the medial malleolus. If the patient has an insertional tendinopathy, then the pain may be located at the medial aspect of the midfoot at the insertion of the tendon of tibialis posterior onto the medial aspect of the navicular and medial cuneiform. Pain may also be reproduced with resisted inversion of the foot.

13.4.3 Equipment

See ▶Table 13.4.

Table 13.4 Equipment needed for tibialis posterior injection

Syringe	Needle	Corticosteroid	Local anesthetic	Transducer
5 or 10 mL	23 gauge	20-mg Depo-Medrone	2-mL 1% (± 10-mL normal saline)	Linear or hockey stick

13.4.4 Anatomical Considerations

The tendon of tibialis posterior is the tendon positioned most anteriorly within the tarsal tunnel and is immediately behind the medial malleolus. Running directly behind tibialis posterior in the tarsal tunnel is the tendon of flexor digitorum longus. Moving further posteriorly is the neurovascular bundle consisting of the tibial nerve and posterior tibial artery and vein. Finally and most posteriorly the tendon of flexor hallucis longus can found as it runs between the medial and lateral posterior talar tubercles. This forms the so-called **T**om (tibialis posterior), **D**ick (flexor digitorum longus), and **H**arry (flexor hallucis longus) of the tarsal tunnel.

13.4.5 Procedure

- The patient is positioned in supine with the symptomatic leg externally rotated and the knee bent to 90 degrees. The lateral aspect of the ankle is supported on a pillow.
- The transducer is placed in the oblique coronal plane longitudinally over the tibialis tendon posterior to the medial malleolus.
- The needle is introduced in the longitudinal plane of the transducer from an inferior to superior direction so that it rests against the tendon.
- Injection is given as a bolus.

13

- If the condition is acute and inflamed indicating a fairly acute tenosynovitis, the injection is given as a relatively low-volume bolus typically with 20-mg Depo-Medrone and 2-mL 1% local anesthetic. However, if the condition is more chronic and if the ultrasound demonstrates significant synovial thickening within the tendon sheath, a higher-volume injection may be given with 20-mg Depomedrone and 2-mL 1%local anesthetic and up to 10-mL normal saline. It is suggested that a connecting tube is used if this procedure is undertaken.

13.4.6 The Injection

See ▶Fig. 13.7 and ▶Fig. 13.8.

13.4.7 Notes

Although a relatively acute tenosynovitis affecting the tibialis posterior tendon is possible, it is for more common for this tendon to be affected by significant tendinopathy. When this is the case, it is almost always associated with significant overpronation of the foot and flattening of the medial longitudinal arch. This results in the tendon being placed in a relatively overstretched position and without the bony support of a good medial arch the tendon is chronically overloaded. If this is the case, injection should only be considered once the patient is compliant with a program of rehabilitation and has also been assessed in regard to appropriate footwear including orthotic.

When significant tendinopathy is noted on ultrasound, care should be taken with regard to injection as the patient is potentially more at risk of tendon rupture. Indeed it may be worth immobilizing the ankle in a boot postinjection for 2 to 4 weeks to allow symptoms to settle prior to recommencing with rehabilitation.

Fig. 13.7 Tibialis posterior sheath injection. The probe is placed in the oblique coronal plane longitudinally over the tibialis tendon posterior to the medial malleolus. The needle is introduced in the longitudinal plane of the probe from an inferior to superior direction so that it rests against the tendon.

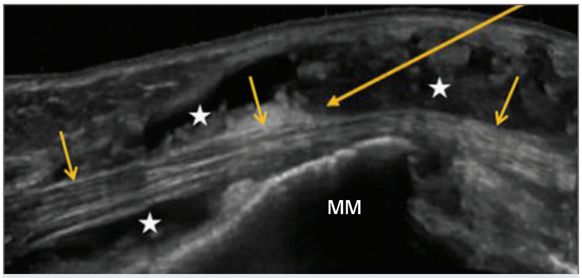

Fig. 13.8 Longitudinal image of the tendon of tibialis posterior (*short yellow arrows*) around the posterior and inferior aspect of the medial malleolus (MM). The image demonstrates a relatively intact tendon of tibialis posterior. However, marked tenosynovitis and associated synovial thickening is noted (*white stars*). The straight arrow demonstrates the direction of the needle. Long yellow arrow, direction of the needle; white stars, effusion and synovial thickening of tendon sheath.

13.5 Flexor Hallucis Longus Tendon Sheath Injection

13

13.5.1 Cause

- Often overuse and related to overpronation of the foot in both the athlete and nonathlete.
- Often associated with an os trigonum and posterior ankle impingement.

13.5.2 Presentation

- Pain is located around the posteromedial aspect of the ankle posterior to the medial malleolus.
- Pain may be reproduced with active flexion of the great toe.
- Pain may also be reproduced with passive extension of the great toe and dorsiflexion of the ankle.

13.5.3 Equipment

See ▶Table 13.5.

Table 13.5 Equipment needed for flexor hallucis longus tendon sheath injection

Syringe	Needle	Corticosteroid	Local anesthetic	Transducer
5 or 10 mL	23 gauge	20-mg Depo-Medrone	2-mL 1% (± 10-mL normal saline)	Linear or hockey stick

13.5.4 Anatomical Considerations

The tendon of flexor hallucis longus is the most posteriorly positioned tendon in the tarsal tunnel lying deep and slightly lateral to the posterior tibial artery and vein and tibial nerve. The tendon runs between the posterior medial and lateral talar tubercles which together form the posterior process of the talus.

The tarsal tunnel consists of the tendon of tibialis posterior which is the most anteriorly placed structure in the tunnel running immediately behind the medial malleolus. Running directly behind tibialis posterior in the tarsal tunnel is the tendon of flexor digitorum longus. Moving further posteriorly is the neurovascular bundle consisting of the tibial nerve and posterior tibial artery and vein. The tendon of flexor hallucis longus is deep and lateral to the neurovascular bundle. This forms the so-called **T**om (tibialis posterior), **D**ick (flexor digitorum longus), and **H**arry (flexor hallucis longus) of the tarsal tunnel.

13.5.5 Procedure

- The patient is positioned in prone with the foot hanging off the edge of the couch.
- The transducer is placed in the anatomical transverse plane over the Achilles tendon so that the tendon of flexor hallucis longus may be seen deep to the Achilles.
- The needle is introduced in the longitudinal plane of the transducer from a lateral to medial direction deep to the Achilles tendon aimed at the tendon of flexor hallucis longus. Injection is given as a bolus.
- If the condition is acute and inflamed indicating a fairly acute tenosynovitis, the injection is given as a relatively low-volume bolus typically with 25-mg Depo-Medrone and 2-mL 1% local anesthetic. However, if the condition is more chronic and if the ultrasound demonstrates significant synovial thickening within the tendon sheath, a higher-volume injection may be given with 20-mg Depo-Medrone and 2-mL 1%local anesthetic and up to 10-mL normal saline. It is suggested that a connecting tube is used if this procedure is undertaken.

13.5.6 The Injection

See ▶Fig. 13.9 and ▶Fig. 13.10.

13.5.7 Notes

Using a lateral approach deep to the Achilles tendon allows the needle to move toward the tendon of flexor hallucis longus from the opposite side to the neurovascular bundle. The needle passes safely though Kager's fat.

Care should be taken to inject deep to the Achilles to avoid the laterally positioned sural nerve.

Problems involving the tendon of flexor hallucis longus are often associated with an accessory os trigonum. This can be readily visualized with ultrasound as the calcific foci deep to the Achilles tendon at the posterior aspect of the ankle. If present, guided injection may still be of therapeutic benefit but also useful diagnostically if surgery is being considered to remove the accessory bone.

Fig. 13.9 Flexor hallucis longus tendon sheath injection. The probe is placed in the anatomical transverse plane over the Achilles tendon so that the tendon of flexor hallucis longus may be seen deep to the Achilles tendon. The needle is introduced in the longitudinal plane of the probe from a lateral to medial direction deep to the Achilles tendon aimed at the tendon of flexor hallucis longus tendon.

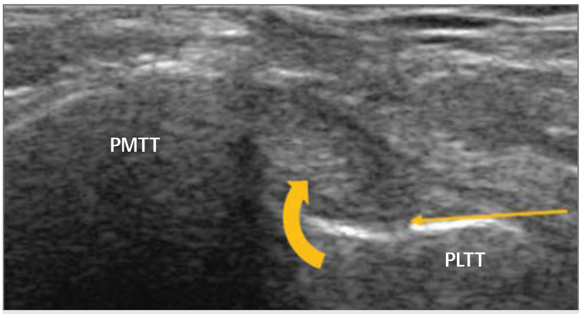

Fig. 13.10 Transverse image of the tendon of flexor hallucis longus. The tendon (*curved arrow*) may be seen within the groove formed by the posterior medial (PMTT) and posterior lateral talar tubercles (PLTT). The straight arrow demonstrates the direction of the needle. Curved arrow, flexor hallucis longus tendon.

13

13.6 Sinus Tarsi Injection

13.6.1 Cause

- May be related to a capsulitis posttrauma.
- Often overuse and related to overpronation of the foot in both the athlete and nonathlete.

13.6.2 Presentation

- Pain is located deep within the ankle joint and heel.
- A capsular restriction of the subtalar joint may be present with a gradually increasing limitation of passive adduction of the calcaneum.

13.6.3 Equipment

See ▶Table 13.6.

Table 13.6 Equipment needed for sinus tarsi injection

Syringe	Needle	Corticosteroid	Local anesthetic	Transducer
2 mL	23 gauge	20-mg Depo-Medrone	1-mL 1%	Linear or hockey stick

13.6.4 Anatomical Considerations

The sinus tarsi (talocalcaneal sulcus) is a tunnel between the talus and the calcaneus and forms part of the subtalar joint dividing the anterior talocalcaneonavicular joint and the posterior facet of the subtalar joint. The joint runs in an oblique direction from anterolateral to posteromedial.

13.6.5 Procedure

- The patient is positioned in supine with the knee bent to 90 degrees and the foot placed flat on the couch.
- The transducer is placed in the anatomical sagittal oblique plane over the sinus tarsi at its anterolateral opening.
- The needle is introduced in the longitudinal plane of the transducer from an anterolateral to a posteromedial direction below the inferior tibiofibular joint.
- The needle is advanced and the injection is given as a bolus.
- It is not possible to clearly see the needle but accuracy can be assured by movement of the overlying soft tissue as the needle passes into the sinus tarsi.

13.6.6 The Injection

See ▶Fig. 13.11 and ▶Fig. 13.12.

13.6.7 Notes

Although ultrasound can assist in the accuracy of injection of the sinus tarsi, it is not possible for ultrasound to give any practical information possible pathology. If further information is required, MRI is the imaging modality of choice.

If injection is being considered, it is important that the patient's foot position is first assessed and that any excessive pronation or lack of support is addressed prior to injection being given.

Fig. 13.11 Sinus tarsi injection. The probe is placed in the anatomical sagittal oblique plane over the sinus tarsi at its anterolateral opening. The needle is introduced in the longitudinal plane of the probe from an anterolateral to a posteromedial direction below the inferior tibiofibular joint.

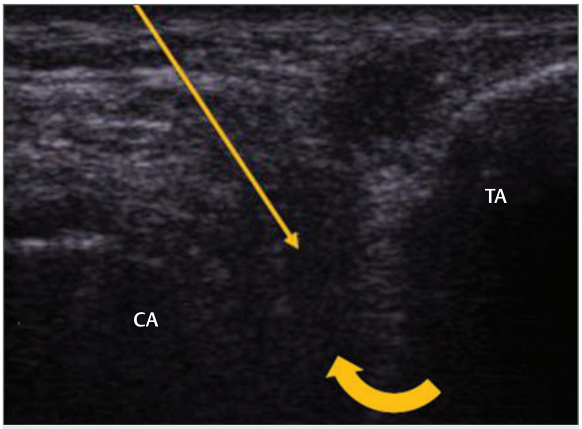

Fig. 13.12 Ultrasound image of the anterolateral opening of the sinus tarsi. The talus (TA) forms the roof of the sinus tarsi and the calcaneum (CA) the floor. The anterolateral opening of the sinus tarsi is shown by the curved arrow. The straight arrow demonstrates the direction of the needle.

13

13.7 Retrocalcaneal Bursa Injection

13.7.1 Cause

- Often related to overuse in such sporting activities which require repeated plantarflexion of the foot such as football and dance.
- This condition may also be related to an underlying inflammatory arthropathy.

13.7.2 Presentation

- Pain is located deep within the posterior aspect of the ankle.
- Pain may be reproduced with passive end-range plantarflexion and direct palpation of the area immediately deep to the Achilles tendon.

13.7.3 Equipment

See ▶Table 13.7.

Table 13.7 Equipment needed for retrocalcaneal bursa injection

Syringe	Needle	Corticosteroid	Local nesthetic	Transducer
2 mL	23 gauge	20-mg Depo-Medrone	1-mL 1%	Linear or hockey stick

13.7.4 Anatomical Considerations

The retrocalcaneal bursa lies deep to the Achilles tendon in the triangular-shaped space created by the anterior surface of the Achilles tendon and the posterior aspect of the distal tibia and upper calcaneus.

13.7.5 Procedure

- The patient is positioned in the prone position with the foot hanging over the edge of the couch at approximately 90 degrees.
- The transducer is placed in the anatomical transverse plane over the retrocalcaneal bursa immediately superior to the upper edge of the posterior calcaneum.
- The Achilles tendon is identified and the depth required to reach the bursa and avoid the tendon is noted.
- The needle is introduced in the longitudinal plane of the transducer from a lateral to medial direction below anterior to the Achilles tendon.
- The needle is advanced and the injection is given as a bolus.

13.7.6 The Injection

See ▶Fig. 13.13 and ▶Fig. 13.14.

13.7.7 Notes

Inflammation of the retrocalcaneal bursa is often associated with a degree of Achilles tendinopathy particularly when this occurs within the Achilles insertion onto the posterior calcaneum. If this is the case, a holistic approach is required with treatment being directed at both the bursa and the Achilles tendon.

In patients who present with a retrocalcaneal bursa with no clear mechanical cause, an underlying inflammatory arthropathy should be considered.

Fig. 13.13 Retrocalcaneal bursal injection. The probe is placed in the anatomical transverse plane over the Achilles tendon and retrocalcaneal bursa immediately superior to the upper edge of the posterior calcaneum. The Achilles tendon is identified and the depth required to reach the bursa and avoid the tendon is noted. The needle is introduced in the longitudinal plane of the transducer from a lateral to medial direction below anterior to the Achilles tendon.

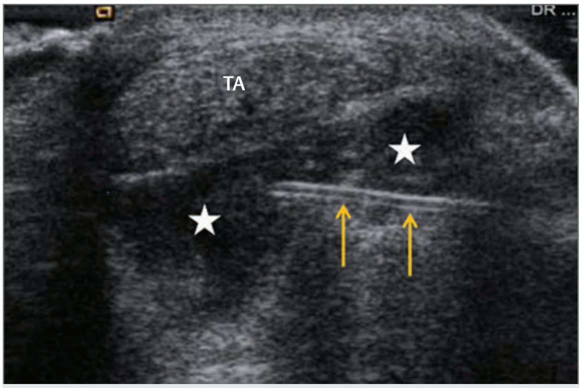

Fig. 13.14 Transverse image of the Achilles tendon (TA). In this image, there is a low echo region deep to the Achilles tendon representing a retrocalcaneal bursitis (*white stars*). The needle may be seen entering this region from the right side of the image (*straight arrows*).

13.8 Midsubstance Achilles Tendon: High-Volume Injection

13.8.1 Cause

Tendinopathy of the Achilles tendon is often related to overuse in sporting activities involving running and jumping. However, this is also a common presentation in those who partake of little exercise.

Pathology may occur within the midsubstance of the tendon or at its insertion onto the posterior aspect of the calcaneum. High-volume injection is a procedure which can be used for pathology within the midsubstance of the tendon.

13.8.2 Presentation

- Pain is located within the midthird of the tendon.
- There may be a visible swelling at the site of pain.
- Pain may be reproduced with active plantarflexion.

13.8.3 Equipment

See ▶Table 13.8.

Table 13.8 Equipment needed for midsubstance Achilles tendon: high-volume injection

Syringe	Needle	Corticosteroid	Local anesthetic	Transducer
10 mL (up to 5 syringes)	23 gauge 1.25 inch	20-mg Depo-Medrone	5-mL 1% (+ 40-mL normal saline)	Linear or hockey stick

The use of connecting tubing (Angiotech–Connecting Tube/LP OWS/Female–Male) allows the clinician to hold the needle in place under ultrasound guidance while an assistant provides the pressure necessary to administer the injection without direct pressure on the needle. The use of connecting tubing also allows the assistant to change syringes over without disturbing the needle position (▶Fig. 13.15, ▶Fig. 13.16).

13.8.4 Anatomical Considerations

A medial approach is used to avoid the sural nerve as it runs along the lateral aspect of the tendon.

It is important to ensure that the needle is placed immediately at the anterior surface of the Achilles tendon.

13.8.5 Procedure

- The patient is positioned in the prone position with the foot hanging over the edge of the couch at approximately 90 degrees.

Fig. 13.15 Syringes, connecting tubing, and 23-gauge needle ready for use.

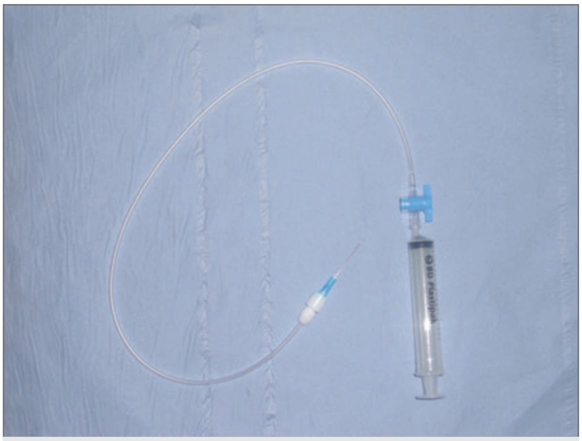

Fig. 13.16 Syringe connected to needle via flexible tubing.

- Four or five syringes are prepared. The first contains 20-mg Depo-Medrone and 5-mL 1% local anesthetic. The remaining three or four are each filled with 10-mL normal saline.
- The transducer is placed in the anatomical transverse plane over the site of maximum Achilles thickening.
- A needle is connected to the flexible tubing and introduced in the longitudinal plane of the transducer from a medial to lateral direction immediately deep to the Achilles tendon.
- The first syringe containing corticosteroid and local anesthetic is connected to the tubing and injected as a bolus.
- Following this the remaining syringes containing normal saline are connected sequentially to the tubing and injected as a bolus.
- In total, the injection consists of 20-mg Depo-Medrone, 5-mL 1% local anesthetic, and up to 40-mL normal saline (▶Fig. 13.17).

13.8.6 The High-Volume Injection

See ▶Fig. 13.18 and ▶Fig. 13.19.

Fig. 13.17 Midsubstance Achilles tendon high-volume injection. The patient is positioned in prone with the foot hanging over the edge of the couch at approximately 90 degrees. The probe is placed in the anatomical transverse plane over the site of maximum Achilles thickening and introduced in the longitudinal plane of the probe from a medial to lateral direction immediately deep to the Achilles tendon.

13.8.7 Notes

Postinjection, the patient is advised on relative rest for 3 days. During this time they are allowed to carry out gentle stretching but no excessive loading of the tendon. Following this 3-day period, the patient can restart a program of more vigorous eccentric loading for a further 3 days but no sport. Following this second period, the patient is allowed a gradual return to sport as pain allows.

Tendinopathy may be considered an ongoing pathological process which in many patients requires regular maintenance in the form of exercise. An injection should therefore be considered as part of an overall rehabilitation management plan. This should include correct stretching and strengthening and where appropriate evaluation of running style and footwear.

13.9 Plantar Fascia Injection

13.9.1 Cause

- Overuse associated with poor foot position and inadequate footwear.
- Idiopathic.

13.9.2 Presentation

- Pain is located inferior to the heel more often at the medial aspect.

Fig. 13.18 High-volume injection is being given. The first operator positions the needle under ultrasound guidance. The second operator connects the needles in order and delivers the injection.

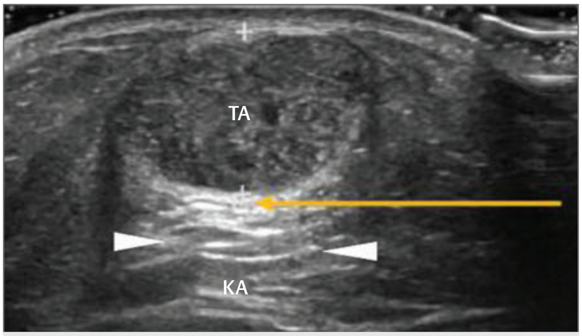

Fig. 13.19 Transverse image of the midsubstance of the Achilles tendon (TA). The tendon appears thickened (*caliper crosses*) and exhibits posterior enhancement (*arrowheads*) in keeping with a decreased density of tendon tissue as the result of tendinopathy. The straight arrow indicates the line of needle entry. Crosses, measurement calipers; KA, Kager's fat; straight arrow, direction of the needle.

- The patient usually describes pain on initial weight-bearing particularly first thing in the morning when getting out of bed.
- Pain may be reproduced with palpation of the fascia at the anterior medial calcaneal tubercle.

13.9.3 Equipment

See ▶Table 13.9.

Table 13.9 Equipment needed for plantar fascia injection

Syringe	Needle	Corticosteroid	Local anesthetic	Transducer
5 mL	23 gauge	20-mg Depo-Medrone	4-mL 1%	Linear

13

13.9.4 Anatomical Considerations

The plantar fascia arises from the anterior medial and lateral calcaneal tubercles on the inferior surface of the calcaneum. Pathology is always located at the medial tubercle. Calcaneal heel spurs may be noted on X-ray or ultrasound. However, although heel spurs appear to be associated with plantar fascia pain, they do not indicate any degree of severity. Indeed heel spurs are commonly present in the asymptomatic heel.

It should be noted that although this condition is commonly referred to as plantar fasciitis, there is no evidence of this being an inflammatory condition. Ultrasound demonstrates this well with marked thickening and loss of normal fascial architecture being noted in the symptomatic heel.

13.9.5 Procedure

- The patient is positioned in supine with the leg rotated externally and the knee best allowing the lateral aspect of the foot to rest on the couch.
- The transducer is placed in the anatomical transverse plane over the plantar fascia at its origin on the anteromedial calcaneal tubercle.
- The plantar fascia is identified and the depth required to reach the inferior surface is noted.
- The needle is introduced in the longitudinal plane of the transducer from a medial to lateral direction so that the needle tip lies superficially to the plantar fascia.
- Approximately 1 mL is injected superficially to the fascia at this point.
- Next, the needle is partially withdrawn and directed toward the deep surface of the plantar fascia so that it lies immediately adjacent to the undersurface of the calcaneum. The remainder of the injection is given here as a bolus.

13.9.6 The Injection

See ▶Fig. 13.20 and ▶Fig. 13.21a,b.

13.9.7 Notes

For this injection to be effective, it is essential that the patient is advised on correct stretching and if needed correct footwear including orthotics when necessary. It is suggested that the patient's foot is taped following the injection to off-load the fascia.

Although this can be a painful injection, using the medial approach outlined above is less painful than injecting directly through the heel pad and fascia. If the patient or clinician is still concerned about pain, a tibial nerve block may be performed.

Fig. 13.20 Plantar fascia injection. The probe is placed in the anatomical transverse plane over the plantar fascia at its origin on the anteromedial calcaneal tubercle. The needle is introduced in the longitudinal plane of the probe from a medial to lateral direction so that the needle tip lies superficially to the plantar fascia. Approximately 1 mL is injected superficially to the fascia at this point. Next, the needle is partially withdrawn and directed toward the deep surface of the plantar fascia so that it lies immediately adjacent to the undersurface of the calcaneum.

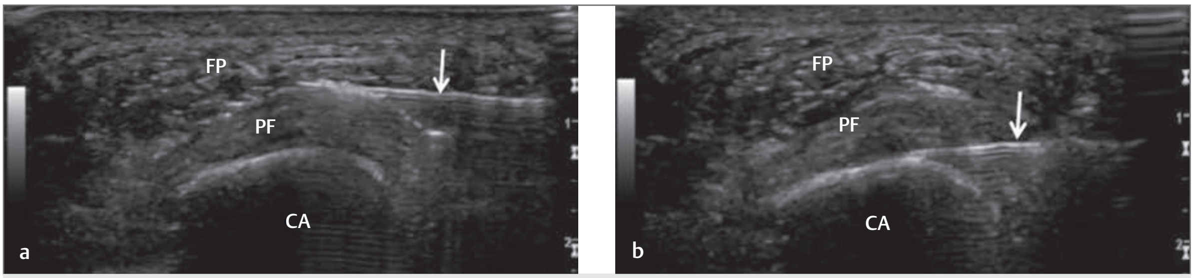

Fig. 13.21 (**a**) Transverse image of the plantar fascia (PF). The needle (*white arrow*) may be seen from the right side of the image laying immediately superficial to the fascia. (**b**) Transverse image of the plantar fascia (PF). The needle (*white arrow*) may be seen from the right side of the image laying immediately deep to the fascia. CA, calcaneum; FP, fat pad.

13.10 First Metatarsophalangeal Joint Injection

13.10.1 Cause

- Osteoarthritis often associated with a hallux valgus or a hallux rigidus.
- May be related to overuse or trauma.

13.10.2 Presentation

- Pain is located within the toe joint.
- There may be a capsular restriction with a painful limitation of flexion more than extension.

13.10.3 Equipment

See ▶Table 13.10.

Table 13.10 Equipment needed for first metatarsophalangeal joint injection

Syringe	Needle	Corticosteroid	Local anesthetic	Transducer
2 mL	25 gauge	10-mg Depo-Medrone	1-mL 1%	Hockey stick

13.10.4 Anatomical Considerations

The metacarpal head is more prominent superiorly than the base of the proximal phalanx. This facilitates needle entry into the joint from a distal to proximal direction.

In patients with pain located at the inferior surface of the first metacarpophalangeal joint attributable to the sesamoid bones, this injection may be of diagnostic and/or therapeutic benefit as it should be noted that these bones are intra-articular.

13.10.5 Procedure

- The patient is positioned in supine with the knee bent to 90 degrees and the foot resting flat on the couch.
- The transducer is placed in the anatomical sagittal plane over the metatarsophalangeal joint.
- The needle is introduced into the joint from distal to proximal direction.
- The injection is given as a bolus.

13.10.6 The Injection

See ▶Fig. 13.22 and ▶Fig. 13.23.

13.10.7 Notes

Injection of the metatarsophalangeal joint of the great toe can give long-lasting symptomatic relief even if the joint is significantly arthritic. A similar approach may be used for second to fifth metatarsophalangeal joints if required.

As an alternative to corticosteroid in the arthritic metatarsophalangeal joint, which exhibits little active inflammation injection of a hyaluronan, may also be considered. The approach would be the same.

Fig. 13.22 First metatarsophalangeal joint injection. The probe is placed in the anatomical sagittal plane over the metatarsophalangeal joint. The needle is introduced into the joint from a distal to proximal direction.

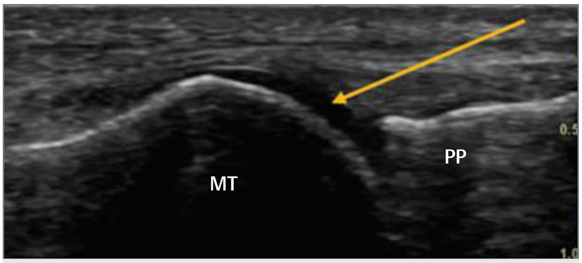

Fig. 13.23 Longitudinal image of the first metatarsophalangeal joint. The metatarsal head (MT) may be seen to the left of the image with the base of the proximal phalanx (PP) to the right. The straight arrow indicates the needle direction.

13

13.11 Morton's Neuroma Injection

13.11.1 Cause

- A benign neuroma of an intermetatarsal nerve.
- The exact cause is unknown, but it may be due to repetitive compression and subsequent irritation of the nerve between the metatarsal heads.

13.11.2 Presentation

- The patient may describe a burning pain, paresthesia, and numbness located between the affected toes.
- The second to third or third to fourth intermetatarsal spaces are most commonly affected.
- Pain is felt on weight-bearing.
- There may be a characteristic "Mulder's click" with transverse pressure of the metatarsal heads.

13.11.3 Equipment

See ▶Table 13.11.

13.11.4 Anatomical Considerations

A Morton's neuroma is normally situated deep between the metatarsal heads. As such it may be difficult to visualize on ultrasound. However, with the probe placed transversely over the plantar aspect of the metatarsal heads the clinician can apply a transverse pressure to the metatarsal heads which may result in the reproduction of a positive Mulder's click and movement of the neuroma in a plantar direction which may be seen as low echo foci. Imaging in an anatomical sagittal plane between the metatarsal heads can also outline the neuroma.

Table 13.11 Equipment needed for Morton's neuroma injection

Syringe	Needle	Corticosteroid	Local anesthetic	Transducer
2 mL	25 gauge	20-mg Depo-Medrone	1-mL 1%	Linear probe or hockey stick

Fig. 13.24 Morton's neuroma injection. The probe is placed in the anatomical coronal plane over the plantar aspect of the metatarsal heads with the interspace to be injected centrally placed on the screen. Gentle transverse pressure can be applied to cause the neuroma to move in a plantar direction. The needle is introduced between the relevant metatarsal heads from a superior to inferior direction so that it approached the probe directly.

13.11.5 Procedure

- The patient is positioned in supine with the leg and foot resting on the couch.
- The transducer is placed in the anatomical coronal plane over the plantar aspect of the metatarsal heads with the interspace to be injected centrally placed on the screen.
- The needle is introduced between the relevant metatarsal heads from a superior to inferior direction so that it approached the probe directly.
- Gentle transverse pressure can be applied to cause the neuroma to move in a plantar direction. The needle can then be seen to rest against the neuroma.
- The injection is given as a bolus so that the fluid can be seen to accumulate between the metatarsal heads deep to the neuroma.

13.11.6 The Injection

See ▶Fig. 13.24 and ▶Fig. 13.25.

13.11.7 Notes

Care should be taken not to inject too deeply. If this is the case, the fluid can be seen to collect within the superficial plantar tissue and the needle should be partially withdrawn.

One or two injections can be effective in alleviating symptoms in the longer term. If, however, the problem returns alternative treatment should be considered.

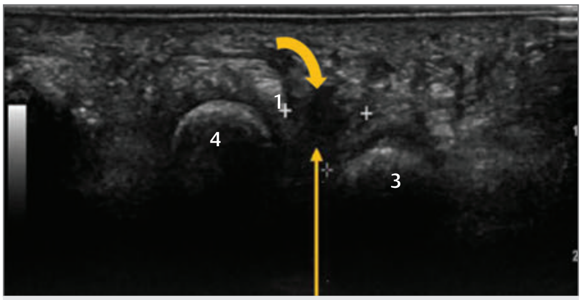

Fig. 13.25 Transverse image of the forefoot and metatarsal heads. The low eco foci (*curved arrow*) may be seen between the third and fourth metatarsal heads (3 and 4). In this example, a transverse pressure has been applied causing the neuroma to move in a plantar direction. The straight arrow indicates the direction of the needle. Curved arrow, neuroma; straight arrow, needle direction for injection; white crosses, measurement calipers.

References

[1] Al-Shawi A, Badge R, Bunker T. The detection of full thickness rotator cuff tears using ultrasound. J Bone Joint Surg Br. 2008; 90(7):889–892
[2] Aly A, Rajasekaran S, Ashworth N. Ultrasound guided shoulder girdle injections are more accurate and more effective than landmark guided injections: a systematic review and meta-analysis. 014. Downloaded from http://bjsm.bmj.com/on January 22, 2015—Published by group.bmj.com. BJSM Online First, published on November 17, 2014 as 10.1136/bjsports-2014–093573
[3] Arslan G, Apaydin A, Kabaalioglu A, Sindel T, Lüleci E. Sonographically detected subacromial/subdeltoid bursal effusion and biceps tendon sheath fluid: reliable signs of rotator cuff tear? J Clin Ultrasound. 1999; 27(6):335–339
[4] Aström M, Rausing A. Chronic Achilles tendinopathy. A survey of surgical and histopathologic findings. Clin Orthop Relat Res. 1995(316):151–164
[5] Backhaus M, Kamradt T, Sandrock D, et al. Arthritis of the finger joints: a comprehensive approach comparing conventional radiography, scintigraphy, ultrasound, and contrast-enhanced magnetic resonance imaging. Arthritis Rheum. 1999; 42(6):1232–1245
[6] Backhaus M, Burmester G-R, Gerber T, et al; Working Group for Musculoskeletal Ultrasound in the EULAR Standing Committee on International Clinical Studies including Therapeutic Trials. Guidelines for musculoskeletal ultrasound in rheumatology. Ann Rheum Dis. 2001; 60(7):641–649
[7] Balint P, Sturrock RD. Musculoskeletal ultrasound imaging: a new diagnostic tool for the rheumatologist? Br J Rheumatol. 1997; 36(11):1141–1142
[8] Bianchi S, Martinoli C, Abdelwahab IF, Derchi LE, Damiani S. Sonographic evaluation of tears of the gastrocnemius medial head (“tennis leg”) J Ultrasound Med. 1998; 17(3):157–162
[9] Bouffard JA, Lee S-M, Dhanju J. Ultrasonography of the shoulder. Semin Ultrasound CT MR. 2000; 21(3):164–191
[10] Ellis JRC, T, e, h JL, Scott PM. Ultrasound of tendons. Imaging. 2002; 14:223–228
[11] Eustace JA, Brophy DP, Gibney RP, Bresnihan B, FitzGerald O. Comparison of the accuracy of steroid placement with clinical outcome in patients with shoulder symptoms. Ann Rheum Dis. 1997; 56(1):59–63
[12] Fenwick SA, Hazleman BL, Harrall RL, et al. Transforming growth factor-β isoform expression in chronic Achilles tendinopathy and their effects on tendon cell populations. Int J Exp Pathol. 2000; 81:A11–A12
[13] Fong G, Backman LJ, Hart DA, Danielson P, McCormack B, Scott A. Substance P enhances collagen remodeling and MMP-3 expression by human tenocytes. J Orthop Res. 2013; 31(1):91–98
[14] Garrett NE, Mapp PI, Cruwys SC, Kidd BL, Blake DR. Role of substance P in inflammatory arthritis. Ann Rheum Dis. 1992; 51(8):1014–1018
[15] Ghozlan R, Vacher H. Where is imaging going in rheumatology? Best Pract Res Clin Rheumatol. 2000; 14(4):617–633
[16] Gotoh M, Hamada K, Yamakawa H, Tomonaga A, Inoue A, Fukuda H. Significance of granulation tissue in torn supraspinatus insertions: an immunohistochemical study with antibodies against interleukin-1 beta, cathepsin D, and matrix metalloprotease-1. J Orthop Res. 1997; 15(1):33–39
[17] Gotoh M, Hamada K, Yamakawa H, Inoue A, Fukuda H. Increased substance P in subacromial bursa and shoulder pain in rotator cuff diseases. J Orthop Res. 1998; 16(5):618–621
[18] Grassi W, Filippucci E, Farina A, Cervini C. Sonographic imaging of tendons. Arthritis Rheum. 2000; 43(5):969–976
[19] Grassi W, Filippucci E, Farina A, Salaffi F, Cervini C. Ultrasonography in the evaluation of bone erosions. Ann Rheum Dis. 2001; 60(2):98–103
[20] Grassi W, Filippucci E, Busilacchi P. Musculoskeletal ultrasound. Best Pract Res Clin Rheumatol. 2004; 18(6):813–826
[21] Hashimoto T, Nobuhara K, Hamada T. Pathologic evidence of degeneration as a primary cause of rotator cuff tear. Clin Orthop Relat Res. 2003(415):111–120
[22] Hermann KG, Backhaus M, Schneider U, et al. Rheumatoid arthritis of the shoulder joint: comparison of conventional radiography, ultrasound, and dynamic contrast-enhanced magnetic resonance imaging. Arthritis Rheum. 2003; 48(12):3338–3349
[23] Hobson-Webb LD, Massey JM, Juel VC, Sanders DB. The ultrasonographic wrist-to-forearm median nerve area ratio in carpal tunnel syndrome. Clin Neurophysiol. 2008; 119(6):1353–1357
[24] de Jesus JO, Parker L, Frangos AJ, Nazarian LN. Accuracy of MRI, MR arthrography, and ultrasound in the diagnosis of rotator cuff tears: a meta-analysis. AJR Am J Roentgenol. 2009; 192(6):1701–1707
[25] Kannus P. Structure of the tendon connective tissue. Scand J Med Sci Sports. 2000; 10(6):312–320
[26] Karim Z, Wakefield RJ, Quinn M, et al. Validation and reproducibility of ultrasonography in the detection of synovitis in the knee: a comparison with arthroscopy and clinical examination. Arthritis Rheum. 2004; 50(2):387–394
[27] Khan KM, Maffulli N, Coleman BD, Cook JL, Taunton JE. Patellar tendinopathy: some aspects of basic science and clinical management. Br J Sports Med. 1998; 32(4):346–355
[28] Khan KM, Cook JL, Bonar F, Harcourt P, Astrom M. Histopathology of common tendinopathies. Update and implications for clinical management. Sports Med. 1999; 27(6):393–408
[29] Khan MH, Li Z, Wang JH. Repeated exposure of tendon to prostaglandin-E2 leads to localized tendon degeneration. Clin J Sport Med. 2005; 15(1):27–33
[30] Klauser AS, Halpern EJ, De Zordo T, et al. Carpal tunnel syndrome assessment with US: value of additional cross-sectional area measurements of the median nerve in patients versus healthy volunteers. Radiology. 2009; 250(1):171–177
[31] Koski JM, Anttila P, Hämäläinen M, Isomäki H. Hip joint ultrasonography: correlation with intra-articular effusion and synovitis. Br J Rheumatol. 1990; 29(3):189–192
[32] Koski JM. Ultrasound guided injections in rheumatology. J Rheumatol. 2000; 27(9):2131–2138
[33] Legerlotz K, Jones ER, Screen HR, Riley GP. Increased expression of IL-6 family members in tendon pathology. Rheumatology (Oxford). 2012; 51(7):1161–1165
[34] Leopold SS, Battista V, Oliverio JA. Safety and efficacy of intraarticular hip injection using anatomic landmarks. Clin Orthop Relat Res. 2001(391):192–197
[35] Levin D, Nazarian LN, Miller TT, et al. Lateral epicondylitis of the elbow. Radiology. 2005; 237(1):230–234
[36] Maffulli N, Barrass V, Ewen SW. Light microscopic histology of Achilles tendon ruptures. A comparison with unruptured tendons. Am J Sports Med. 2000; 28(6):857–863
[37] Maffulli N, Wong J, Almekinders LC. Types and epidemiology of tendinopathy. Clin Sports Med. 2003; 22(4):675–692
[38] Mallouhi A, Pülzl P, Trieb T, Piza H, Bodner G. Predictors of carpal tunnel syndrome: accuracy of gray-scale and color Doppler sonography. AJR Am J Roentgenol. 2006; 186(5):1240–1245
[39] Movin T, Gad A, Reinholt FP, Rolf C. Tendon pathology in long-standing achillodynia. Biopsy findings in 40 patients. Acta Orthop Scand. 1997; 68(2):170–175
[40] Ollivierre CO, Nirschl RP. Tennis elbow. Current concepts of treatment and rehabilitation. Sports Med. 1996; 22(2):133–139
[41] Ostlere S. Imaging the shoulder. Imaging. 2003; 15:162–173
[42] Peetrons P. Ultrasound of muscles. Eur Radiol. 2002; 12(1):35–43
[43] Potter HG, Hannafin JA, Morwessel RM, DiCarlo EF, O'Brien SJ, Altchek DW. Lateral epicondylitis: correlation of MR imaging, surgical, and histopathologic findings. Radiology. 1995; 196(1):43–46
[44] Schubert TE, Weidler C, Lerch K, Hofstädter F, Straub RH. Achilles tendinosis is associated with sprouting of substance P positive nerve fibres. Ann Rheum Dis. 2005; 64(7):1083–1086
[45] Shirtley GS. Musculoskeletal ultrasound: its current use and its place in the ADF. ADF Health. 1999; 1(25):33–41
[46] Silvestri E, Martinoli C, Derchi LE, Bertolotto M, Chiaramondia M, Rosenberg I. Echotexture of peripheral nerves: correlation

between US and histologic findings and criteria to differentiate tendons. Radiology. 1995; 197(1):291–296

[47] Sullo A, Maffulli N, Capasso G, Testa V. The effects of prolonged peritendinous administration of PGE1 to the rat Achilles tendon: a possible animal model of chronic Achilles tendinopathy. J Orthop Sci. 2001; 6(4):349–357

[48] Swen WAA, Jacobs JWG, Bussemaker FEAM, de Waard J-WD, Bijlsma JWJ. Carpal tunnel sonography by the rheumatologist versus nerve conduction study by the neurologist. J Rheumatol. 2001; 28(1):62–69

[49] Takebayashi S, Takasawa H, Banzai Y, et al. Sonographic findings in muscle strain injury: clinical and MR imaging correlation. J Ultrasound Med. 1995; 14(12):899–905

[50] Tan AL, Wakefield RJ, Conaghan PG, Emery P, McGonagle D. Imaging of the musculoskeletal system: magnetic resonance imaging, ultrasonography and computed tomography. Best Pract Res Clin Rheumatol. 2003; 17(3):513–528

[51] Teefey SA, Rubin DA, Middleton WD, Hildebolt CF, Leibold RA, Yamaguchi K. Detection and quantification of rotator cuff tears. Comparison of ultrasonographic, magnetic resonance imaging, and arthroscopic findings in seventy-one consecutive cases. J Bone Joint Surg Am. 2004; 86-A(4):708–716

[52] Wakefield RJ, Gibbon WW, Emery P. The current status of ultrasonography in rheumatology. Rheumatology (Oxford). 1999; 38(3):195–198

[53] Wakefield RJ, Gibbon WW, Conaghan PG, et al. The value of sonography in the detection of bone erosions in patients with rheumatoid arthritis: a comparison with conventional radiography. Arthritis Rheum. 2000; 43(12):2762–2770

[54] Weidner S, Kellner W, Kellner H. Interventional radiology and the musculoskeletal system. Best Pract Res Clin Rheumatol. 2004; 18(6):945–956

[55] Zanetti M, Metzdorf A, Kundert HP, et al. Achilles tendons: clinical relevance of neovascularization diagnosed with power Doppler US. Radiology. 2003; 227(2):556–560

[56] Zhang J, Wang JH. Production of PGE(2) increases in tendons subjected to repetitive mechanical loading and induces differentiation of tendon stem cells into non-tenocytes. J Orthop Res. 2010; 28(2):198–203

[57] Zingas C, Failla JM, Van Holsbeeck M. Injection accuracy and clinical relief of de Quervains tendinitis. J Hand Surg Am. 1998; 23(1):89–96

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