Musculoskeletal Ultrasound

Author(s)	Beggs, Ian
Imprint	Lippincott Williams & Wilkins, 2014
ISBN	9781451144987, 1451144989
Permalink	https://books-scholarsportal-info.myaccess.library.utoronto.ca/en/xml/chapter?id=/ebooks/ebooks1/lww/2014-07-29/1/01762492&chapterId=B01762492-C7

Chapter 7

Knee

David Connell
Guilio Comin

INTRODUCTION

Ultrasound (US) is frequently used to guide percutaneous intervention in and around the knee joint and for the diagnosis of juxta-articular tendinopathies. Beyond this, some may consider ultrasound of the knee to be rather limited, with little else to contribute. Magnetic resonance imaging (MRI) is often favored as a multi-purpose tool for the evaluation of the knee, allowing an overall inspection of structures in and around the joint. However, ultrasound is often superior to MRI for the assessment of superficial structures such as tendons and is surprisingly capable for the assessment of deeper structures. As technology and operator experience have improved, the scope and application of diagnostic ultrasound have enlarged. Its utility has been demonstrated for the assessment of cartilage degeneration,[1],[2],[3] chondrocalcinosis,[4] anterior cruciate ligament rupture,[5] meniscal injuries,[6],[7] impingement by intra-articular plicae,[8] “snapping” syndromes,[9] and other intra-articular pathology that are often considered the exclusive domain of MRI. Ultrasound has a major advantage over MRI when there has been a knee joint replacement, which usually results in substantial artifact, and has proven utility in diagnosis of postoperative complaints such as fibrous impingement[10] and prosthetic loosening.[11]

Aside from its capability in tendon imaging due to excellent near-field spatial resolution and useful technical applications such as color Doppler and elastography, the main advantages of ultrasound are the ability to perform focussed examinations at sites of interest, during dynamic movement, and in varying positions.

CLINICAL ASSESSMENT

Ultrasound of the knee is predicated on targeted and dynamic scanning. When performed without consideration for the clinical features, this advantage is lost and ultrasound becomes less fruitful. Clinical assessment is an integral component of ultrasound examination of the knee and commences before meeting the patient, with an evaluation of the patient’s age. Children, young adults, and old adults are more likely to present with some specific pathologies than others. For example, anterior knee pain in a young child raises suspicion of Osgood-Schlatter disease, in an older child or a young adult of patellar tendinopathy, in a middle-aged adult of fat pad impingement or plica syndromes, and in an older adult of patellofemoral osteoarthritis. The patient’s stance and gait on entering the examination room give useful cues to the site and severity of pathology before any words have been spoken.

History Taking

The patient should be asked to recount current symptoms and concerns, recent and previous injuries, and previous surgery, and should be given time to do so without prompting or interruption, as valuable information can be brought to light that would otherwise be missed. The most important information to be gleaned includes:

- Acute injury versus gradual development.
- The nature of the injury or the activity(ies) that led to symptom development.
- The type of symptom: pain, swelling, locking or snapping, stiffness, etc.
- Region of symptoms. This can be grossly characterized as anterior, posterior, lateral, or medial, but patients are often able to localize pain with a fingertip, particularly in tendinopathies.
- Exacerbating and relieving factors.
- When pain is the predominant symptom, the type of pain: dull, sharp, burning, vague, etc.
- The patient’s physical abilities and requirements: the type and “seriousness” of any sports played, the nature of their work, etc.
- History of surgery and/or prior treatments.

Physical Examination

This should be performed in the ultrasound room with the lights fully up to permit proper observation of sometimes subtle clinical findings such as swelling, redness, bruising, surgical scars, or muscle wasting. Palpation should be performed for confirmation of tenderness or lump. It is often useful to mark regions of interest with a pen. The dynamic part of the clinical examination is usually best done with the ultrasound probe. A number of tests have

P. 127

been described and validated. An in-depth discussion of their technique is beyond the scope of this chapter, but it may help sonologists to learn some of the more frequently used ones such as Apley, patella apprehension, Lachman, and anterior and posterior drawer tests.

Clinical Correlation

Perhaps the most important reason for ensuring that a good history and examination have been performed is to allow a final consideration of the ultrasound findings in light of the clinical presentation. Do the ultrasound abnormalities explain all of the patient’s symptoms? If so, is the severity of the symptoms concordant with the severity of the ultrasound abnormality? If not, further investigation is required, perhaps with a different imaging modality, such as radiography or MRI, especially if there is suspicion of meniscal, bony, or chondral pathology.

ANATOMY

As ultrasound technology has improved, the anatomical knowledge required to perform and interpret ultrasound of the knee has increased. In the 1980s ultrasound involved a comparatively crude visualization of the juxta-articular tendons and assessment for joint effusion or Baker cyst. Current scanners allow visualization and characterization of intra-articular structures such as meniscus and cartilage, discrimination of tendons and capsule into component parts, and identification of fine nerve and vessel branches.

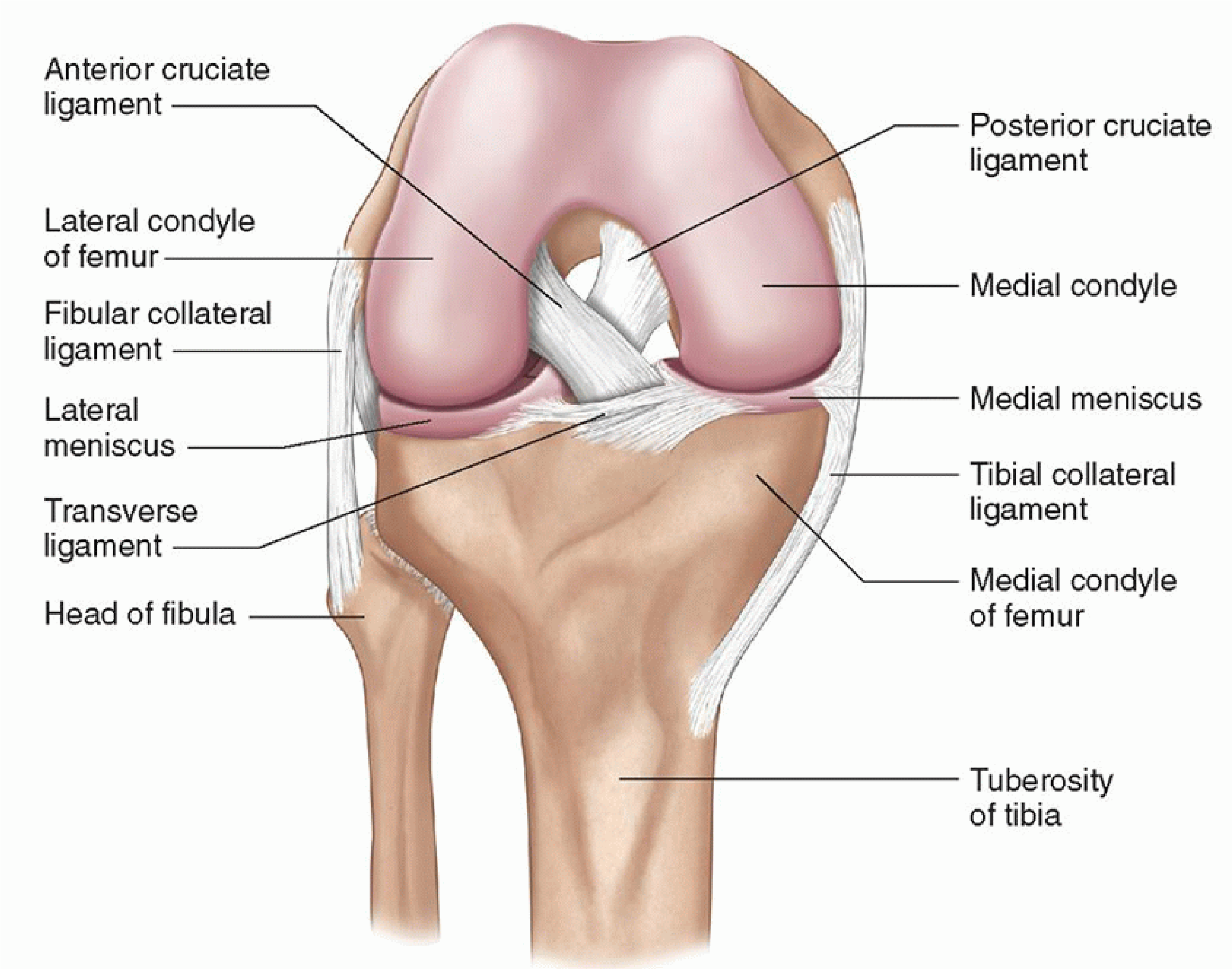

Figure 7.1. Deep dissection diagram of the anterior knee demonstrating the articular surfaces and the menisci.

As knowledge of knee mechanics and pathology has improved, there has been renewed interest in once obscure anatomical details, such as the vastus medialis insertion or the posterolateral capsular structures. The sonologist requires a wider and more intricate awareness of the normal location, function, and appearance of these structures.

Although a full description of this anatomy would require much more space than is available here, we will attempt to provide an overview and highlight the clinically and sonographically important points by breaking the anatomy down into its constituent parts:

Bone: Bone edges, periosteum, and tendon and ligament insertions.

Joint: Articular cartilage, meniscus and joint fluid.

Ligaments and Capsule

Tendons and Muscle

Bursae

Fat and fibrous layers

Nerves

Vessels

Bones

There are four or five bones at the knee joint: Femur, tibia, fibula, patella, and the inconsistently present fabella. The tibia and femur articulate at two surfaces or compartments: the medial femoral condyle with the medial tibial plateau, and the lateral femoral condyle with the lateral tibial plateau (Figs. 7.1 and 7.2). The medial articulation provides flexion and extension, while the

P. 128

lateral articulation additionally provides some rotation and anterior/posterior translation.

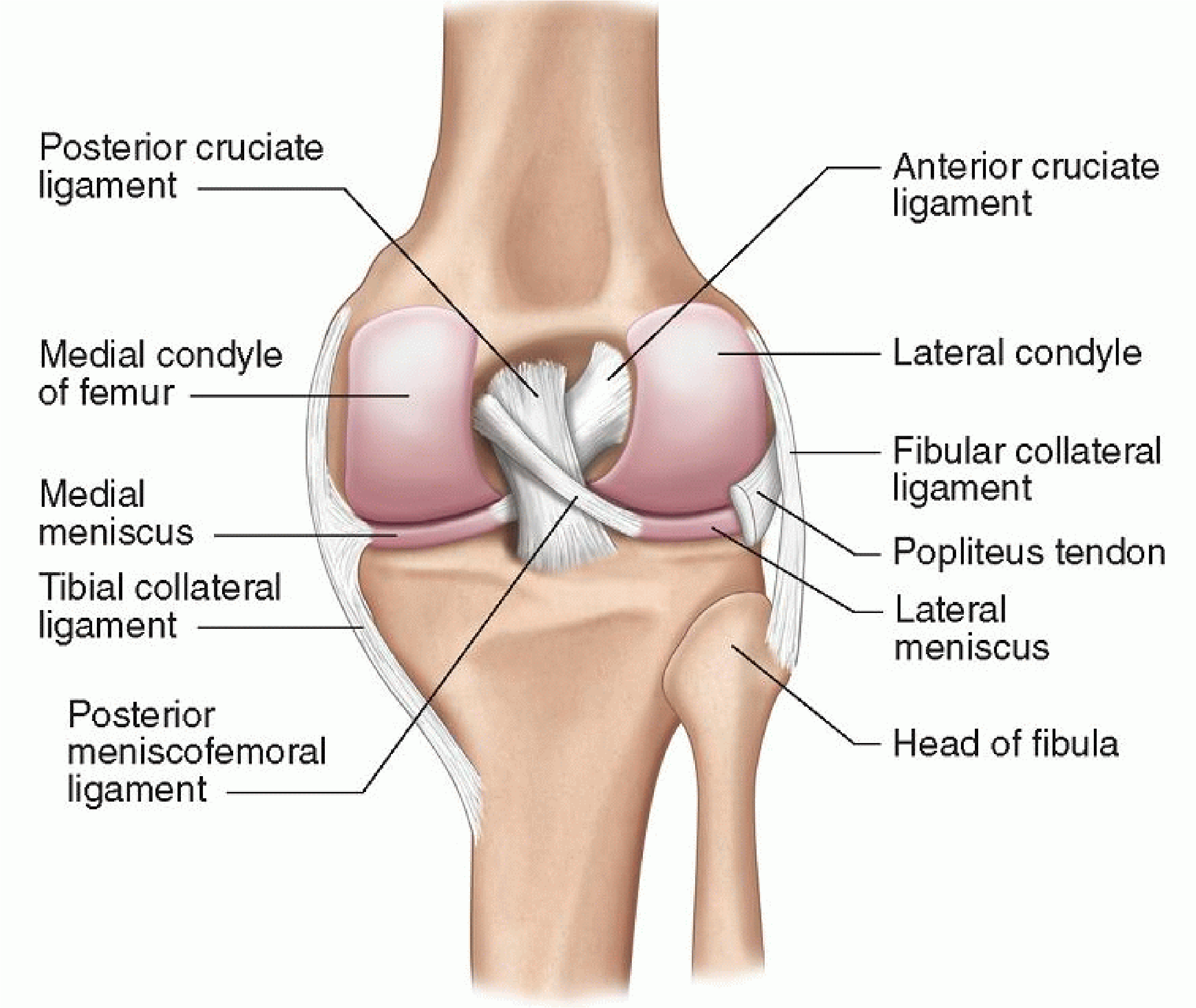

Figure 7.2. Deep dissection diagram of the posterior knee demonstrating the articular surfaces and the menisci.

The patella articulates with the trochlea of the femur, a V-shaped groove, with medial and lateral facets of variable inclination that articulate with the medial and lateral patellar facets, respectively. A third and small "odd" patellar facet lies most medially and only articulates with the trochlea beyond 90 degrees of flexion.[12]

A bipartite (or tripartite) patella is a variant that results from failure of fusion of an accessory ossification center(s) with the remainder of the patella (Fig. 7.3). It occurs in 2% of the population, is more common in males than in females,[13] and is typically, but not always, superolaterally located. As well as potentially being mistaken for a fracture, a bipartite patella occasionally becomes symptomatic when the fibrous union between the ossified parts is placed under stress. The so-called "dorsal defect of the patella" is a similar but incomplete bony defect in a superolateral position; it is unclear whether this is a related forme fruste of bipartite patella or an acquired lesion.

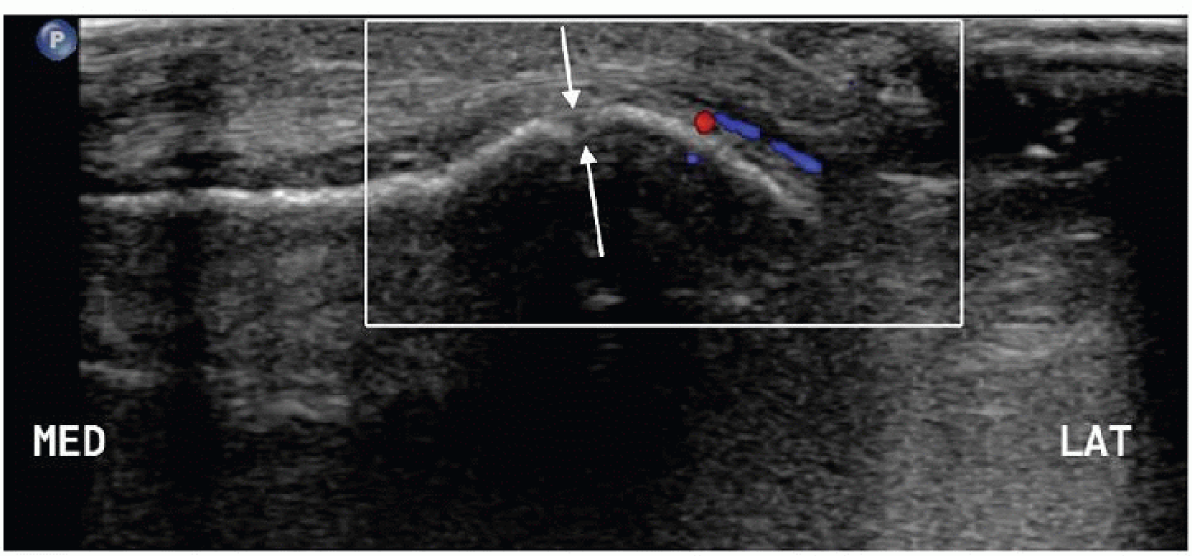

Figure 7.3. Transverse ultrasound image of the patella demonstrating a bipartite patella (arrows).

The base of the lateral tibial plateau articulates with the medial fibular head to form the proximal tibiofibular joint.
The fabella is a sesamoid bone that lies posteriorly, usually laterally, occasionally medially, and has a synovial articulation with the posterior femoral condyle. It is found, in varying states of ossification, in up to two-thirds of subjects,[14] and has a potentially important role in stabilization of the posterior (and particularly posterolateral) capsule. When lateral, it has a complex relationship with the lateral gastrocnemius (Fig. 7.4) and plantaris tendons, and the oblique popliteal, arcuate, and fabellofibular ligaments (see below).
Bony prominences around the knee joint that are important and reliable landmarks for tendon insertion include the tibial tuberosity (for the patellar tendon) and Gerdy tubercle (for the iliotibial band [ITB]).
Joints
There are three consistent and distinct articulations at the knee. The largest are the tibiofemoral joint, which is further divided into medial and lateral compartments, and the patellofemoral joint. They share a common synovial cavity. Their articular surfaces are covered by hyaline cartilage of varying thickness. The medial and lateral menisci are interposed between the respective tibiofemoral articular surfaces. Menisci are fibrocartilaginous structures and act as shock absorbers and distributors of force, helping to maintain stability of the joint. They are attached centrally to the tibia by their anterior and posterior roots, as well as peripherally to the capsule. (Figs. 7.1 and 7.2)

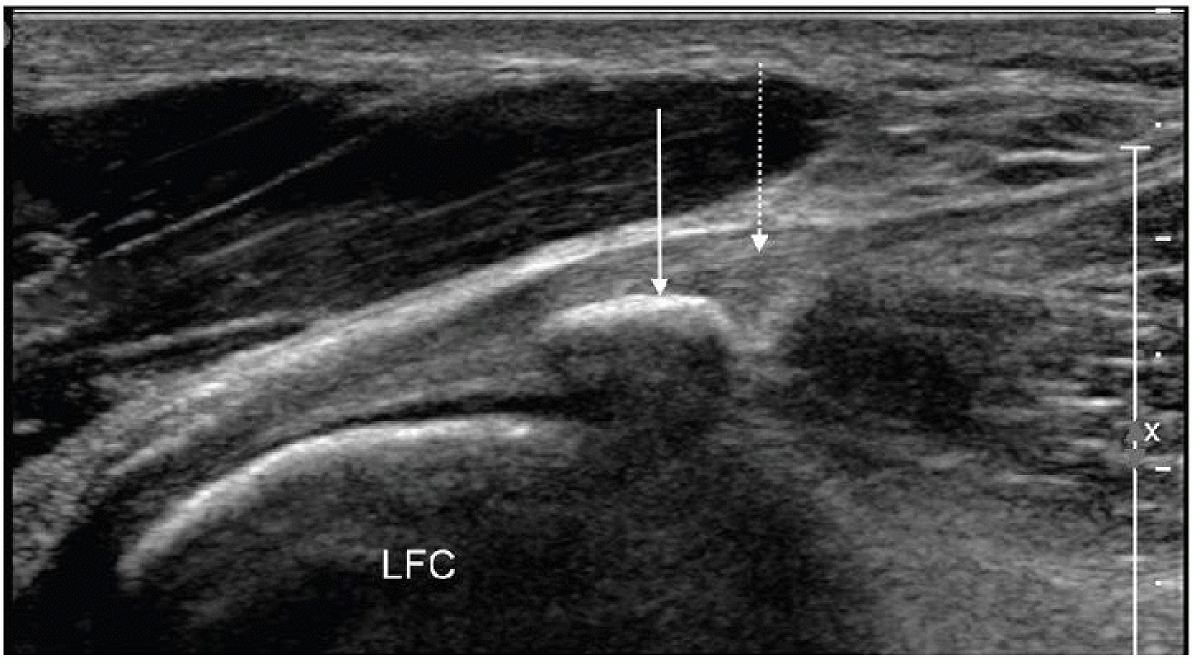

Figure 7.4. Longitudinal ultrasound image of the posterolateral capsule demonstrating the lateral gastrocnemius tendon with fabella (arrow). Lateral gastrocnemius tendon (dashed arrow).
P. 129

Plicae are folds of synovium within the knee joint. They are remnants of embryological structures and have three common locations in the knee:

- Infrapatellar (ligamentum mucosum): Running obliquely in the intercondylar notch, in front of the anterior cruciate ligament (ACL).
- Suprapatellar: Running vertically in the suprapatellar recess.
- Mediopatellar: Running vertically at the medial aspect of the knee joint. When large, its free border can extend into the medial aspect of the patellofemoral joint, potentially resulting in symptomatic irritation.

The proximal tibiofibular joint is a separate, small joint and has its own synovial lining and hyaline cartilage surfaces.
Ligaments
The ligaments of the knee are classified as intra-articular or capsular.
The intra-articular ligaments are the cruciate ligaments and the variably present and thick meniscal and meniscofemoral ligaments.
The ACL originates from the posterolateral wall of the intercondylar notch and passes caudally, anteriorly, and medially to insert on the anterior tibial plateau, in front of the tibial spine (Figs. 7.1 and 7.2). It has two principal components, named for their position at the tibial insertion: The larger posterolateral bundle and the smaller anteromedial bundle. The former resists anterior translation in extension, and the latter resists anterior translation in flexion.

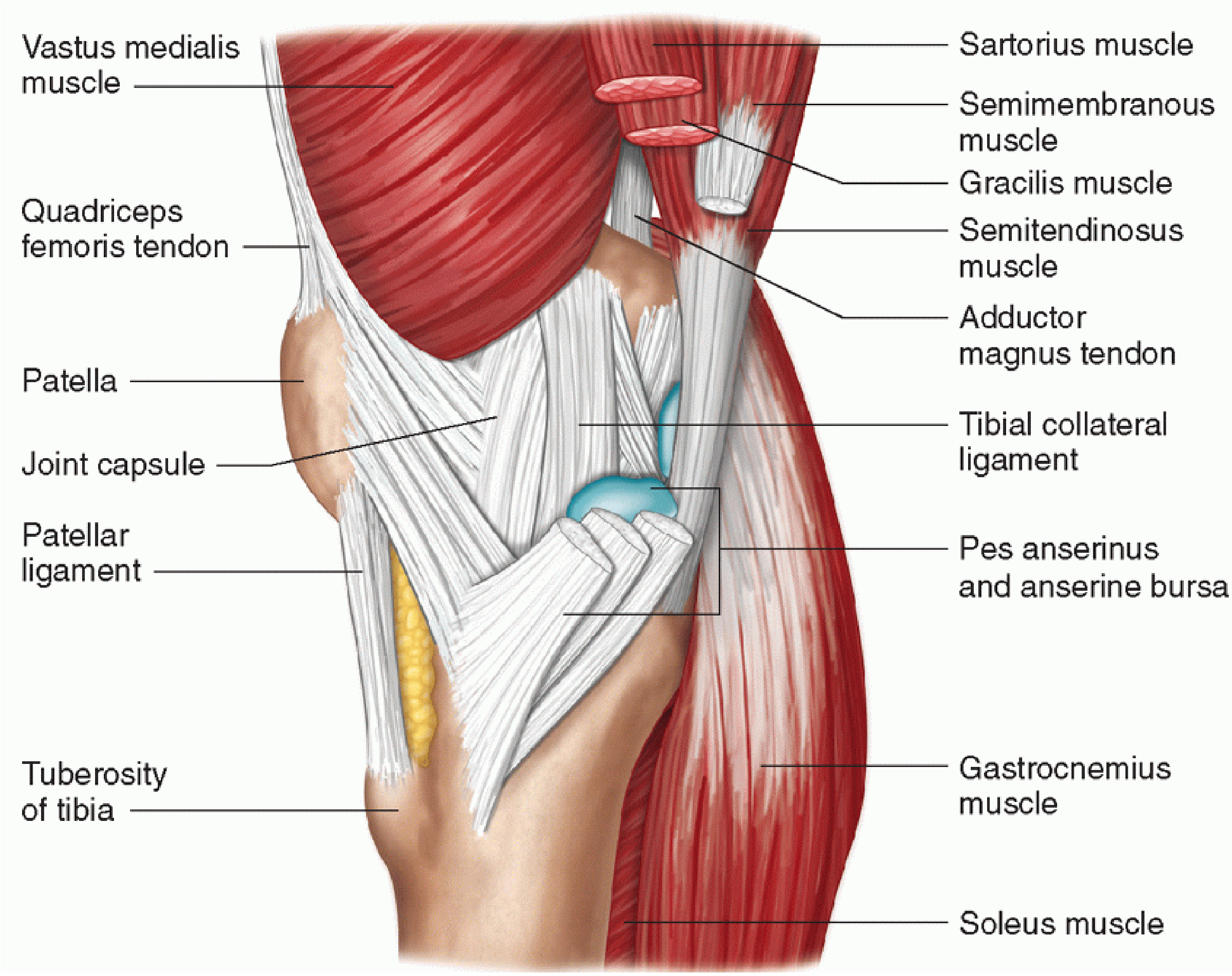

Figure 7.5. Superficial dissection diagram of the medial knee showing ligaments and bursa.

The posterior cruciate ligament (PCL) arises from the anteromedial wall of the intercondylar notch and passes caudally, posteriorly, and laterally to insert on the posterior aspect of the tibia, inferior to the tibial plateau (Figs. 7.1 and 7.2). It has two principal components: The larger anterolateral bundle and the smaller posteromedial bundle. The former resists posterior translation in flexion, and the latter resists posterior translation in extension.

The most anatomically consistent meniscal ligament is the transverse or meniscomeniscal ligament or intermeniscal ligament. The other meniscomeniscal ligaments are the posterior transverse ligament, connecting the posterior horns of the menisci, and the medial and lateral oblique ligaments, connecting the anterior and posterior horns. The meniscofemoral ligaments run from the posterior horn of the lateral meniscus to the posterolateral aspect of the medial femoral condyle, the ligament of Wrisberg posterior to the PCL and the ligament of Humphrey anterior to the PCL. There is no literature regarding ultrasound assessment of these structures, and they are not currently considered particularly clinically significant.

The capsular ligaments are focal condensations of the joint capsule and adjacent tissues. The largest are the medial and lateral collateral ligaments. They are thin elongated structures, are well defined, and have a lamellar appearance. The medial or tibial collateral ligament (MCL) arises from the medial femoral condyle and runs to insert on the medial edge of the tibia, well below the joint line (Fig. 7.5). It acts as a restraint to valgus angulation and external rotation. It is a discrete structure on ultrasound but blends imperceptibly at its anterior and

P. 130

posterior borders with the adjacent superficial capsule. The superficial capsule at the anterior edge is composed of fibers from the MCL, fibers from the pes anserinus tendons (described below) and the so-called "crural" fascia. The superficial capsule at the posterior edge is composed of fibers from the MCL (the so-called posterior oblique ligament) and fibers from the semimembranosus tendon (described below) (Fig. 7.6). At the deep surface of the MCL are ligamentous attachments to the meniscus and the adjacent bones at the level of the joint, the meniscofemoral and meniscotibial (or coronary) ligaments, which are all well seen at ultrasound.[15]

The lateral collateral ligament (LCL) arises from the lateral femoral epicondyle and runs posterolaterally to insert on the head of the fibula, often blending with the insertion of the biceps femoris (Fig. 7.7). Anteriorly, it may blend with the ITB insertion. The LCL primarily resists varus angulation and internal rotation and is well seen at ultrasound.

The capsuloligamentous anatomy at the posterior edge of the LCL (dubbed the posterolateral corner [PLC]) is both complex and clinically important. The PLC is primarily a restraint against varus angulation and external rotation. Identifying injuries to this area has important implications for surgical repair. Ultrasound is useful,[16] and possibly superior to MRI, which is slightly handicapped by magic angle artifacts and the non-orthogonal orientation of the structures. The main components of the posterolateral corner are (Fig. 7.6):

- Arcuate ligament: arises from the fibular tip and has a limb that passes posteriorly to form part of the posterior joint capsule, and a limb that passes superiorly to the lateral femoral condyle, paralleling the course of the LCL.

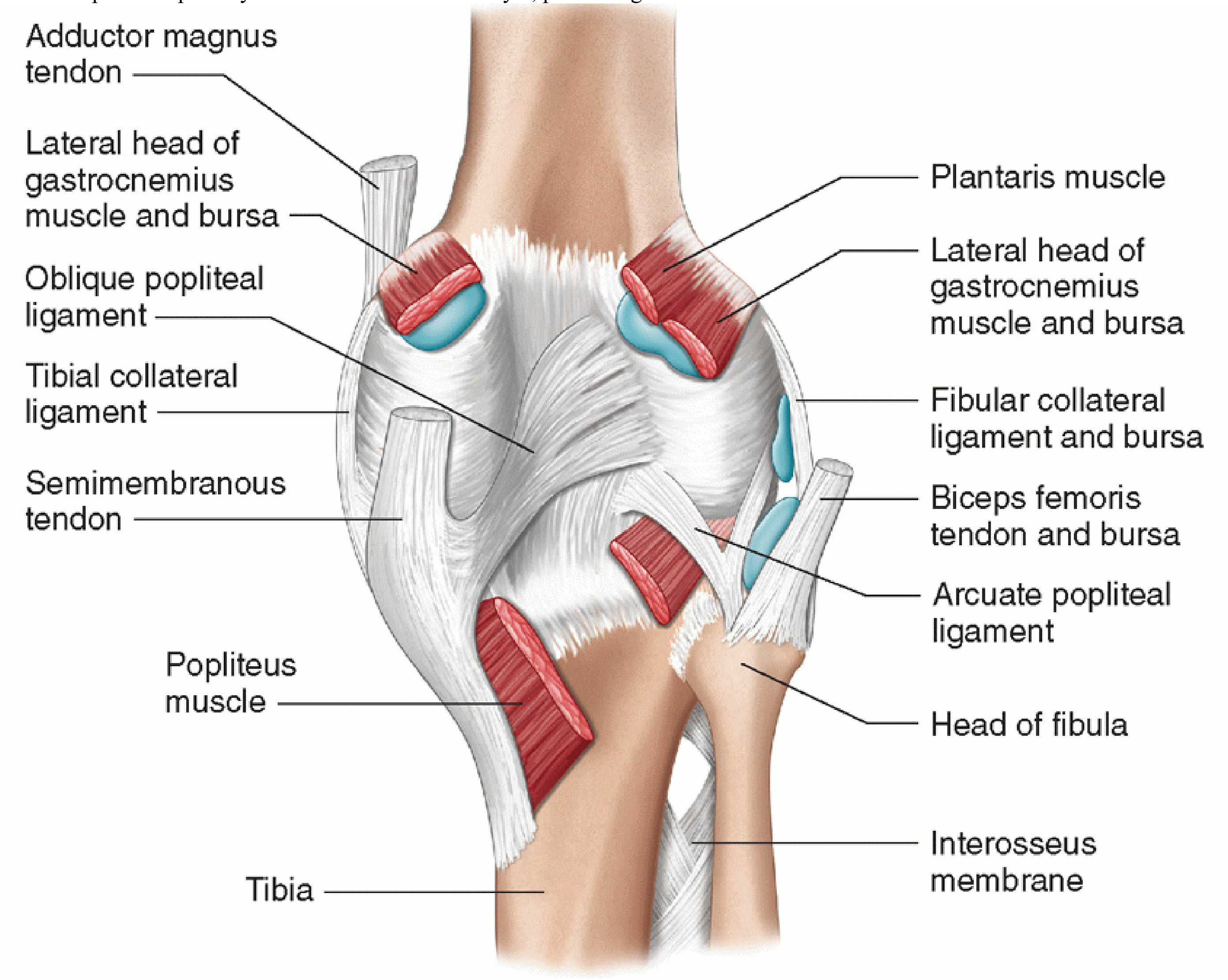

Figure 7.6. Superficial dissection diagram of the posterior knee showing posterior ligaments and bursa.

- Popliteus tendon: runs from the popliteal groove of the lateral femoral condyle (an easy sonographic landmark), behind the joint and deep to the arcuate ligament, to the posteromedial tibia.
- Fabellofibular ligament: passes from fabella to fibular head.
- Popliteofibular ligament: passes from the popliteus to the fibular head.
- Meniscopopliteal ligament: passes from the popliteus to the lateral meniscus. This structure may be important in facilitating the important role of popliteus in stabilizing the lateral meniscus.

All except the meniscopopliteal ligament are visible by ultrasound.[17]
The ligaments vary in size between individuals. In particular, the size of the arcuate ligament is inversely proportional to the size of the fabellofibular ligament, which in turn is variably important depending on the presence or absence of the fabella.[18]

Tendons

The tendons around the knee are classified into three groups: Anterior, posteromedial, and lateral.

Anteriorly, the quadriceps tendon is formed by the confluence of fibers from rectus femoris, vastus lateralis, vastus medialis, and vastus intermedius. It has a trilaminar appearance, often appreciable on ultrasound with the superficial layer formed by fascicles from rectus femoris, the middle layer by fascicles from vastus medialis and
P. 131

vastus lateralis, and the deep layer by fascicles from vastus intermedius (Fig. 7.8). The three layers are not completely fused and do have some degree of independent differential movement on knee extension. The quadriceps tendon inserts on the superior pole of the patella. The patellar tendon passes from the inferior pole of the patella to the tibial tubercle. Variable amounts of superficial quadriceps fibers run across the anterior surface of the patella and contribute to the patellar tendon. Strictly speaking, the non-quadriceps component of the patellar tendon is not a tendon as it connects bone with bone and should be more accurately described as a ligament.

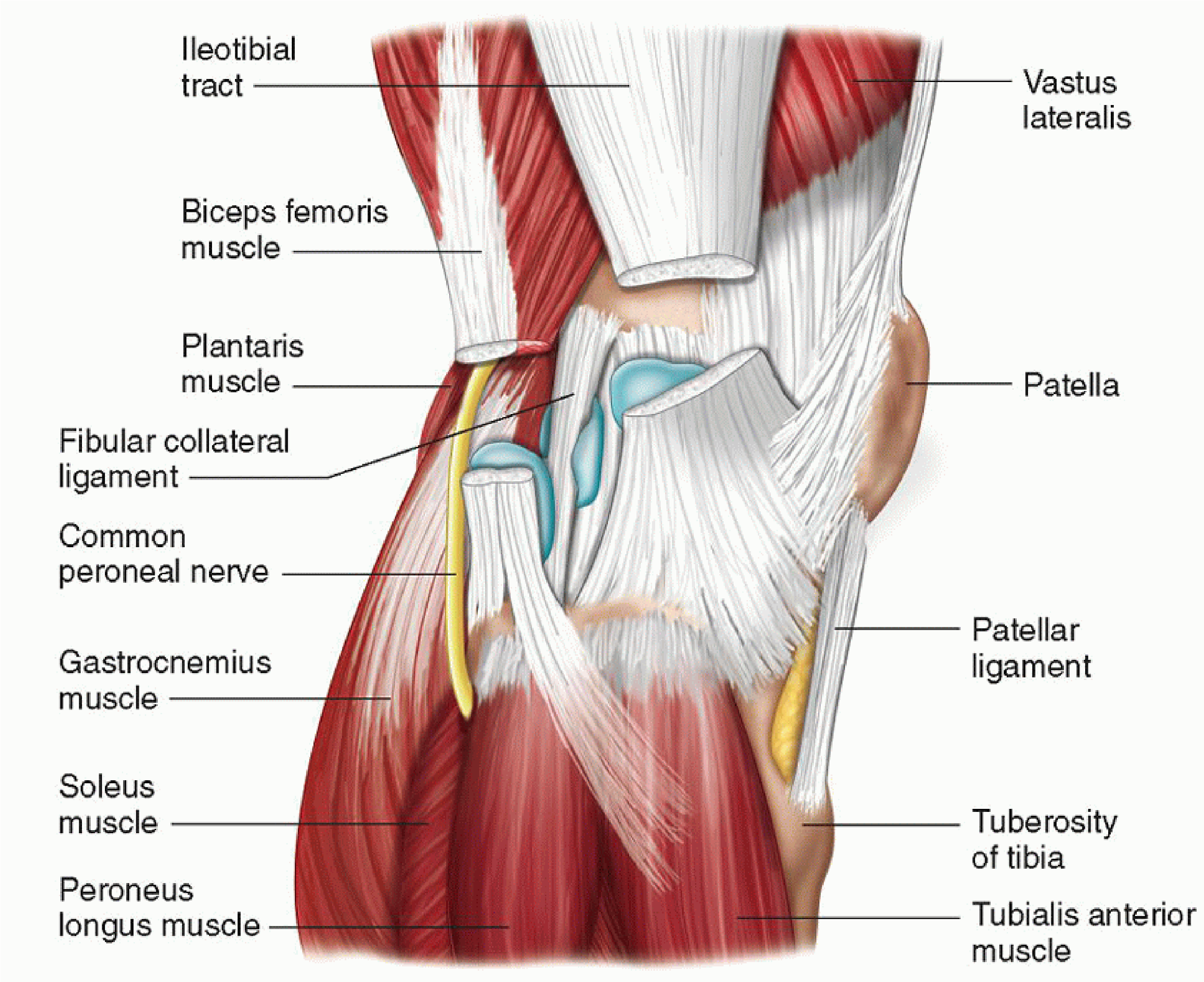

Figure 7.7. Superficial dissection diagram of the lateral knee showing ligaments and bursa.

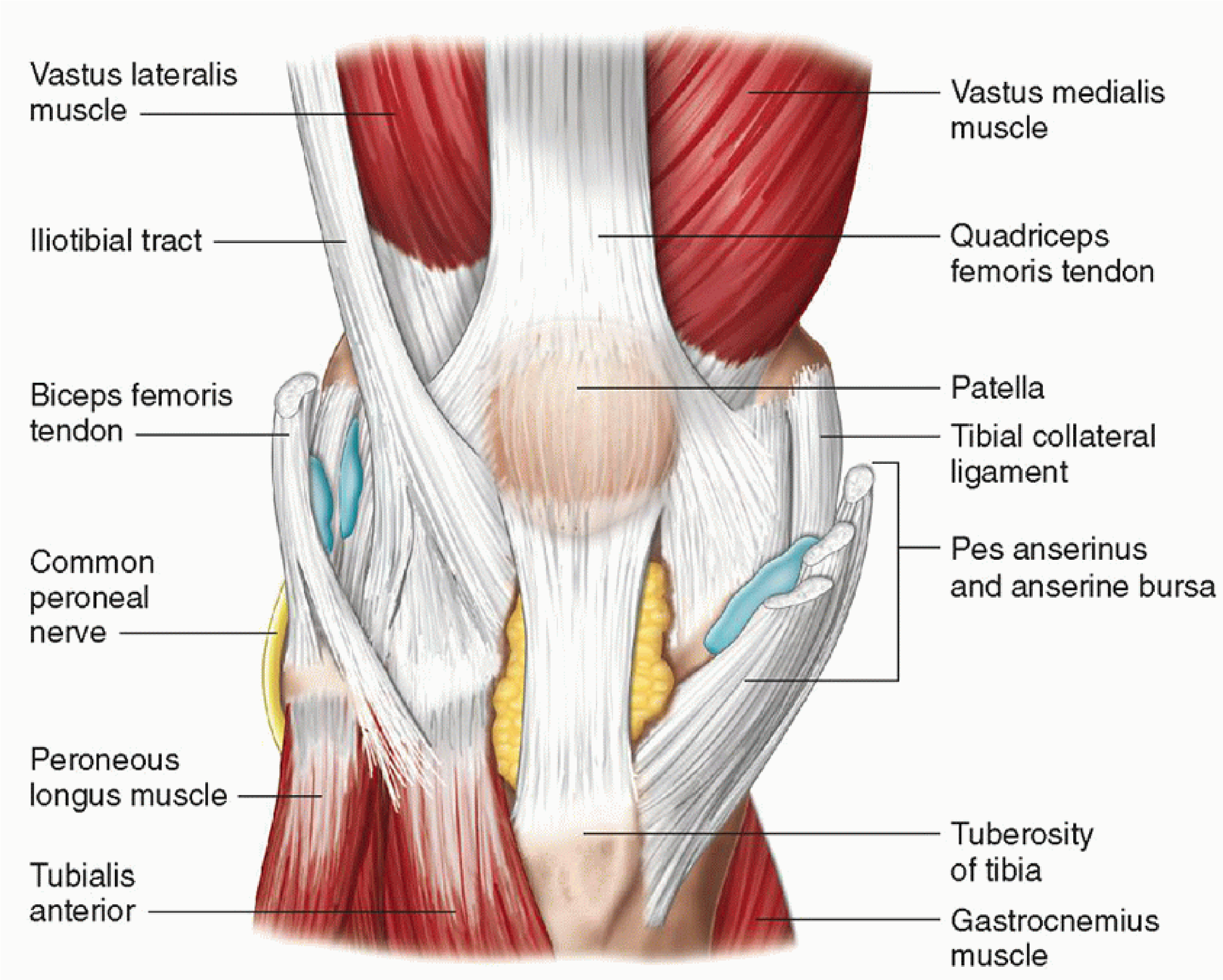

Figure 7.8. Superficial dissection diagram of the anterior knee showing the extensor mechanism.

The patellar tendon is contiguous on either side with the medial and lateral patellar retinacula, which are important in ensuring appropriate patellar tracking. The medial retinaculum is formed by condensation of the joint capsule, medial fibers of the vastus medialis tendon (the so-called vastus medialis obliquus [VMO], and the medial patellofemoral ligament (MPFL), which arises from the adductor tubercle. The VMO and MPFL are important structures, both visible at ultrasound.[19], [20], [21] The lateral retinaculum is formed by fibers from the vastus lateralis, ITB, and condensation of the joint capsule, and often has a bilaminar appearance

P. 132

on ultrasound.[22] The superficial layer is believed to be formed predominantly from the musculotendinous contributions, and the deep layer predominantly from the capsular contribution.

Posteromedially are the internal rotators and flexors (Fig. 7.5). The semimembranosus has a relatively wide insertion along the posterior and medial tibia near the joint line, and provides an important contribution to the posterior joint capsule (part of this contribution is named the oblique popliteal ligament (Fig. 7.6)), which is visible on ultrasound. The sartorius, gracilis, and semitendinosus tendons (or the "pes anserinus") insert more anteriorly and more distally, at the transverse level of the tibial tuberosity (Fig. 7.5). The medial head of gastrocnemius originates above the posterior aspect of the medial femoral epicondyle and passes superficial to the joint.

Laterally, the biceps femoris inserts on the fibular head, blending here with the LCL insertion (Fig. 7.7), while further fibers variably extend to the adjacent tibia. The ITB, a condensation and continuation of the deep fascia of the thigh, is an important lateral stabilizer of the knee. It passes over the lateral femoral condyle, where it can become irritated by repetitive contact/friction, and inserts on Gerdy tubercle, which lies anteriorly, on the lateral edge of the lateral tibial plateau (Figs. 7.7 and 7.8). The lateral head of gastrocnemius and the plantaris arise from above the posterior aspect of the lateral femoral condyle (Fig. 7.7).

Bursae

Bursae are synovial-lined, fluid-filled sacs that lubricate movement between adjacent structures. They can become inflamed independently or fill with fluid due to communications with the knee joint, either congenital or acquired (degenerative/traumatic).

The most common bursae are:

Anterior (Fig. 7.9)

- Suprapatellar bursa (or recess): Deep to the quadriceps tendon and patella.

- Prepatellar: Between patella and skin.
- Deep infrapatellar: Between tibia and distal patellar tendon.
- Subcutaneous infrapatellar bursa: Between patellar tendon and skin.
- Pretibial: Between tibial tuberosity and skin.

Medial (Fig. 7.5)

- Medial gastrocnemius: Between medial head of gastrocnemius and knee joint capsule.
- Semimembranosus: Between semimembranosus and MCL.
- Anserine bursa: Between MCL and pes anserinus.
- Bursa between semimembranosus and tibia.

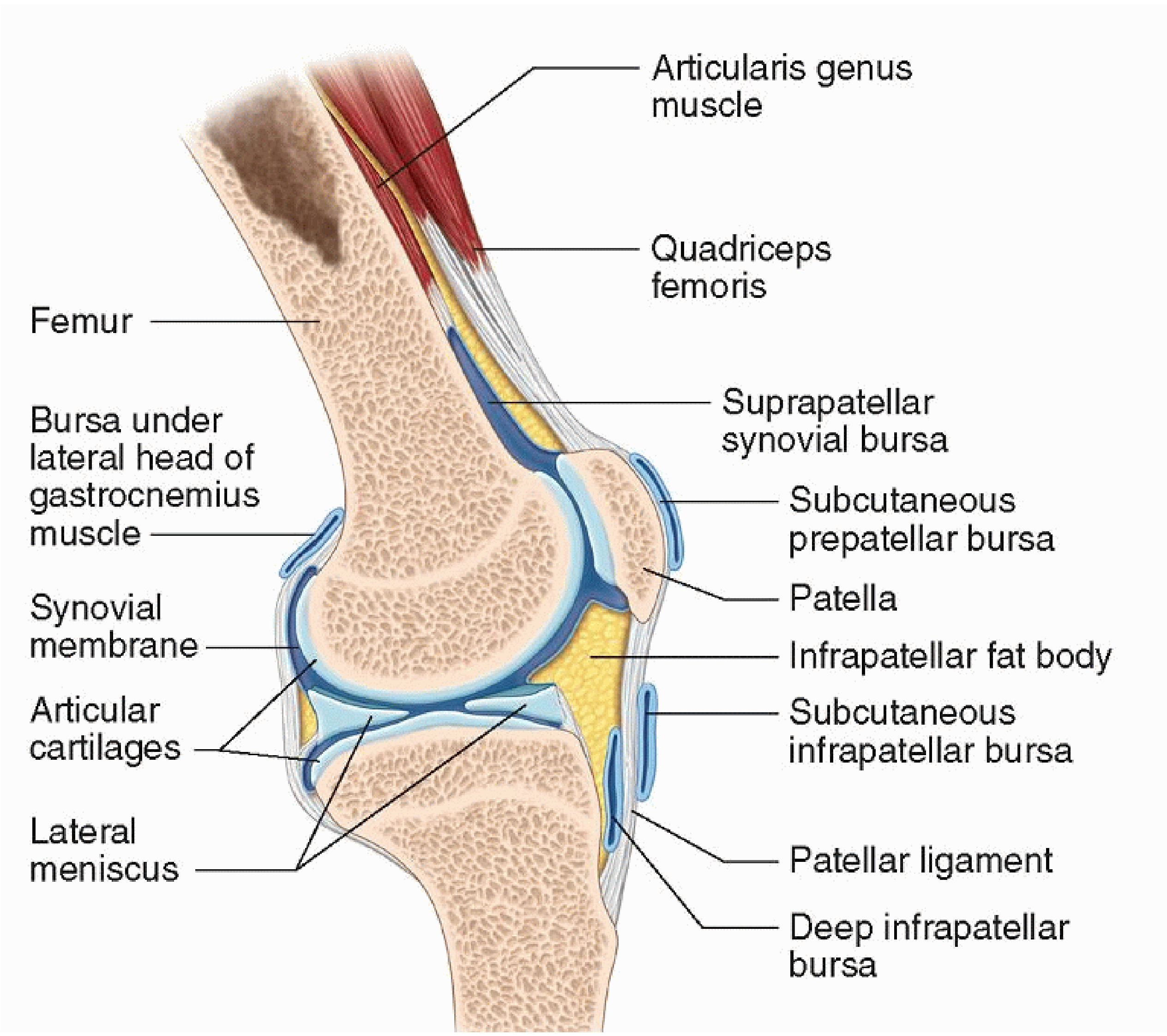

Figure 7.9. Mid-sagittal section diagram of the knee.

Lateral (Fig. 7.7)

- Lateral gastrocnemius: Between the lateral head of gastrocnemius and knee joint capsule.
- Fibular: Between LCL and biceps femoris.
- Fibulopopliteal: Between LCL and popliteus tendon.
- Subpopliteal: Between tendon of popliteus and lateral femoral condyle.

Vascular

The popliteal artery is the continuation of the femoral artery and passes posterior to the joint and the popliteus muscle. It branches into the anterior tibial artery and the tibioperoneal trunk at a variable level around the knee joint. The popliteal vein is the confluence of the anterior and posterior tibial veins. Anatomical variations are common. The most significant involves muscular entrapment of the popliteal artery by an abnormal course of the vessel or adjacent muscles.

The knee joint blood supply is from the various geniculate artery branches. The inferior lateral geniculate branch is an important and readily identifiable landmark at the posterolateral corner; it passes superficial to the popliteofibular and arcuate ligaments and deep to the LCL and fabellofibular ligament.

Nerves

The sciatic nerve runs along the posterior thigh and divides into its two main branches proximal to the knee joint. The tibial branch runs with the popliteal vessels directly posterior to the joint, while the common peroneal branch veers laterally to pass superficial to the distal biceps femoris and the fibular head. Both branches give

P. 133

off further superficial sural cutaneous branches that supply the skin around the knee, whereas the common peroneal nerve divides into deep and superficial branches distal to the head of the fibula.

The femoral nerve runs anteromedially in the thigh, giving off multiple branches along the way. The most distal of these is the saphenous nerve, which runs deep along the posteromedial aspect of the knee, behind the sartorius tendon, and then becomes subcutaneous, piercing the fascia between the sartorius and gracilis tendons. The saphenous nerve gives off the infrapatellar branch, which supplies the skin of the anterior knee and is sometimes injured at surgery.

All of these nerves can be visualized by ultrasound, particularly when pathological.

TECHNIQUE

Several transducers are required to perform a scan of the whole knee. Superficial structures should be examined with a high-frequency linear transducer. Deeper structures need lower frequency transducers; for example, a 3.5 MHz transducer may be required to examine the deepest aspects of the popliteal fossa, such as the PCL origin.

The core controls of gain, time gain compensation (TGC), depth, and focus should be continually adjusted to optimize the ultrasound image. Harmonic imaging provides improved contrast resolution at the cost of poorer spatial resolution, and is useful when scanning fluid-filled structures such as ganglia, joint effusions, collections, or fluid-filled muscle or meniscal tears. The fluid appears more obviously anechoic, and any true echoes within the fluid will be highlighted.

Compound imaging improves images by obtaining echoes from areas that previously were anechoic; for example, when there is anisotropy or acoustic shadowing from calcifications or wall edges, compound imaging can fill in these areas. The downside is that sometimes identification of these artifacts is required to make a diagnosis, for example, dense acoustic shadowing distal to foreign bodies and calcification or acoustic enhancement to confirm that a structure is fluid-filled.

Color Doppler imaging should be used since hyperemia is a sensitive marker for inflammation and tendinopathy. Accurate assessment requires skilled use of the Doppler controls. When examining superficial structures with Doppler, it may be worth switching transducers as lower frequency transducers show low-velocity blood flow better than high-frequency transducers. The pulse repetition frequency (PRF) and wall filter should be set low and the Doppler gain setting below the level of saturation. The knee should be extended to relax the quadriceps and patellar tendons, and only very light transducer pressure should be employed or vascularity may be obliterated. Comparison with the opposite side may help.

A complete knee scan that examines all four anatomical quadrants is rarely needed. Most ultrasound examinations of the knee are targeted to answer specific clinical questions, but a systematic approach to each quadrant is desirable so that all relevant anatomy is scanned. This text describes a uniform approach to positioning and examination that should be adapted to meet the needs of the individual patient.

Anterior Knee Assessment

Ultrasound assessment of the extensor mechanism can be considered as a three-part examination, starting superiorly and finishing inferiorly. First, the suprapatellar structures of the quadriceps tendon, suprapatellar recess and the trochlea of the femur are examined; second, the patella and associated structures including the retinacula; and third, the patella tendon and bursae (e.g., prepatellar and infrapatellar bursa).

The anterior knee also includes the slightly off-midline structures of the ITB and the pes anserine insertion.

The examination starts with a higher frequency transducer. Two patient positions are used:

1. The examination commences with the knee in 30 degrees of flexion (Fig. 7.10) to ensure that the quadriceps and patellar tendons are stretched and the risk of anisotropy artifact reduced. Careful scanning in longitudinal and transverse planes should be performed. For the quadriceps, this is from the distal third of the thigh to the insertion on the patella. Due to the large area to be covered, this is achieved by multiple sweeps, scanning each of the four muscles

P. 134

separately into their tendon and down to the patellar insertion. The contours of the patella and the retinaculum should be included in the examination to look for retinacular thickening or tears.

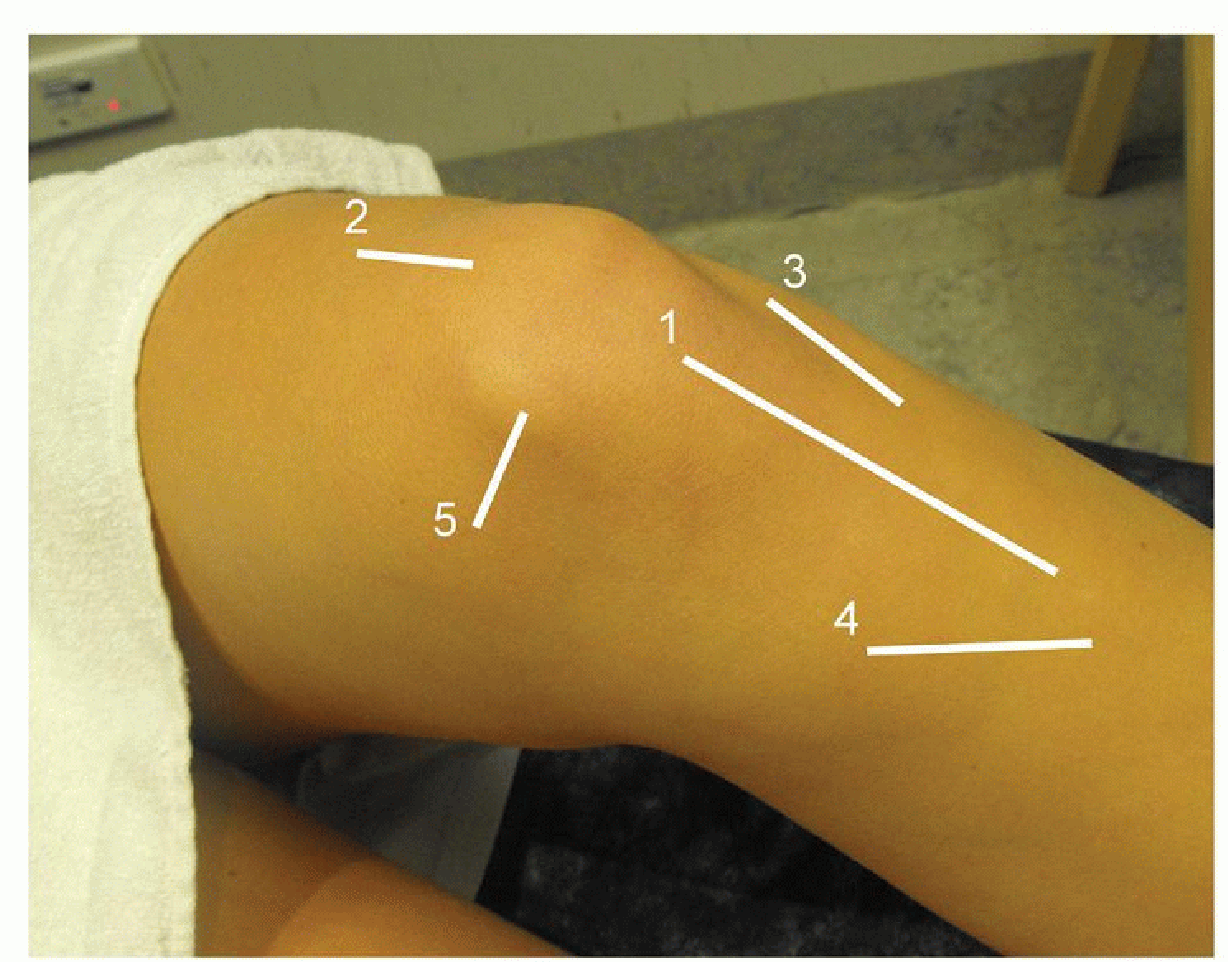

Figure 7.10. Image planes for the anteromedial knee. (1). Longitudinal plane of the patella tendon. (2). Longitudinal plane of the quadriceps tendon. (3). Longitudinal plane of the ITB insertion. (4). Longitudinal plane of the pes anserine insertion. (5). Transverse plane of the medial patellar retinaculum.

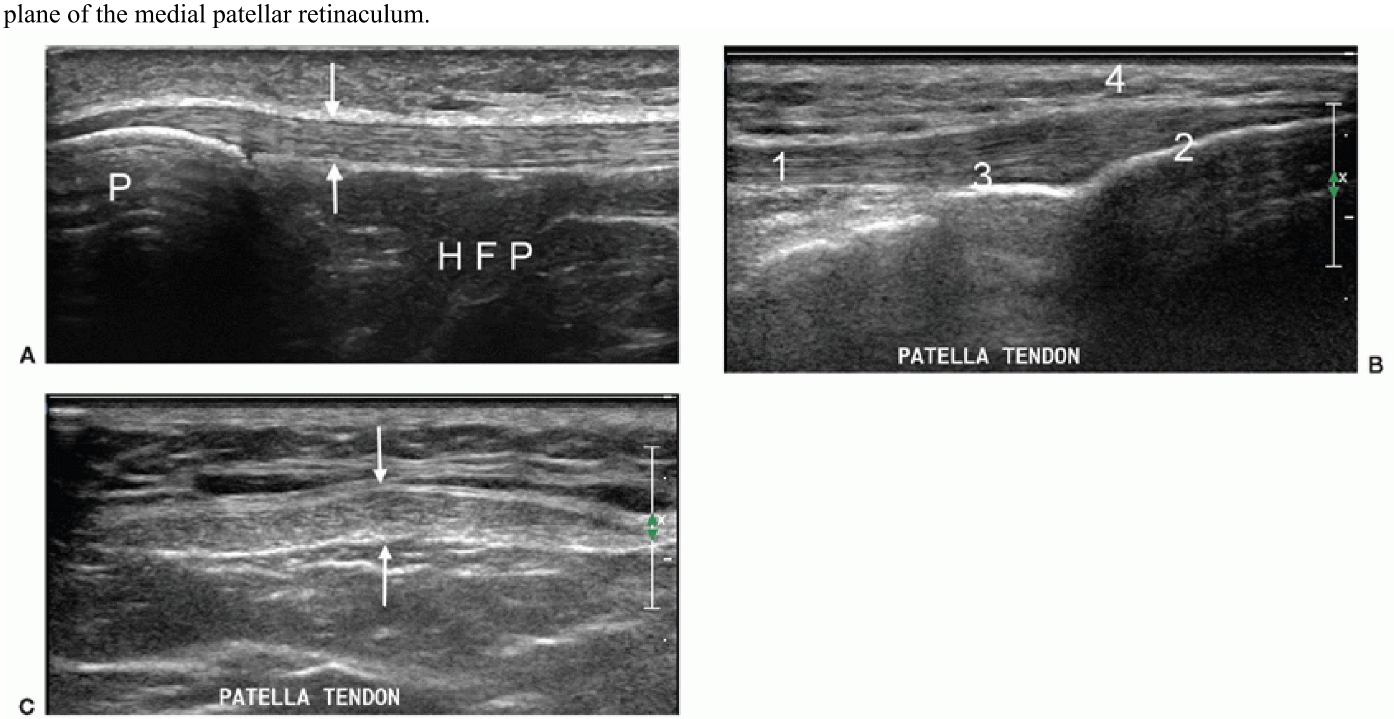

Figure 7.11. A: Normal longitudinal ultrasound image of the proximal patella tendon (arrows). P, patella; HFP, Hoffa fat pad. The tendon is well-defined and is uniform in caliber and texture. B: Normal longitudinal ultrasound image of the distal patella tendon (1). Tibial insertion of patella tendon (2). Deep infrapatellar bursa (3). Subcutaneous infrapatellar bursa (4). The tendon expands slightly as it runs to its insertion and often appears hypoechoic due to anisotropy. C: Transverse image demonstrating a normal patellar tendon (arrows). Note fine fascicle pattern.

The patellar tendon is scanned from its origin on the patella to its insertion on the tibial tuberosity in longitudinal and transverse planes (Fig. 7.11 A-C). As pathology here can be subtle, the contralateral tendon should be scanned for comparison. The structures seen superficial and deep to the tendon should also be assessed. Some may only present when pathological, such as the prepatellar or pretibial bursae. The infrapatellar fat pad of Hoffa (Fig. 7.11A) lies deep to the patellar tendon. There is normally clear demarcation between the lower level echoes of fat lobules and the hyperechoic interconnecting fascia. The remaining infrapatellar structures of the ITB and pes anserinus should also be assessed.

Parts of the femoral cartilage can be examined if the knee is positioned in full flexion (Fig. 7.12). Changes in its usual hypoechoic echogenicity should be noted. Comparison with the opposite knee helps to assess thickness and contour.

2. With the knee fully extended and relaxed, the tendons and fat pads are assessed with color Doppler.

Tip:

Examine for vascularity in the patellar tendon with the knee extended and relaxed. This is not the optimum position for B-mode assessment as the tendon is not fully stretched and anisotropy artifact may occur.

The suprapatellar space can be examined for excess fluid in varying degrees of knee flexion to increase sensitivity for knee joint fluid.[23]

Tip:

Knee joint fluid is best detected by asking the patient to elevate the ankle with the knee extended. This tenses the knee joint and pushes any excess joint fluid into the supra patellar space.

While these are the minimum two positions required for the anterior knee, scanning in other degrees of flexion may produce more fluid in or around structures or open up defects/tears in retinacula, ligaments, or tendons.)

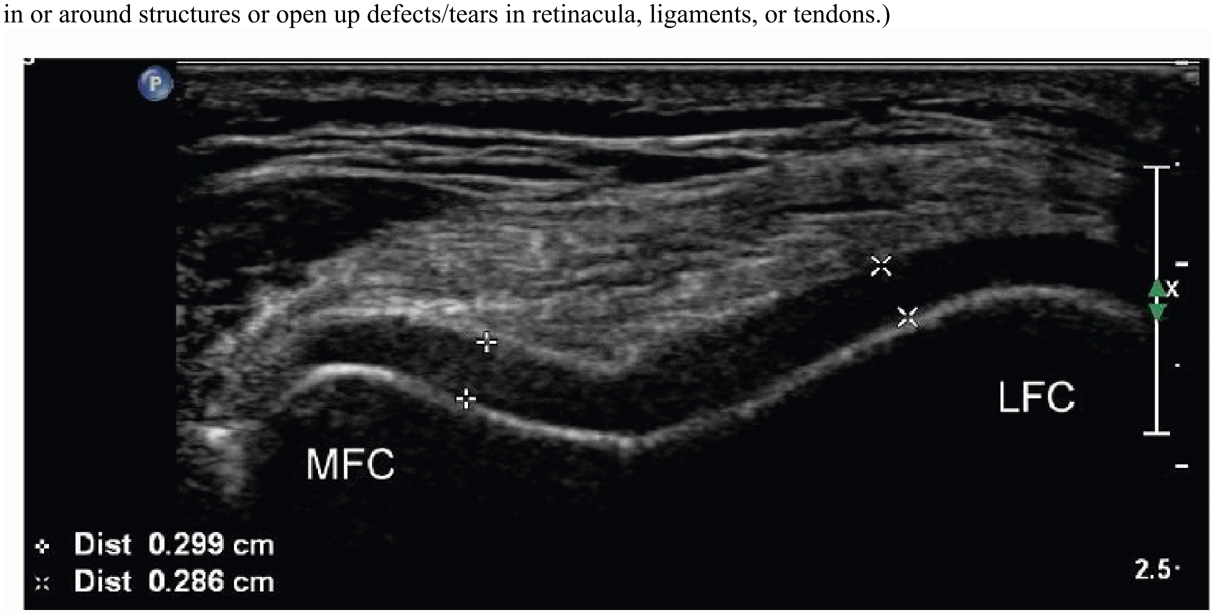

Figure 7.12. Transverse ultrasound image of the distal femur demonstrating the anechoic articular cartilage of the distal femur with measurements (calipers). MFC, medial femoral condyle; LFC, lateral femoral condyle.

P. 135

Tip:

If the patient is mobile, consider scanning while the patient sits on the edge of the examination couch with the foot or calf resting on the knee of the sonologist who sits opposite the patient. This allows access to all four quadrants of the knee without the patient having to move, and achieves good venous distension and visualization.

Medial Knee Assessment

The patient is positioned as in Figure 7.13, lying on the side to be examined with the knee partly flexed. The MCL, medial meniscus, pes anserinus tendons and their muscles, and the semimembranosus tendon are examined. Each structure should be scanned in longitudinal and transverse planes, optimized by adjusting the degree of knee flexion to elongate the fibers maximally. Assessment of the menisci by ultrasound is limited as a large proportion of the meniscus is intra-articular and not readily seen[24] (Fig. 7.14). Nevertheless, there can be clinical value in scanning the peripheral margins of the menisci to look for cysts, degenerative changes (Fig. 7.15), and, on occasion, meniscal tears.

Lateral Knee Assessment

The patient is positioned as in Figure 7.16, lying on the opposite side and the knee partly flexed. The lateral knee has more complicated anatomy than the medial side and takes longer to assess. The key structures to examine in both longitudinal and transverse planes are the insertions of the biceps femoris tendon, LCL and ITB, and the lateral meniscus and popliteus tendon (Fig. 7.17) in varying degrees of knee flexion and extension. Care should be taken in examining the biceps femoris insertion as the junction with the LCL can create areas of anisotropy or a heterogeneous echo pattern that can be mistaken for pathology such as a tear or tendinosis (Fig. 7.18). Examining the arcuate ligament complex[25] is best done with direct comparison with the opposite knee to detect subtle changes in the echo pattern or size of the ligament (Figs. 7.19 and 7.20). Other structures to examine are the common peroneal nerve as it passes around the fibula, and the superior tibiofibular joint looking for joint effusion or capsular thickening. The lateral meniscus appears similar to the medial meniscus.

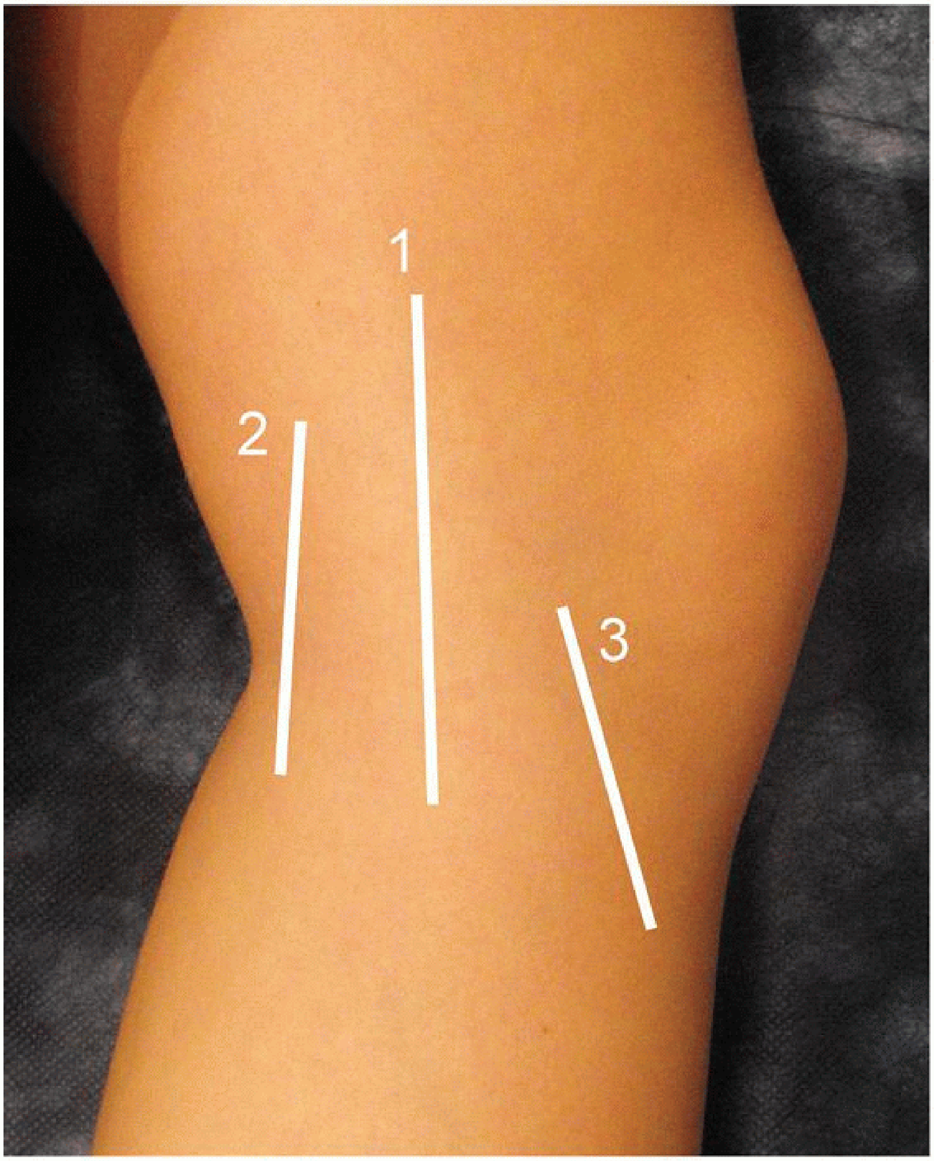

Figure 7.13. Image planes for the medial knee. (1). Longitudinal plane of the MCL. (2). Longitudinal plane of the distal semimembranosus tendon and insertion. (3). Longitudinal plane of the pes anserinus.

Posterior Knee Assessment

The patient should be prone with the knee extended, as in Figure 7.21.

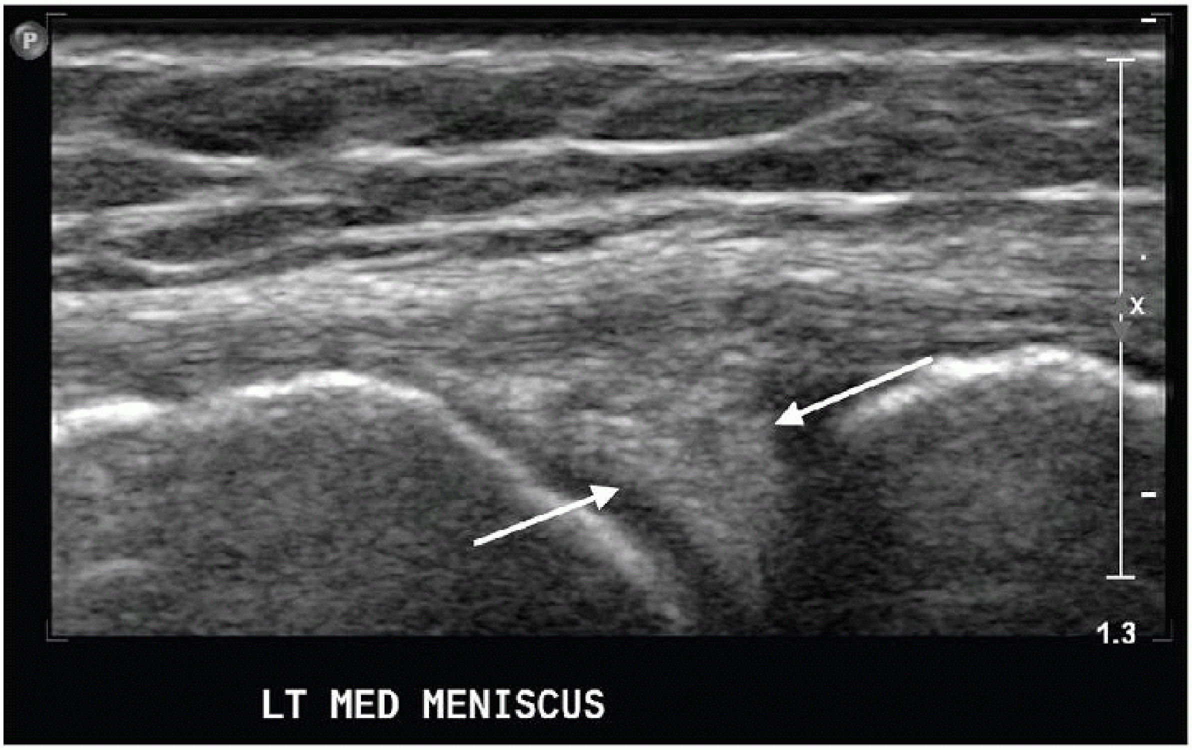

Figure 7.14. Longitudinal image of a normal medial meniscus (arrows).

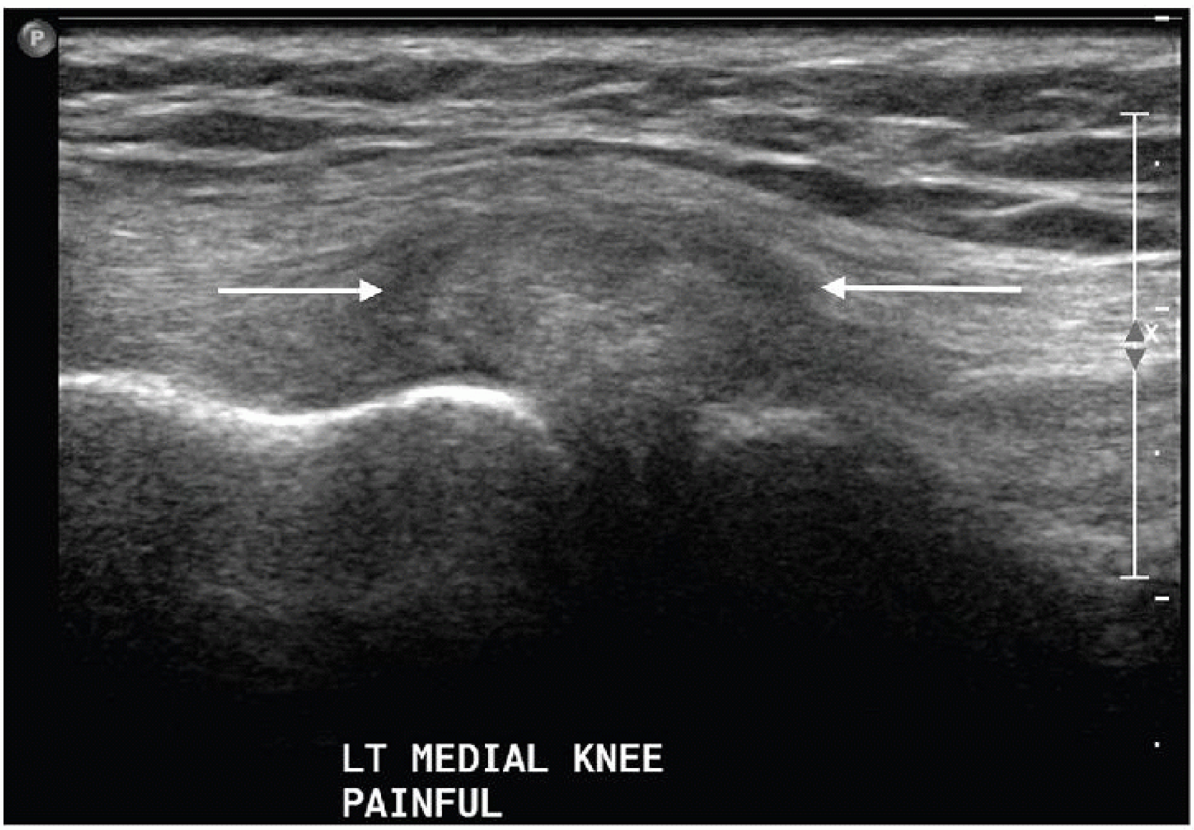

Figure 7.15. Longitudinal image of the medial knee demonstrating a bulging medial meniscus (arrows). The normal meniscus is usually flush with the line between the femur and the tibia.
P. 136

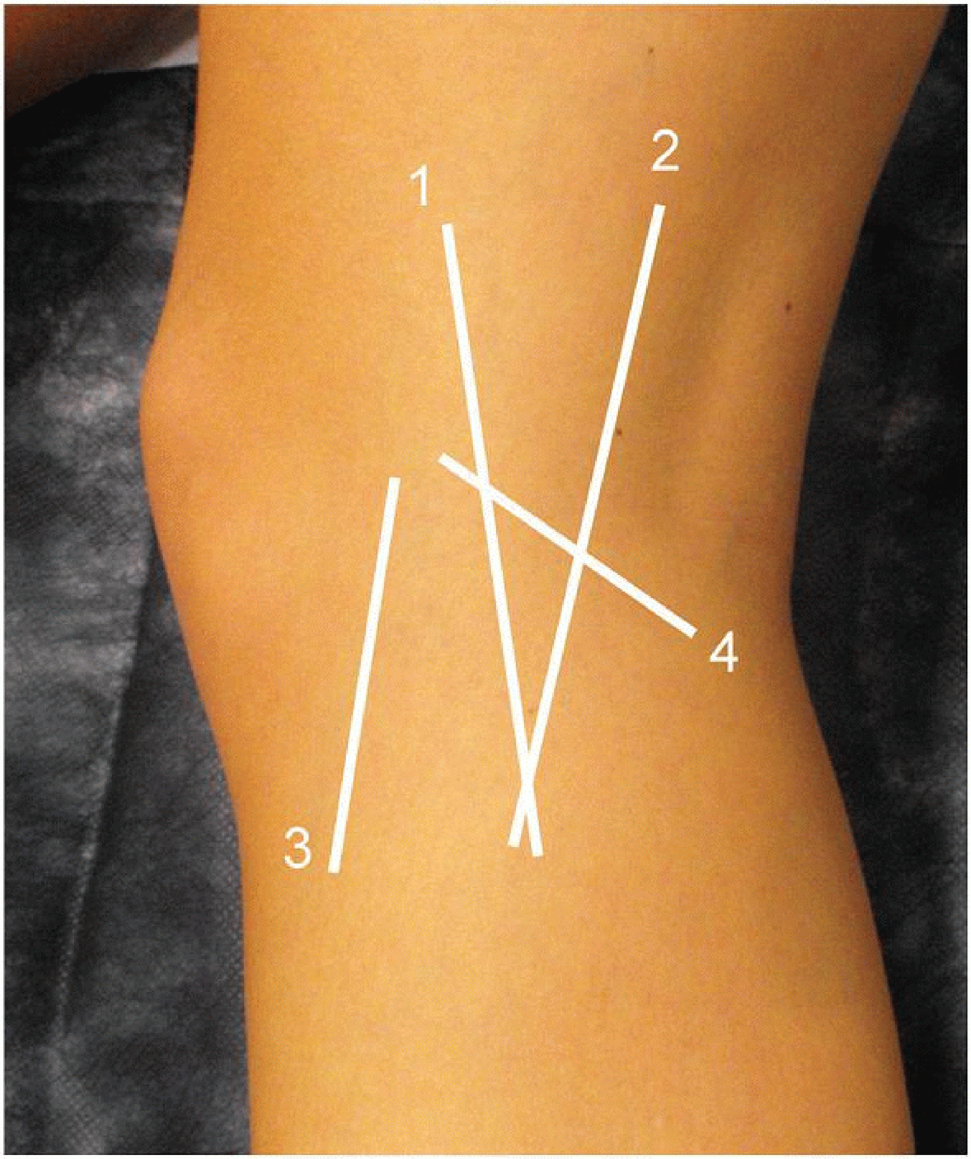

Figure 7.16. Image planes for the lateral knee. (1). Longitudinal plane of the LCL. (2). Longitudinal plane of the biceps femoris insertion on the fibula. (3). Longitudinal plane of the ITB insertion. (4). Longitudinal plane along the popliteus tendon origin.

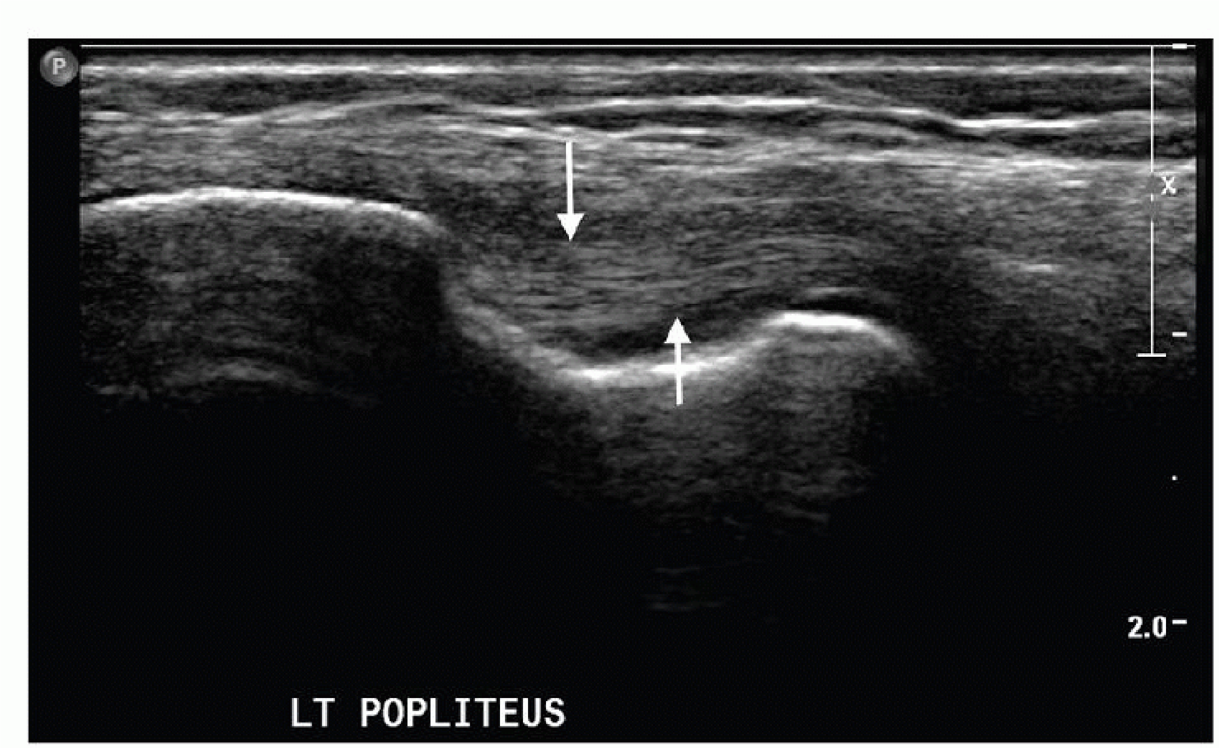

Figure 7.17. Longitudinal image of the origin of a normal popliteus tendon (arrows).

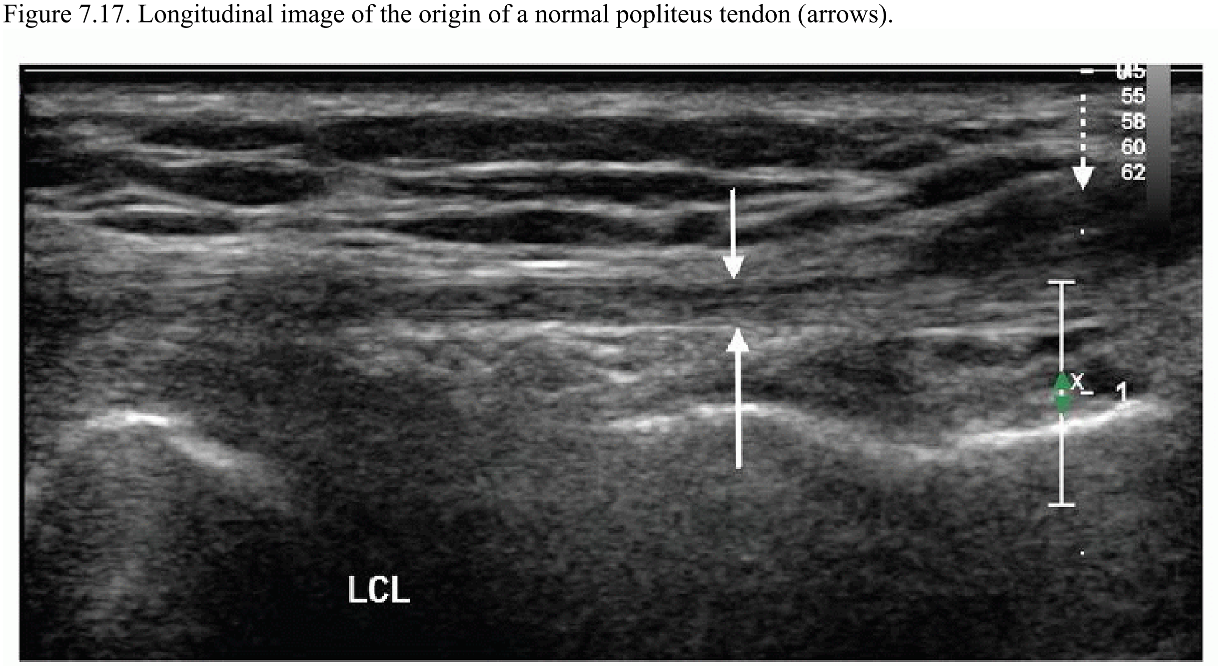

Figure 7.18. Longitudinal image of the normal LCL (solid arrows). Dashed arrow indicates biceps femoris insertion, which is hypoechoic due to anisotropy.

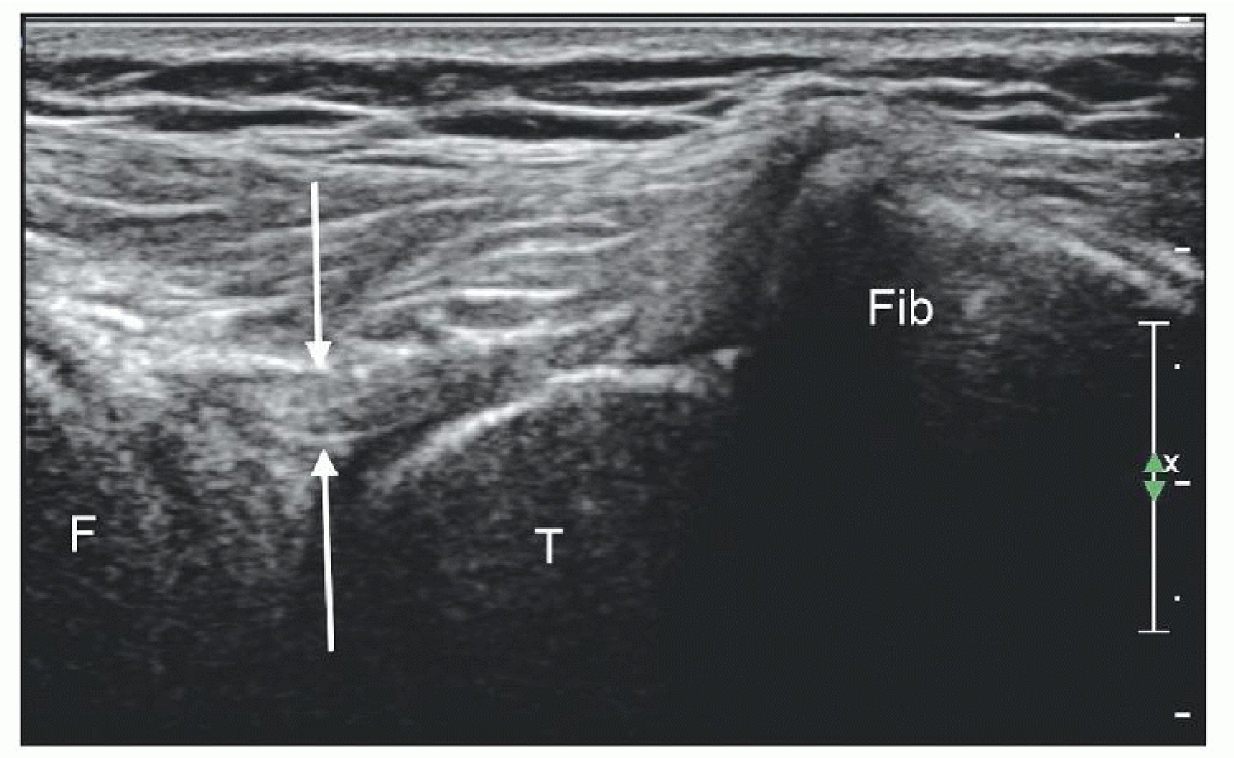

Figure 7.19. Longitudinal image of the arcuate ligament (arrows). F, femur; T, tibia; Fib, fibula.

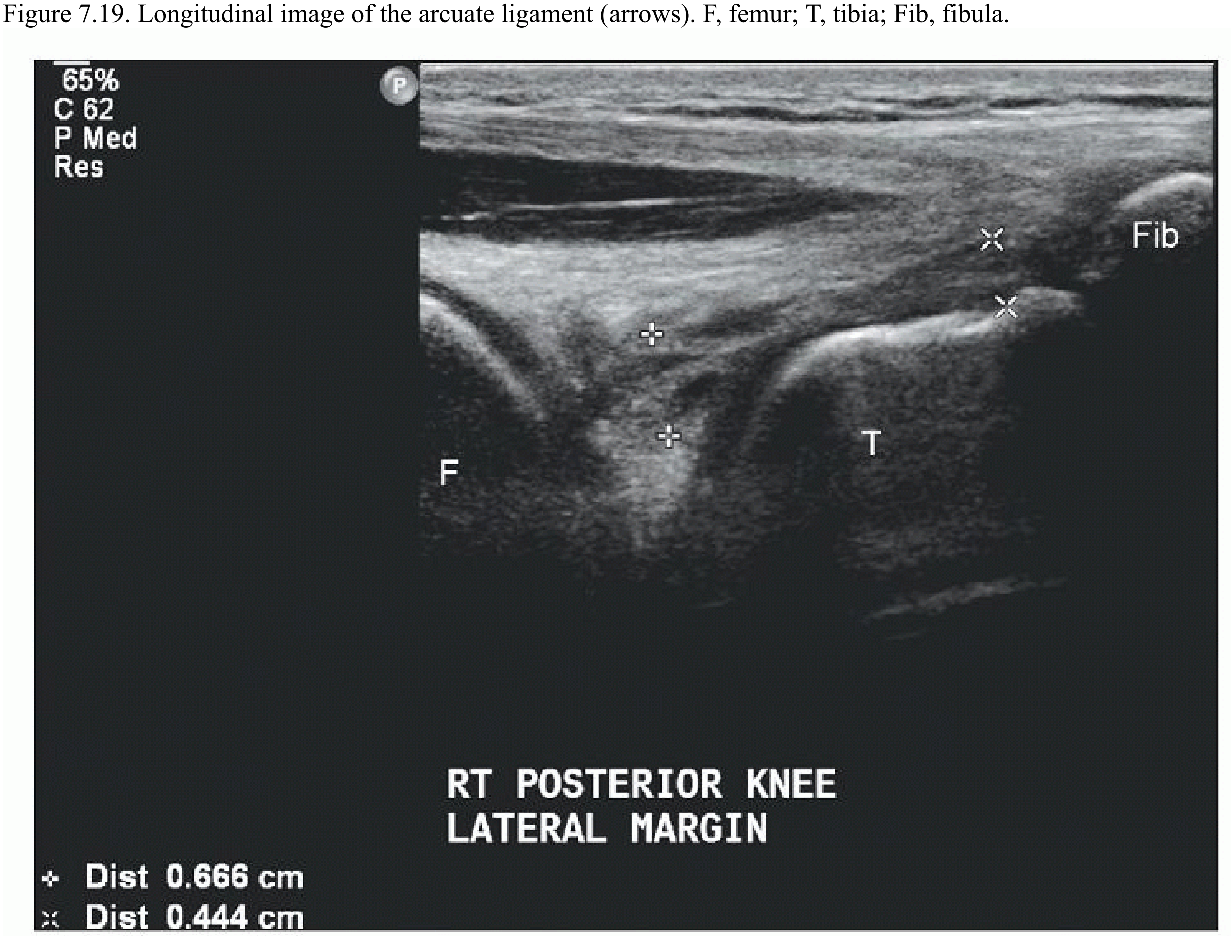

Figure 7.20. Longitudinal oblique ultrasound image of a scarred arcuate ligament (caliper marks). F, femur; T, tibia; Fib, fibula.

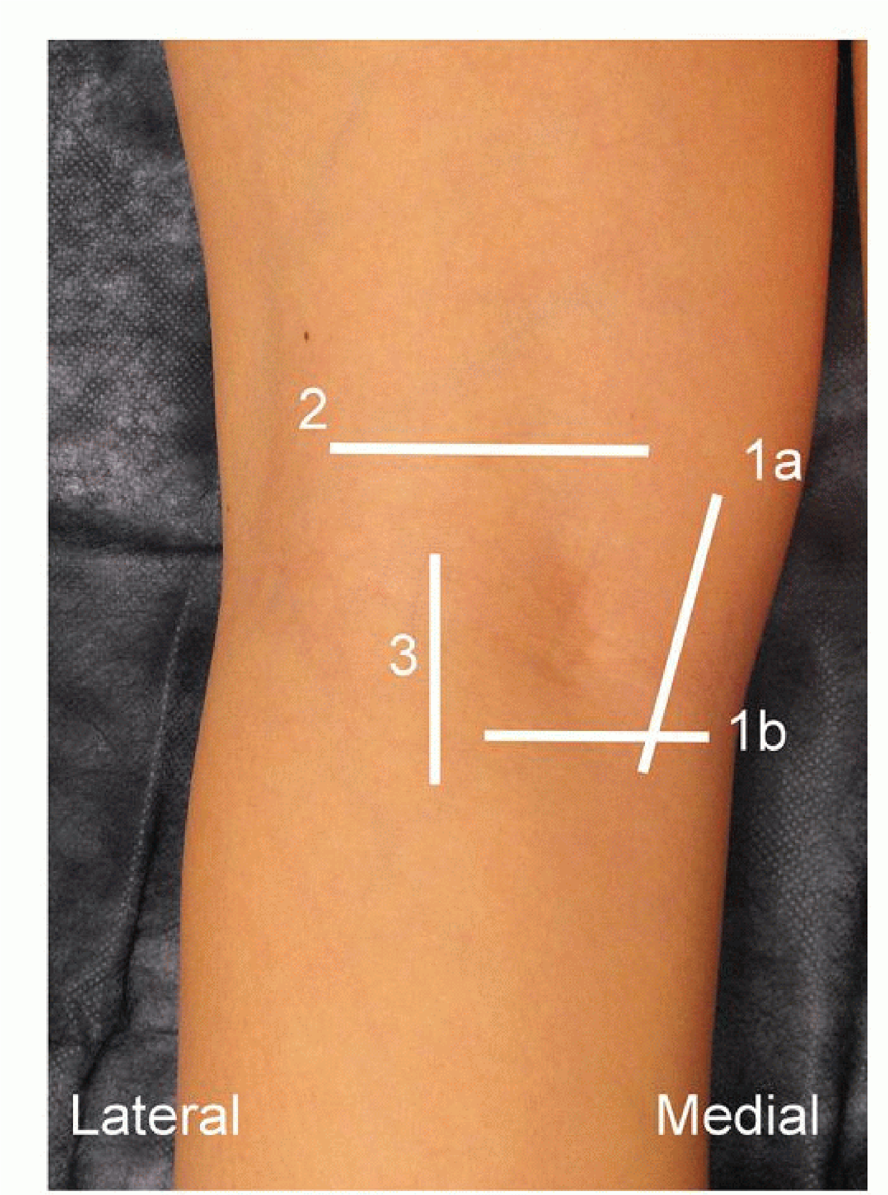

Figure 7.21. Imaging planes for the posterior knee. (1a). Longitudinal plane of the distal semimembranosus tendon and insertion. (1b). Transverse plane of the semimembranosus tendon insertion. (2). Transverse plane of the intercondylar notch for assessing the ACL origin. (3). Longitudinal image of the PCL insertion.

P. 137

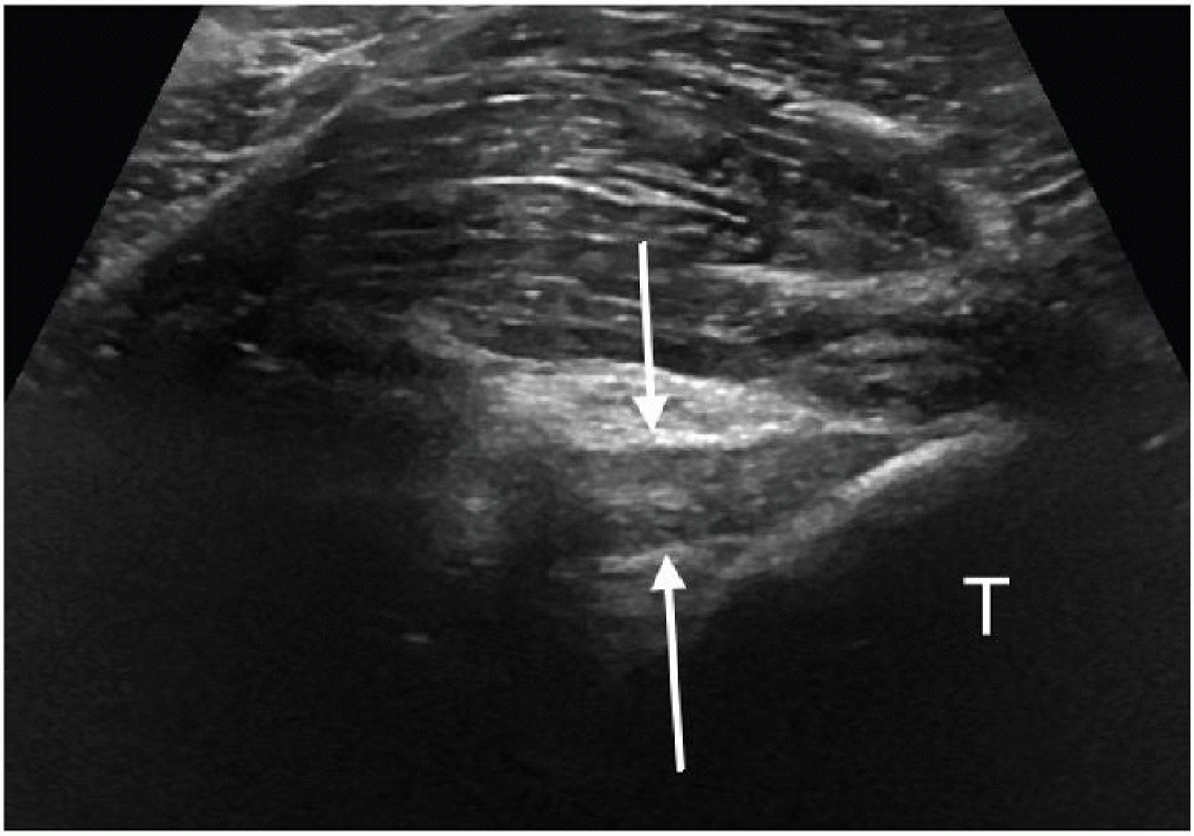

Figure 7.22. Longitudinal image of the PCL insertion into the tibia (arrows). T, tibia.

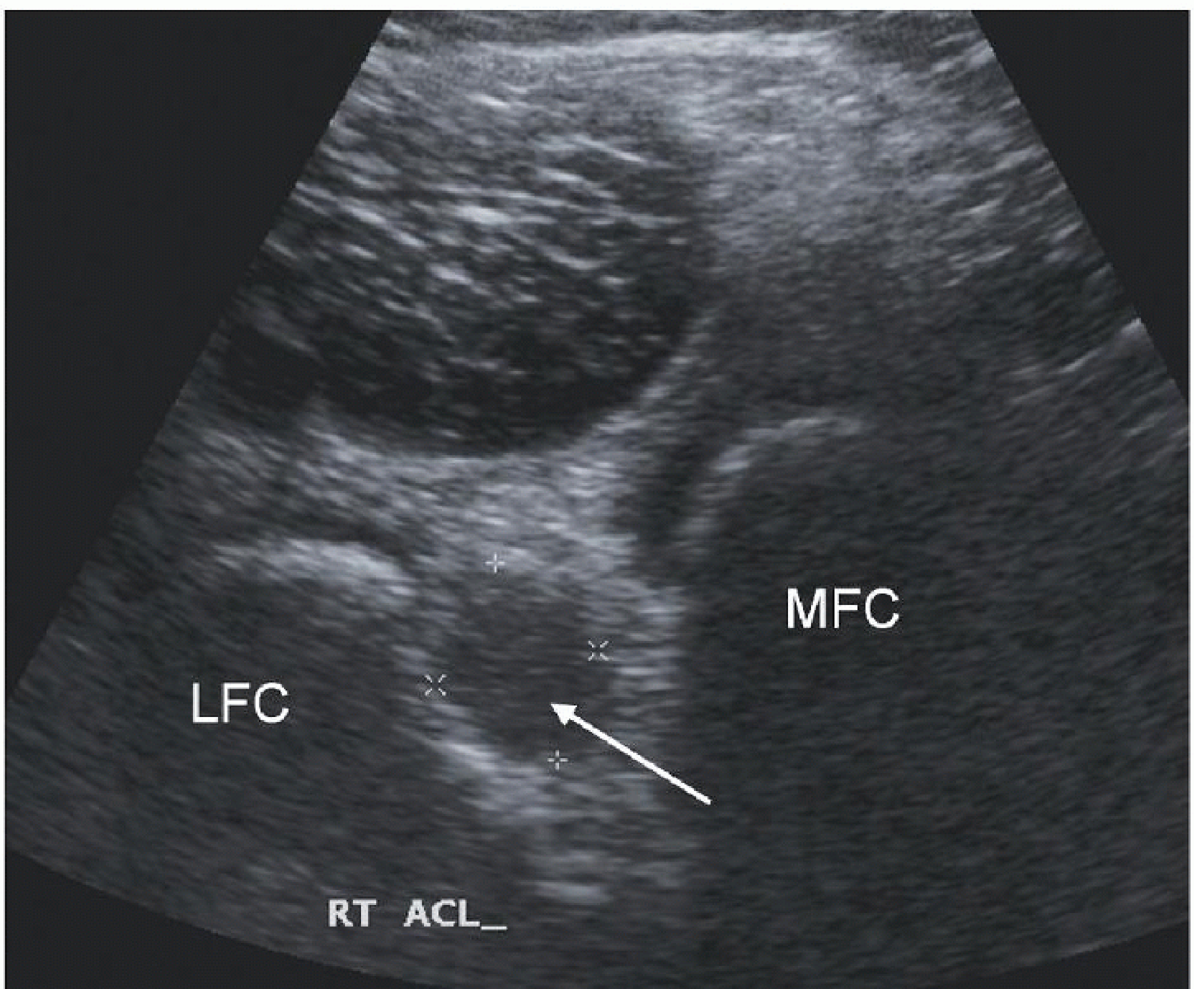

Figure 7.23. Transverse image demonstrating a hematoma at the site of the torn ACL (arrow and calipers). LFC, lateral femoral condyle; MFC, medial femoral condyle.

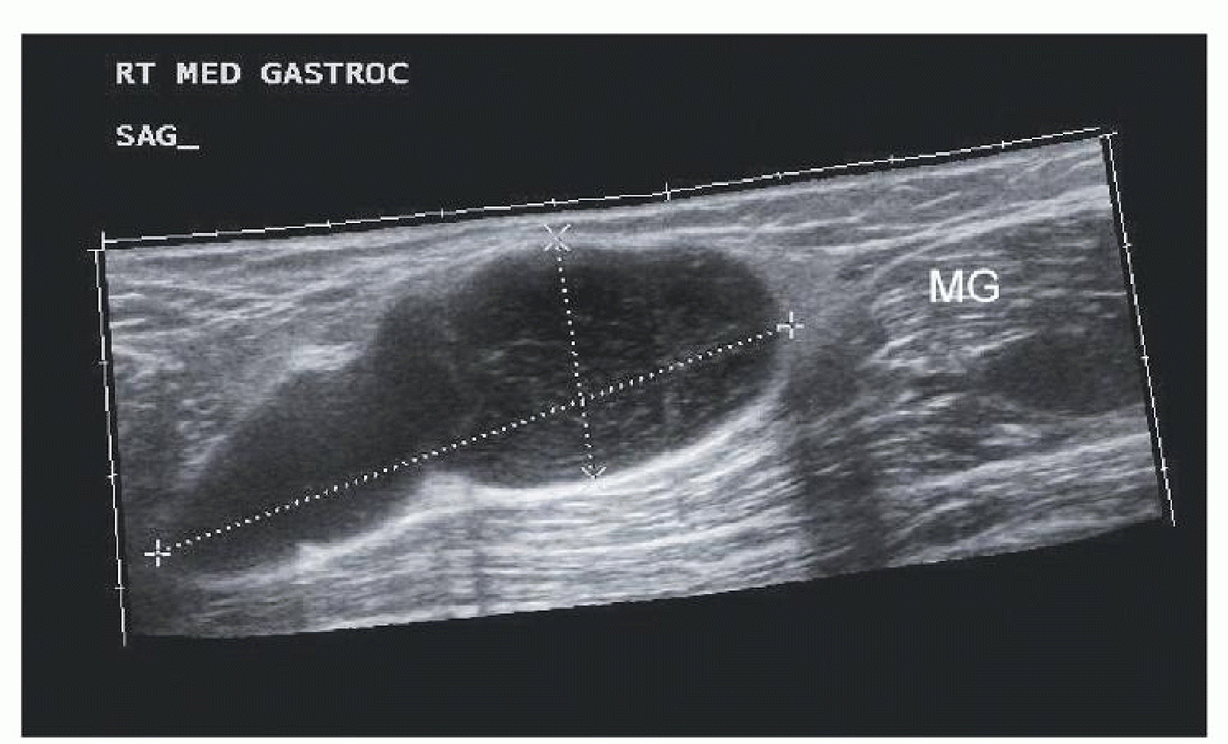

Figure 7.24. Extended field of view, longitudinal image demonstrating a Baker cyst (calipers) with low-level internal echoes and distal acoustic enhancement. MG, medial gastrocnemius muscle.

Tip:

This position can be uncomfortable, particularly if the knee is already painful, and a towel bolster or support sponge placed under the anterior ankle to gently flex the knee can help. This makes it more comfortable for the patient and relaxes the popliteal fossa so that structures like the popliteal vein can be visualized.

The posterior knee examination requires multiple transducers of varying frequency to visualize structures at variable depth. Using a high-frequency transducer, the popliteal artery and vein and sciatic and tibial nerves are inspected. Next, a lower frequency linear, or even curvilinear, transducer is used to assess the deeper structures, for example, the PCL insertion on the tibia (Fig. 7.22), the lateral margin of the intercondylar notch looking for a hematoma as a marker for an ACL tear (Fig. 7.23), or a Baker cyst (Fig. 7.24).

Tip:

Use of harmonic imaging allows better assessment of fluid within a Baker cyst. Echogenic fluid can be an indicator of blood/bleeding in a Baker cyst.

While this four-quadrant approach covers most clinical problems, the sonologist should also listen to the patient. If the patient points to the mid thigh or mid calf, this region should also be scanned.

PATHOLOGY

Anterior/Extensor Mechanism

Anterior/extensor mechanism-related knee pain is perhaps the most common indication for ultrasound of the knee. Pathology includes patellar tendinosis, quadriceps tendinosis, patellar maltracking, medial plica syndrome, and bursitis.

Patellar and Quadriceps Tendinosis (or Tendinopathy)

Tendinosis is common at the patellar tendon and can affect the quadriceps tendon, with similar clinical, pathological, and sonographic manifestations. Tendinosis generally results from overuse. Histology shows disruption of normal collagen architecture with deposition of mucoid ground substance and sometimes dystrophic ossification.[26] Clinically, tendinosis manifests with pain, particularly on activity, tenderness, and swelling. In the patellar tendon, it occurs most commonly at the proximal end of the tendon, in the midline, known as "jumper's knee." In its most subtle form, there is minimal sonographic abnormality with reduction in echogenicity and some blurring of the normal fiber pattern. As tendinosis becomes more severe, the tendon becomes swollen with reduction of

P. 138

echogenicity and loss of the normal fibrillar pattern[27] (Fig. 7.25). Neovascularity on Doppler examination is a sensitive sign of tendinosis[28] (Fig. 7.26). Discrete defects or tears in the tendon are important and have prognostic and treatment implications (such as whether autologous blood or platelet-rich plasma [PRP] injections are to be used). Examination of the patellar tendon should extend to the fat pad of Hoffa. In moderate-to-significant tendinosis, the fat pad has increased echogenicity and there are blurring of fascial planes (Fig 7.27) and increased Doppler vascularity. At the chronic end of the disease spectrum, tendinosis is associated with enthesopathy, and minor bony contour changes, hyperostosis, or large bony excrescences are seen[29] (Fig 7.25). Intratendinous calcifications (dystrophic ossification) can also be seen in chronic tendinosis.[30]

Most of these sonographic abnormalities are frequently found in the patellar tendons of asymptomatic individuals, particularly those who engage in regular or strenuous athletic activity.[31] Although many of the changes may be adaptive rather than pathological, the presence

of focal hypoechoic changes has some predictive value for the future development of symptoms.[32]
PRP and autologous whole blood are often used to treat patellar tendinosis. Both utilize the theoretical ability of platelet-related growth factors to encourage healing of tendon tissue. The best technique for their administration and the overall efficacy of therapy remain controversial.[33] We have anecdotally found the following protocol effective in treatment of patellar tendinopathy:
Five milliliters of blood is drawn from the patient's antecubital vein and centrifuged in a test tube for 3 to 5 minutes. This yields a three-layered appearance: The supernatant and middle platelet layer are aspirated from the test tube using a 3 mL syringe, while the precipitant of red cells is discarded. A 25G needle is placed in the abnormal part of the tendon, under ultrasound guidance. We most often use a transverse approach, entering the patellar tendon from lateral or medial, with the probe held longitudinally along the planned course of the needle. The contents of the 3 mL syringe are gently injected under ultrasound visualization. There should be little resistance to injection, and injected material should be observed entering small clefts (often running longitudinally along the tendon and therefore out of the original transverse plane of the probe). If this is not the case, the needle can be minimally repositioned until this occurs. Distension of the tendon and small clefts often results in discomfort for several days after the procedure, and the patient should be warned about this.
Following completion of the procedure, the patient is counseled to rest for several days before recommencing any rehabilitative exercise.
The patient is also counseled not to expect an immediate improvement, and that a further treatment may be required in 4 to 6 weeks.

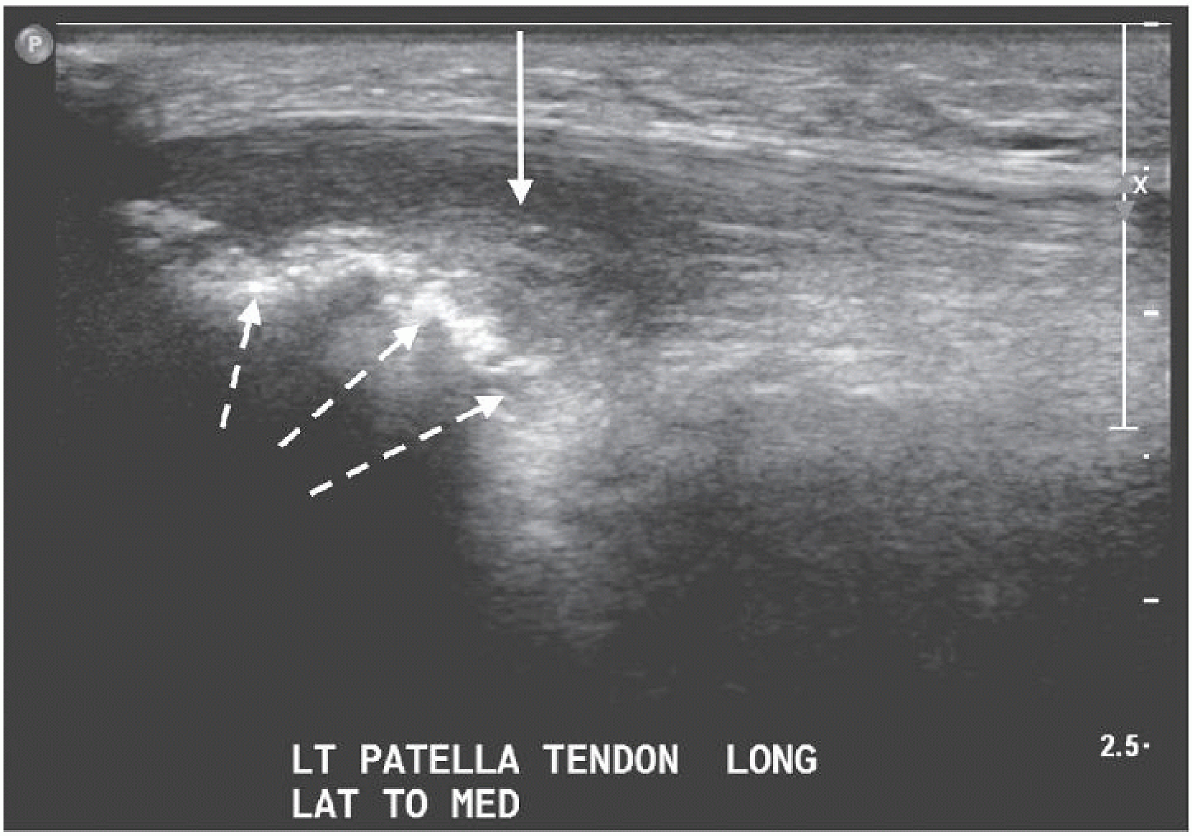

Figure 7.25. Longitudinal image of the proximal patella tendon demonstrating severe chronic patellar tendinosis and enthesopathy of the patella. Note the loss of normal tendon architecture and reduced echogenicity (solid arrow). Dashed arrows depict enthesopathy/hyperostosis of the patella.

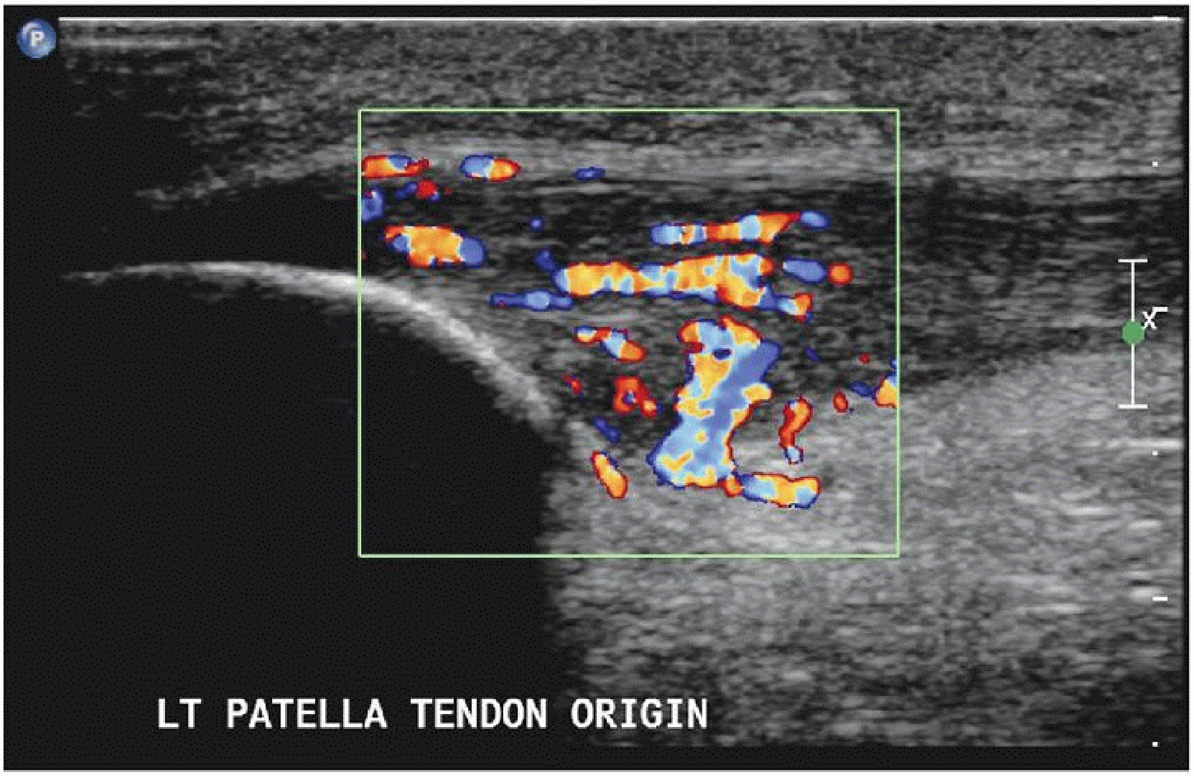

Figure 7.26. Longitudinal color Doppler image of the proximal patella tendon demonstrating severe tendinosis with marked hyperemia.

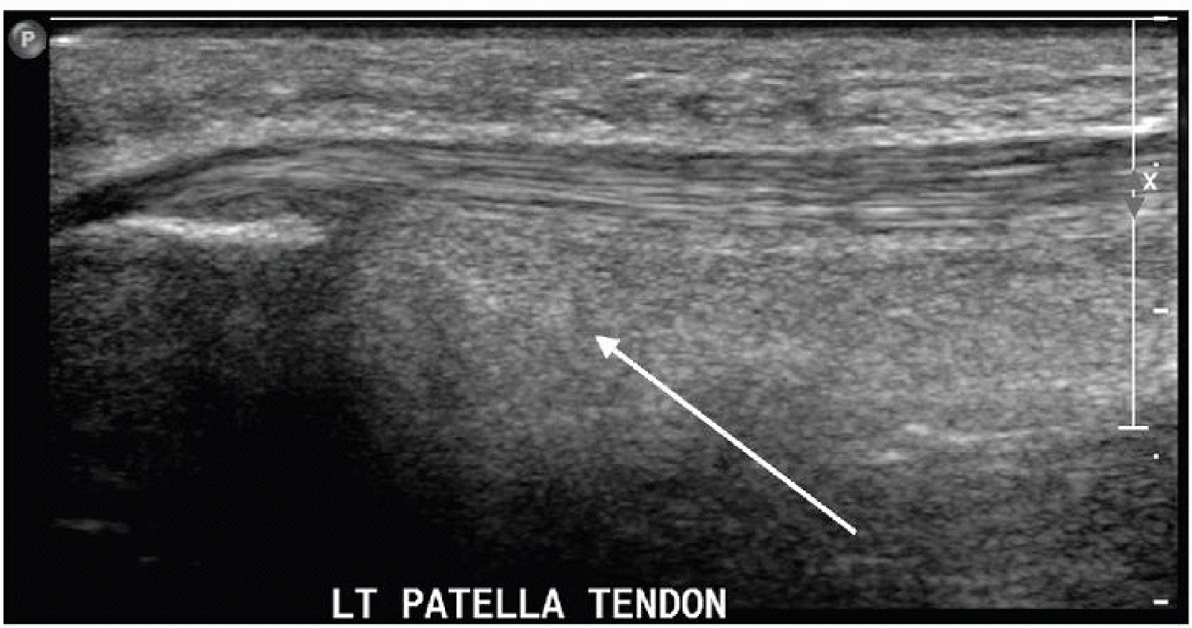

Figure 7.27. Longitudinal image of the proximal patella tendon and Hoffa fat pad (arrow). The fat pad has increased echogenicity and has lost the normal fascial lines that demarcate the individual fat lobules, indicative of inflammation.

P. 139

A similar technique can be applied to the treatment of tendinopathy elsewhere in the body. Variations on the substance used (PRP vs. whole blood), the amount injected, and the location of injection (intratendinous vs. peritendinous) are common among different practitioners.

Quadriceps and Patellar Tendon Tears

Tears of these tendons are unusual and are far less common than tendinosis of the same tendons or tears of other tendons, such as the Achilles or supraspinatus. Tears often result from relatively minor trauma in tendons that are already severely degenerated from connective tissue disease or old age/disuse. They are readily recognized sonographically as a focal discontinuity of tendon fibers; the interval is often filled with hematoma or granulation tissue that is amorphous and hypointense, lacking the normal organized appearance of parallel tendon fibers. The most common type of tears are intratendinous delaminations that occur in the proximal and deep surfaces of the patellar tendon. Anechoic foci may evolve, which may breech the deep surface of the tendon. Neovascularity and hyperemia are common.

Patellar Maltracking

Abnormalities of the patellofemoral articulation are extremely common and result from abnormalities of trochlear and patellar morphology, malposition of the tibial tubercle, muscular imbalances of the quadriceps muscles, or abnormal tension of the patellar retinacula. Maltracking manifests as the patellofemoral pain syndrome and includes pain from chondral wear and impingement of juxtapatellar fat. Chondral damage is difficult to visualize sonographically because the patellar articular surface lies deep to and is obscured by the patella itself.[34] Impingement of the fat is readily appreciated sonographically as increased echogenicity and color Doppler vascularity, which, if identified, suggest maltracking. This can be further assessed with radiographs, computed tomography, or MRI.[35]

Medial Plica Syndrome

The medial patellar plica is a remnant embryological structure of variable size and extent. Its role in the development of knee symptoms and patellofemoral chondral wear is controversial,[36] as the plica is commonly present in asymptomatic individuals. Symptomatic patients usually present with chronic anterosuperior knee pain, and sometimes snapping or local tenderness medially. Ultrasound complements MRI by showing friction of the plica against the patella or femoral condyle during dynamic movement[37] and thickening.[38]

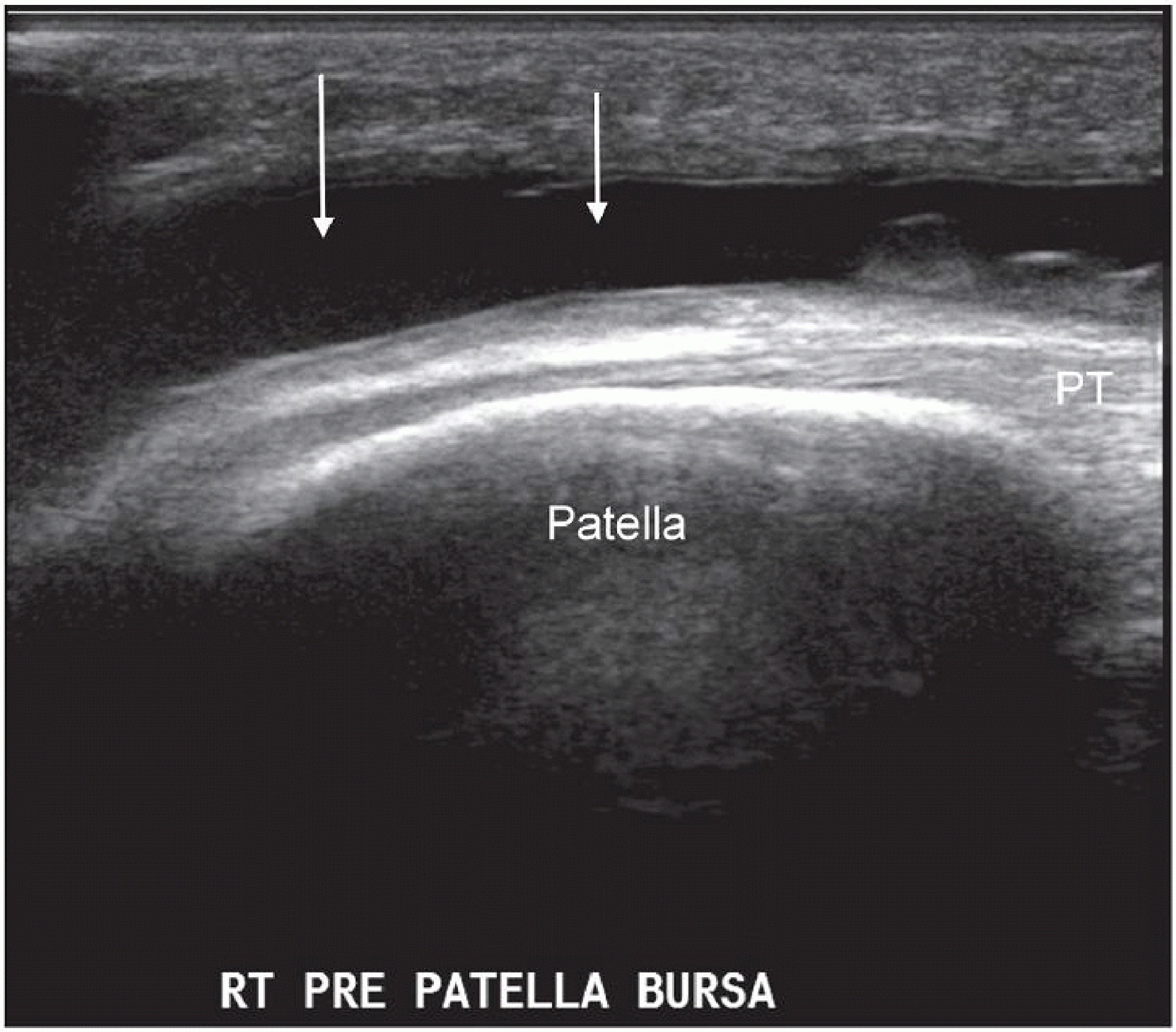

Figure 7.28. Longitudinal image of a distended fluid-filled prepatella bursa (arrows).

Bursitis

Inflammation of the prepatellar bursa is most often seen after acute (e.g., a fall on to the knee) or repetitive (e.g., prolonged kneeling) trauma. The soft tissues superficial to the patella are thickened and edematous, or there may be an effusion in the bursa (Fig. 7.28) with prominent neovascularity. The transducer must be applied very lightly to the skin as the sonographic changes are easily obliterated by even light pressure and may be embarrassingly missed. The suprapatellar bursa is often distended when there is a joint effusion, and is a sensitive location to look for joint fluid and synovial thickening either just proximal to the patella or in the medial or lateral gutters (Fig. 7.29). The infrapatellar bursae may be inflamed and distended if there is adjacent patellar tendinopathy (Fig. 7.30).

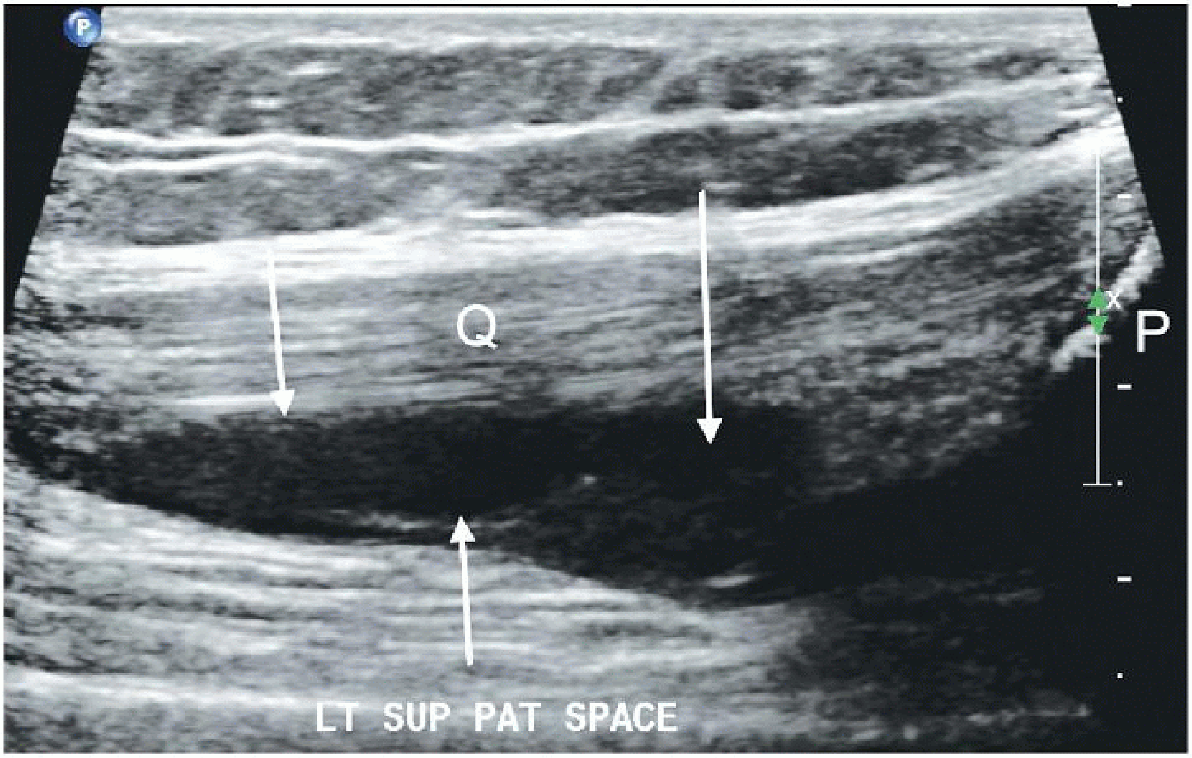

Figure 7.29. Longitudinal ultrasound image demonstrating fluid in the suprapatellar recess (arrows). Q, quadriceps tendon; P, patella.
P. 140

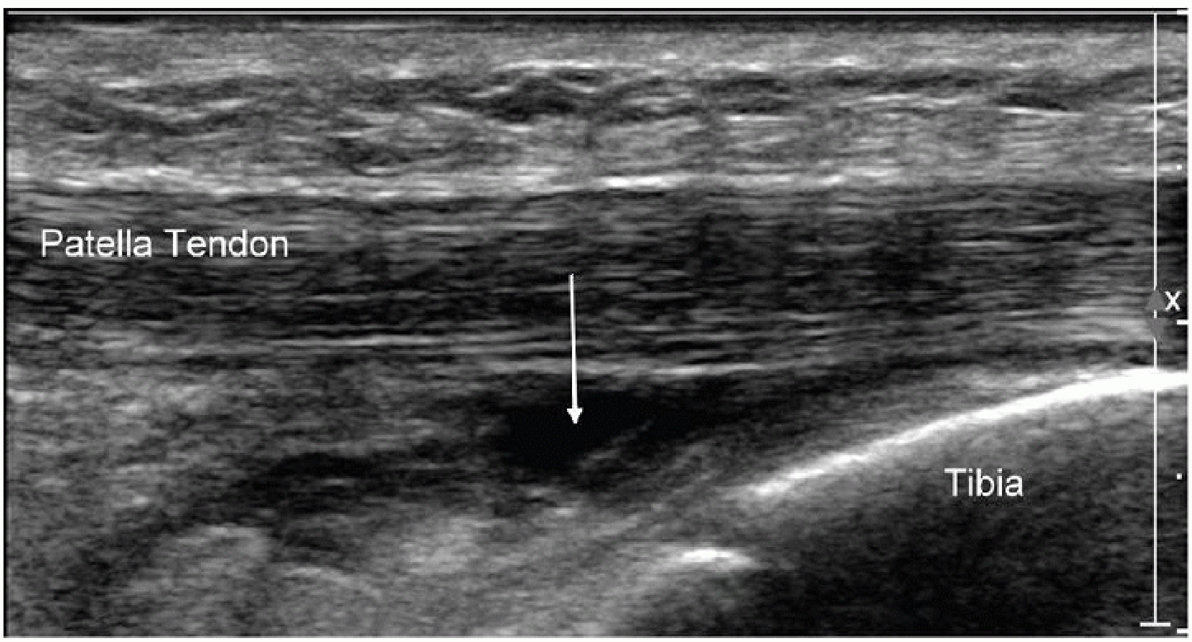

Figure 7.30. Longitudinal image demonstrating fluid in the deep infrapatellar bursa (arrow).

MEDIAL AND LATERAL KNEE

MCL Injury

The MCL is the most commonly injured ligament in the knee,[39] usually from valgus stress or, in conjunction with cruciate injury, rotational or translational stress.[40] Injuries are usually proximal and range in severity from mild sprain to complete disruption. No ultrasound-specific grading classification is in routine use, but MRI classification (Grade I intact ligament with periligamentous edema, Grade II partially disrupted ligament, and Grade III completely disrupted ligament) can be adapted with little difficulty or confusion, although grading is usually performed clinically.[41] The ultrasound appearances are:

- “Sprain”/Grade I injury—Thickened ligament (relative to the contralateral side) with minor loss of fibrillary pattern, and possibly periligamentous edema and neovascularity (Fig. 7.31).
- Partial thickness tear/Grade II injury—More extensive loss of fibrillary pattern with a hypoechoic area (Fig. 7.32).

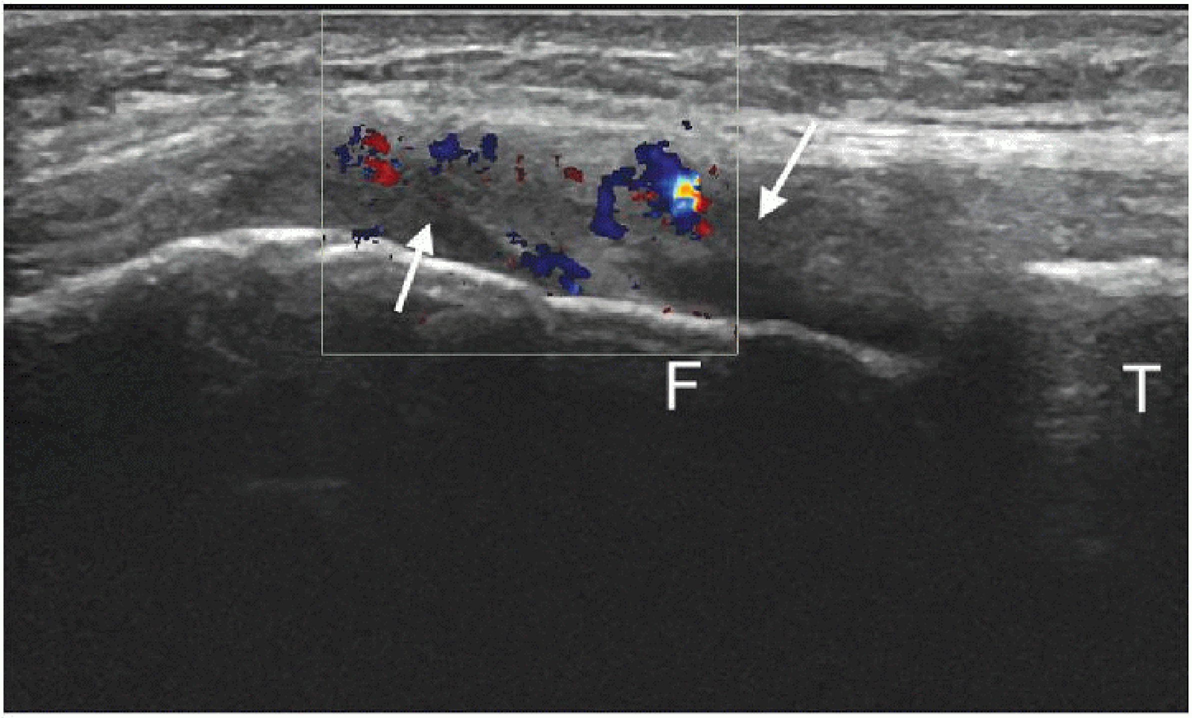

Figure 7.31. Longitudinal image of the MCL origin demonstrating a grade I tear with loss of texture and echogenicity (arrows) and hyperemia. F, femur; T, tibia.

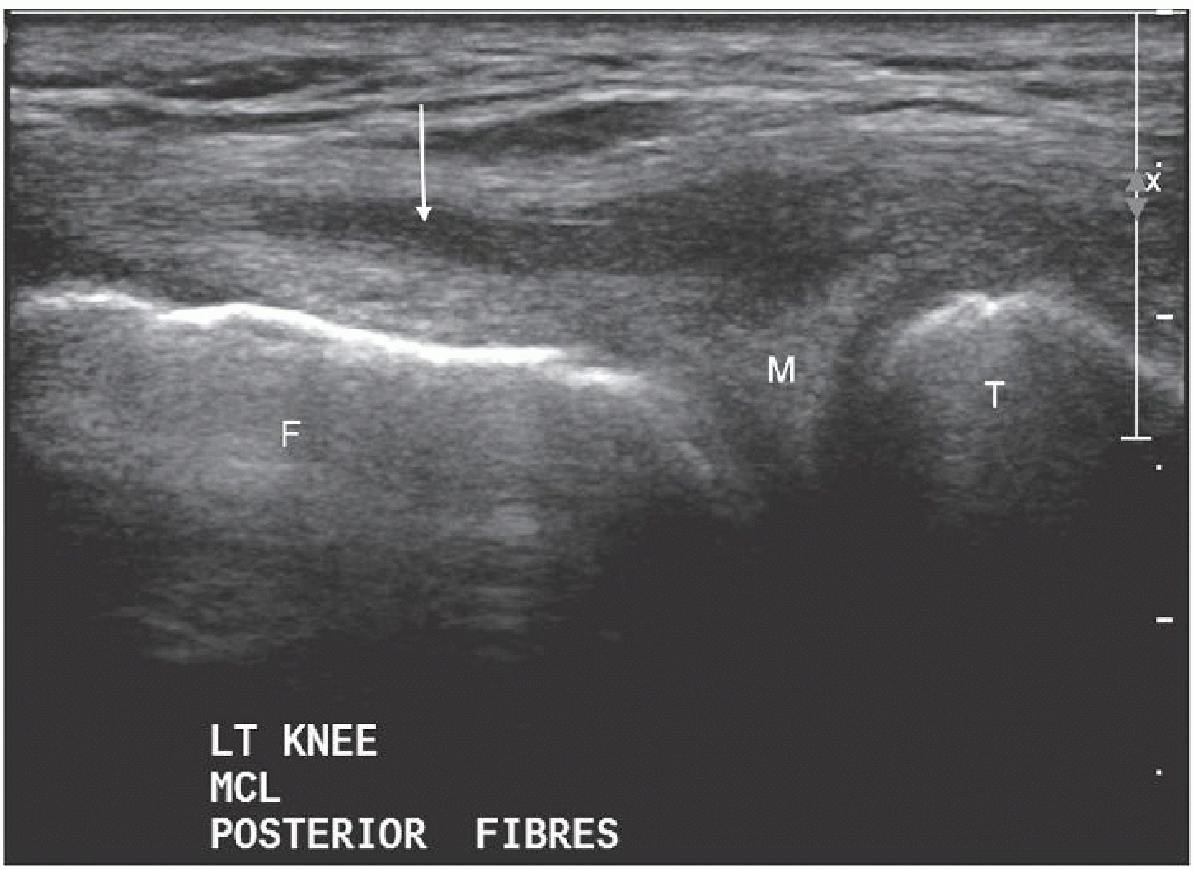

Figure 7.32. Longitudinal image of the MCL origin demonstrating a grade II tear with a defect in the ligament (arrow). F, femur; T, tibia; M, meniscus.

- Complete tear/Grade III injury—Redundancy and laxity of the ligament, with a demonstrable gap in tendon fibers (Fig. 7.33).

The Pellegrini-Stieda lesion is calcification at the femoral attachment of a previously injured MCL seen as a curvilinear echogenic band. It may be symptomatic.

LCL Injury

This structure is less commonly injured than the MCL. Care should be taken in assessing the LCL insertion on the head of the fibula, as the distal insertion blends with the fibers of the biceps femoris tendon and alteration of sonographic appearance is normal here. Sonographic appearances and grading of injuries are similar to those of the MCL.

Injuries to the structures of the posterolateral corner are often associated with LCL injuries, and without surgical repair can result in chronic instability and eventually

P. 141

osteoarthritis. Ultrasound may have some advantages in identifying these important injuries.[42] The anatomy and technique for identifying these structures has been described above. Due to their small size and complex anatomy, substantial operator experience is required for accurate diagnosis. However, the diagnosis is often suspected clinically and, as there are frequently other severe injuries, confirmation is often made arthroscopically.

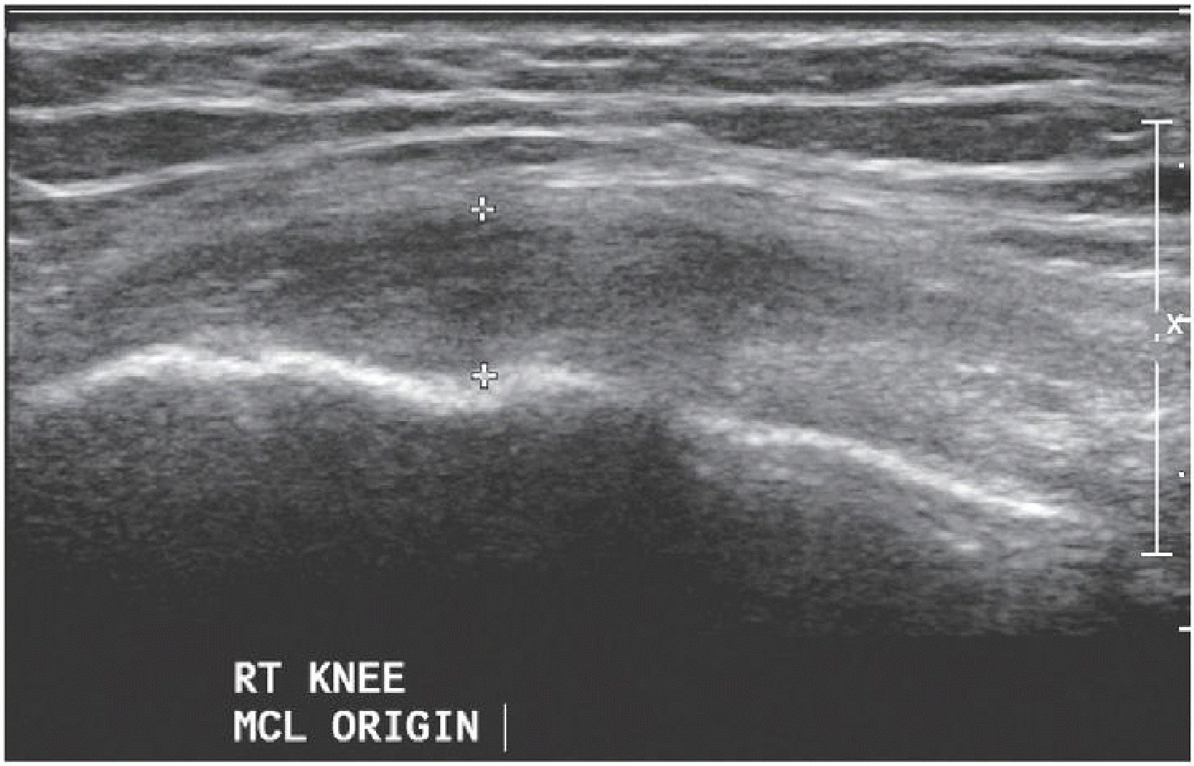

Figure 7.33. Longitudinal image of the MCL origin demonstrating a Grade III tear with complete loss of ligament (calipers).

Menisci

Meniscal tears are often appreciated on ultrasound as hypoechoic defects that reach the superior or inferior articular margin of the meniscus and should be distinguished from meniscal degeneration, where hypoechoic defects do not reach an articular surface. Dynamic movement of the knee during ultrasound interrogation often enhances visualization of tears, by creating relative movement of the tear margins. Paramensical cysts or ganglia are easily seen with ultrasound, and their presence is highly suggestive of a meniscal tear[43] (Figs. 7.34 and 7.35). It is the proximity of the mass to the meniscus that suggests the diagnosis. Depending on their structure and contents, cysts may appear unilocular or multilocular, anechoic or hypoechoic, and thin or thick-walled. There may be a visible connection to the meniscus. The sensitivity and specificity of ultrasound for meniscal tears is only moderate, of the order of 80%,[44] and MRI remains the preferred examination technique when meniscal injury is suspected.

The meniscus is often slightly extruded in the presence of osteoarthritic tibiofemoral changes, and this is readily appreciable on ultrasound[45](Fig. 7.15).

Iliotibial Band Friction Syndrome (ITBFS)

This results from inflammation of the ITB and surrounding tissues over the lateral femoral condyle/epicondyle, caused by friction as the ITB rubs against the bone.[46] It is common in runners. Patients usually complain of pain, with or without swelling, and sometimes clicking during flexion/extension. Potential sonographic abnormalities include thickening of the ITB with or without change in its fibrillar pattern, and edema, hypoechoic change, or neovascularity of the surrounding soft tissues (Fig. 7.36). The diagnosis is usually readily apparent clinically but ultrasound is useful to guide injection of steroid between tendon and condyle. A 25G needle is placed between condyle and ITB under ultrasound control using a short-axis approach, and the space distended with 40 mg of steroid such as betamethasone or methylprednisolone diluted in 2 to 3 mL of long-acting anesthetic such as bupivacaine. Needling the ITB can serve to attenuate the fibers and lessen the friction.

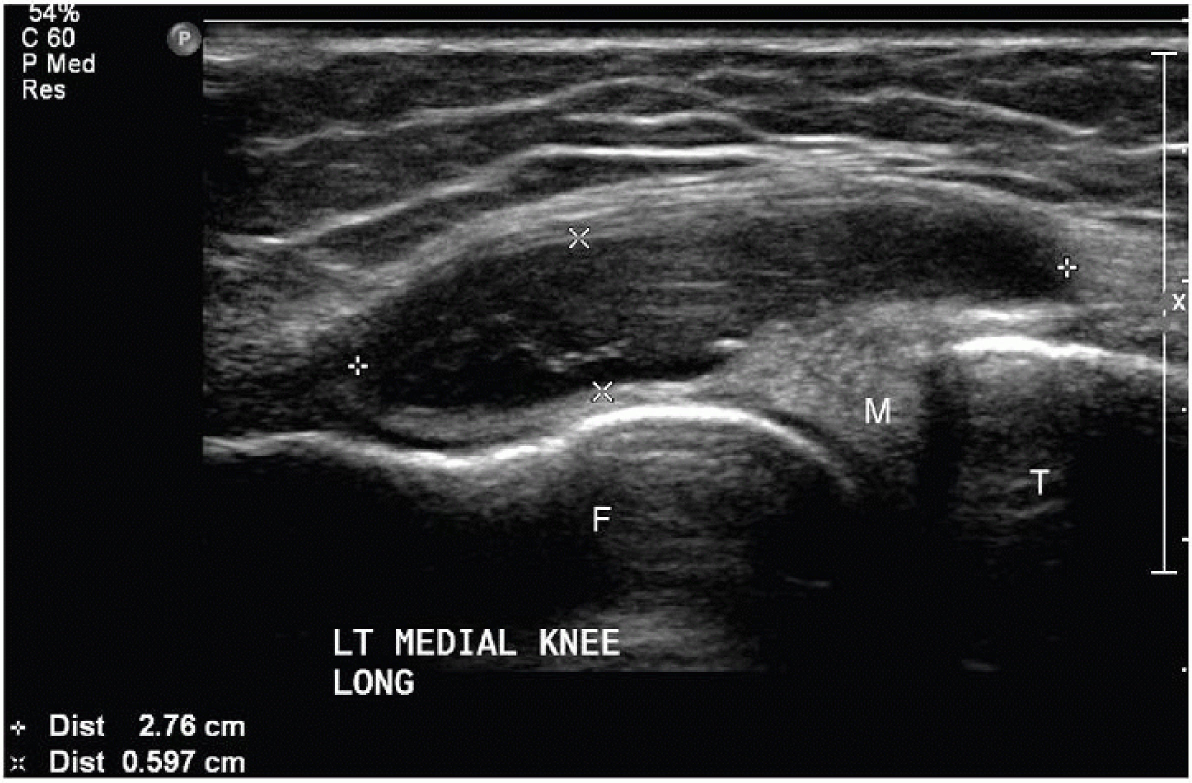

Figure 7.34. Longitudinal image of the medial knee demonstrating a meniscal cyst (calipers). Note the close proximity of the cyst and meniscus. F, femur; T, tibia; M, meniscus.

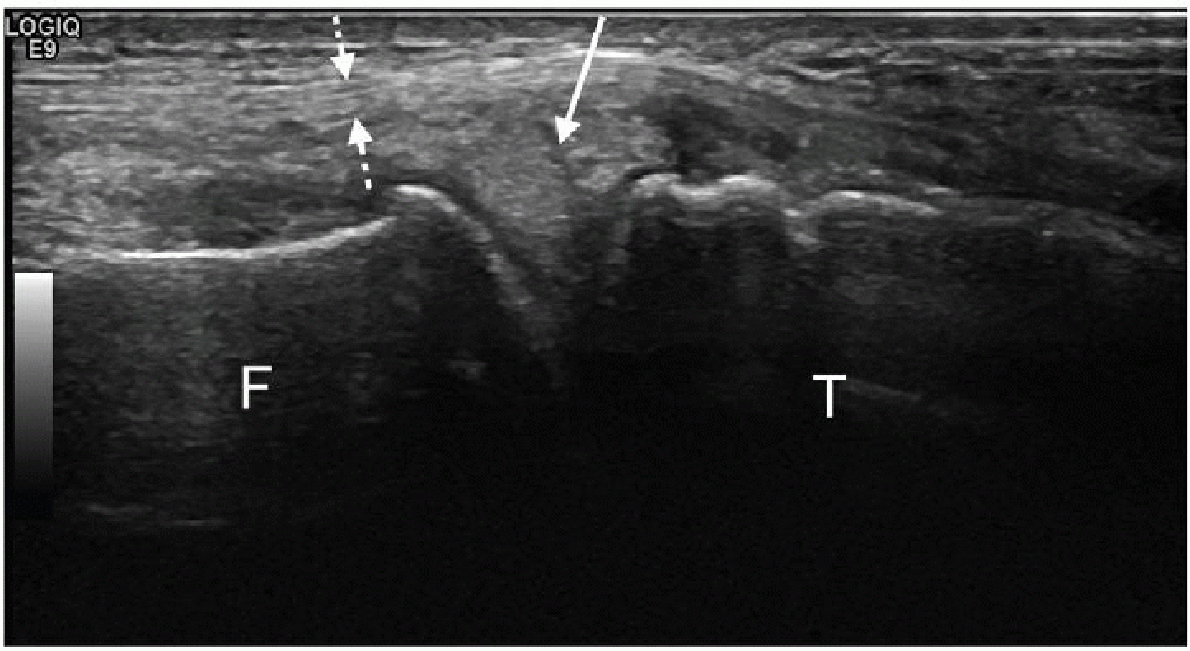

Figure 7.35. Longitudinal ultrasound image of the medial meniscus demonstrating an axial split tear (solid arrow). Dashed arrow = MCL.

Iliotibial Band Tendinopathy

This is distinguished clinically from ITBFS as it occurs more distally than ITBFS, with pain and tenderness inferior to the joint line, at the level of Gerdy tubercle, and occurs in older patients, often after knee arthroplasty. Sonographic findings are similar to those demonstrated for other tendinopathies (Fig. 7.37).

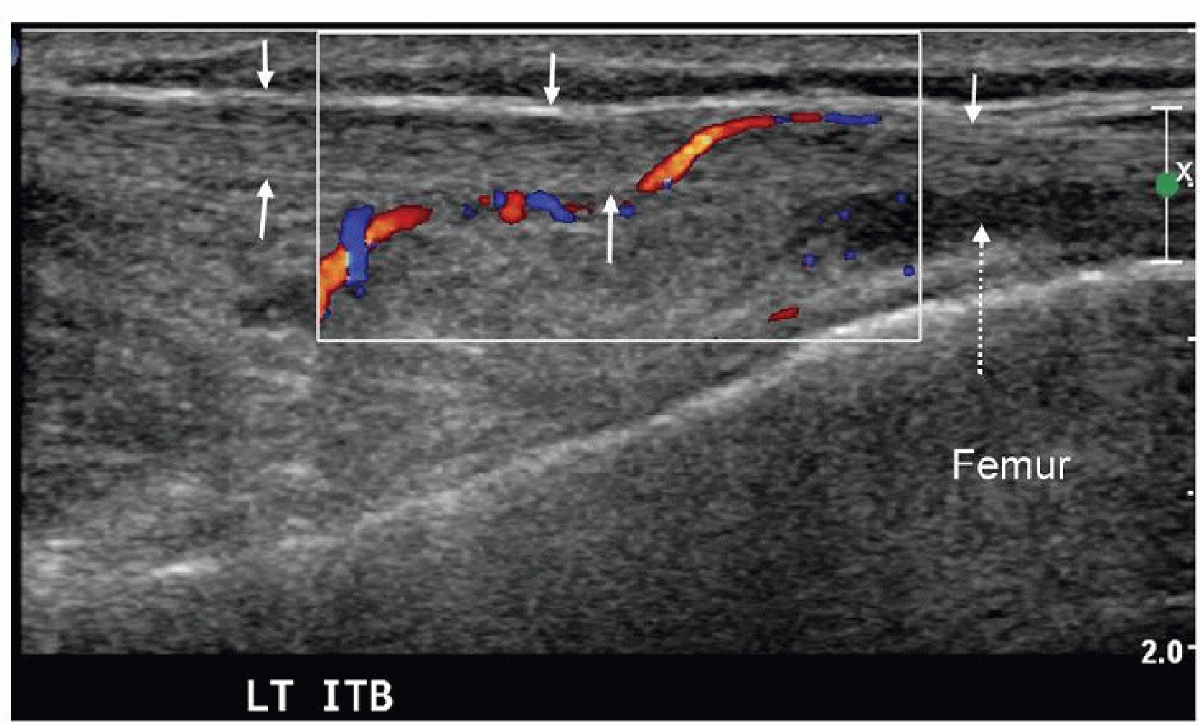

Figure 7.36. Longitudinal color Doppler image demonstrating ITBFS. ITB (solid arrows). Fluid deep to ITB (dashed arrow). Note hyperemia in and deep to the ITB.
P. 142

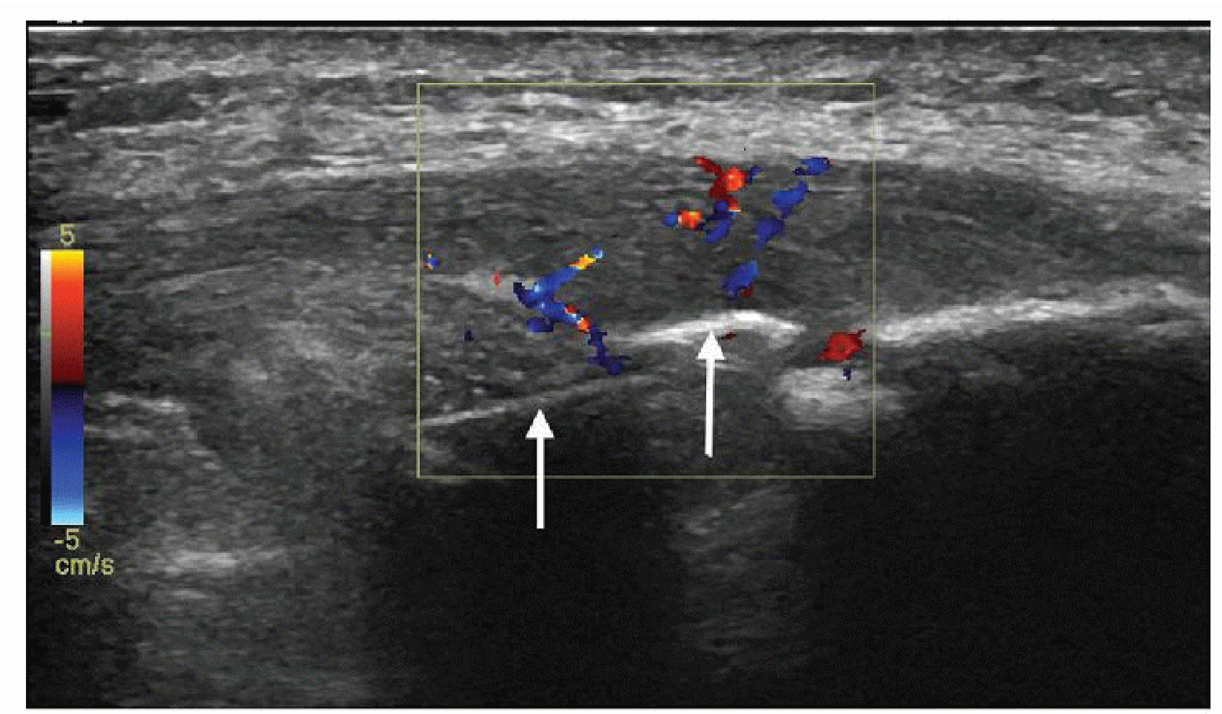

Figure 7.37. Longitudinal image of the ITB insertion demonstrating tendinosis (reduced echogenicity and hyperemia). Also note this patient has had an arthroplasty (arrows).

Pes Anserinus Bursitis

Inflammation of the bursa that is interposed between the tibia and the distal pes anserinus tendons is seen in athletes and older sedentary individuals, who often have diabetes or connective tissue disease.[47] Ultrasound shows the fluid-distended bursa between the MCL and the pes anserinus tendons. It sometimes has a thickened and hypervascular wall[48] (Fig. 7.38). As for ITBFS, the diagnosis is often apparent clinically, and ultrasound has an additional important role in guiding injections into the bursa[49] using the same technique and materials as for ITBFS.

Semimembranosus Tendinopathy

This is seen occasionally in young athletic patients, more commonly in less active older patients. It often coexists with degenerative changes in the knee,[50] and is more common in women.[51] It may be related to abnormal valgus orientation and friction at the adjacent medial joint line (with osteophytes possibly creating additional friction). Pain and discomfort occur more posteriorly and proximally than in pes anserinus bursitis. Ultrasound shows typical tendinopathy (Fig. 7.39).

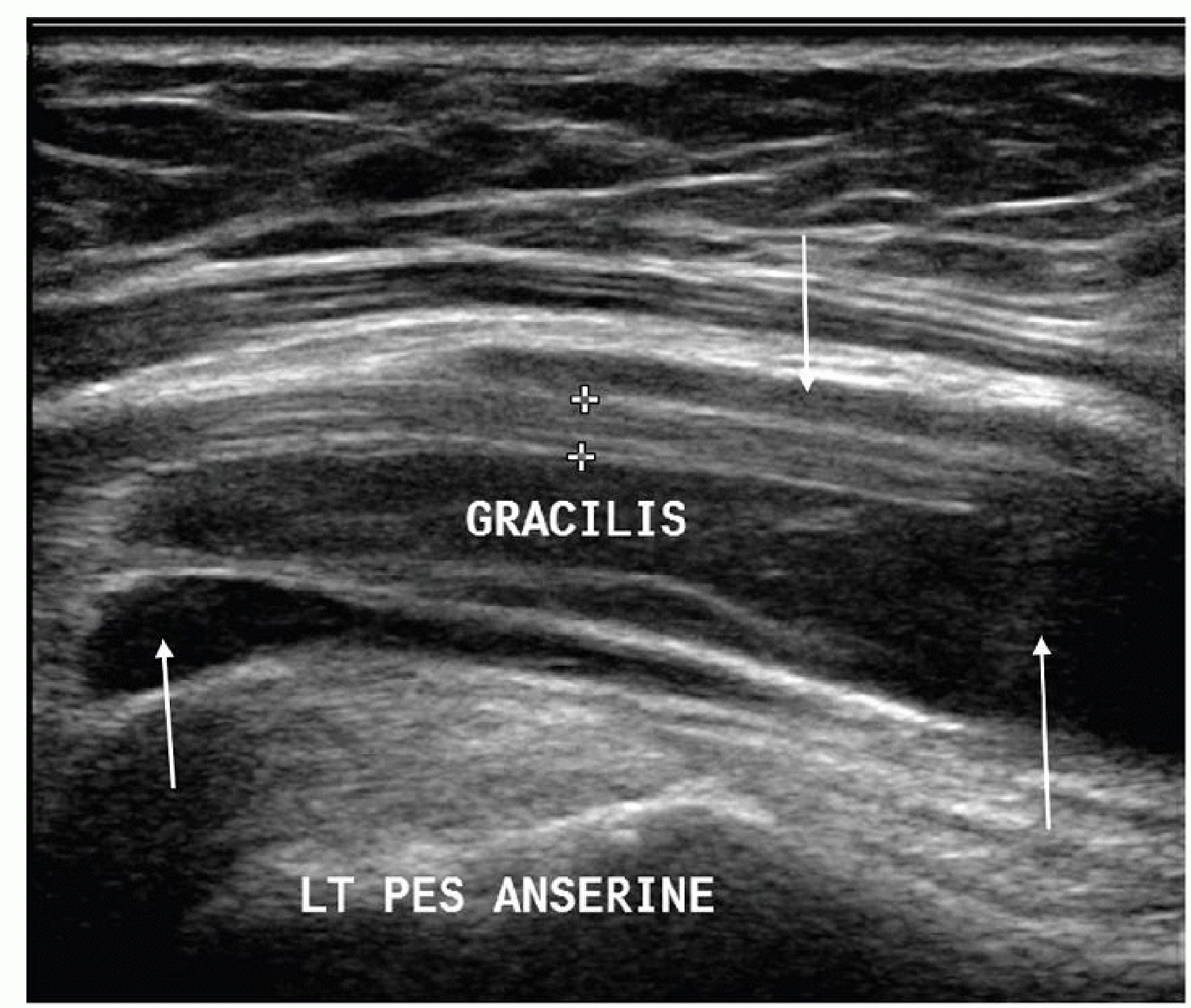

Figure 7.38. Longitudinal image of the pes anserinus in the presence of a large pes anserinus bursitis (arrows). Note separation of tendons such that gracilis is clearly seen (calipers).

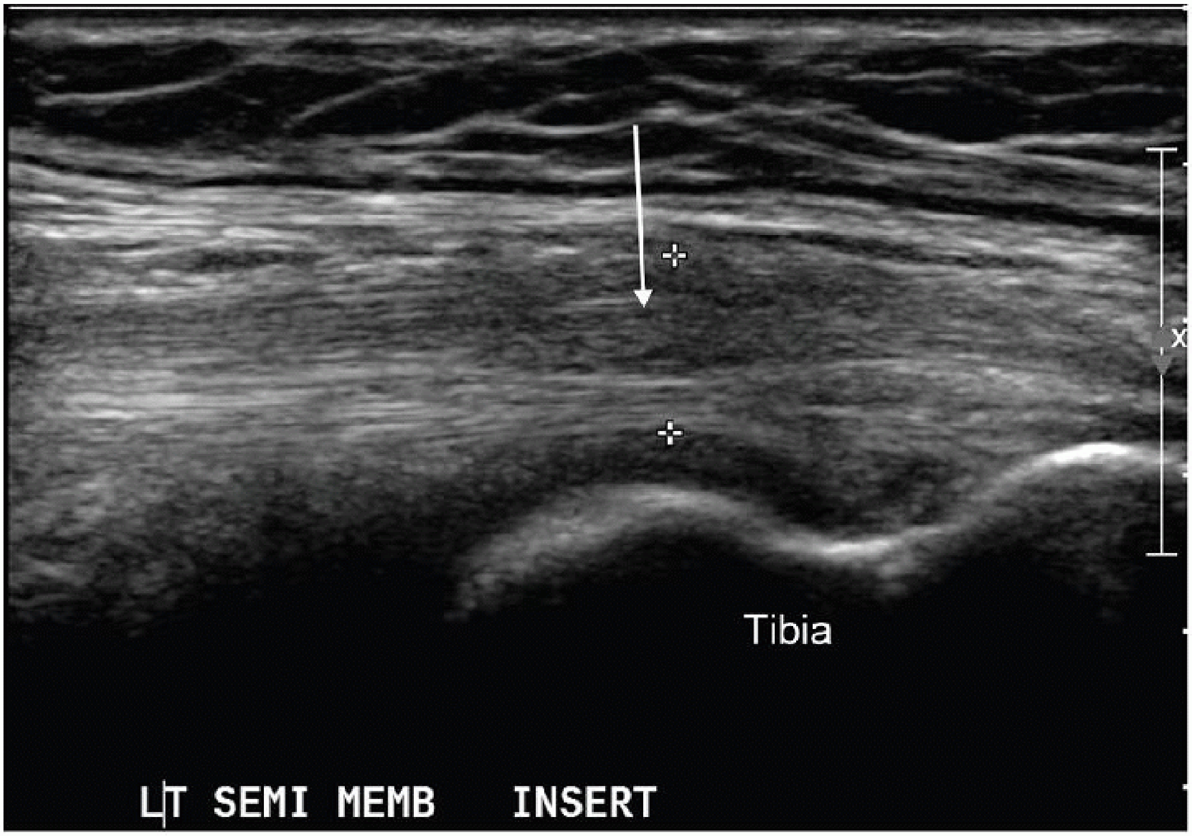

Figure 7.39. Longitudinal image of the distal semimembranosus tendon. The tendon is focally swollen and hypoechoic with loss of the normal fibrillary architecture due to tendinosis (arrow).

CRUCIATE LIGAMENTS

Cruciate ligament injuries occur when there is substantial overextension or overrotation of the knee, generally in sports or motor vehicle accidents. Diagnosis is important as surgical repair is often performed acutely, particularly in young and active patients.

The ACL is normally not identifiable with ultrasound, but degenerative injury may be inferred by the presence of ganglia,[52] and acute injury by a joint effusion and hematoma in the intercondylar notch[53] (Fig. 7.23) or by small variations in ultrasound measurements of tibial translation.[54] The PCL is identifiable,[55] (Fig. 7.22) particularly in those with a slim body habitus, and ultrasound has reasonable accuracy in detecting injury.[56,57] Frank disruption or thickening and loss of the normal architectural pattern can be seen in the accessible distal portion of the tendon.[58] Comparison should be made with the opposite side.

Ultrasound has very limited utility in the assessment of cruciate injuries, especially when compared with MRI, which has the substantial advantage of being able to identify associated injuries. MRI is the preferred examination for acute knee injuries.

CARTILAGE ASSESSMENT

Osteoarthritis is one of the most significant causes of morbidity in the western world.[59] Its pathology and etiology are complex. Genetic factors likely play a role,[60] but the

P. 143

condition is generally due to acute or chronic mechanical cartilage injury that triggers an inflammatory response. Manifestations include loss of cartilage thickness, surface uniformity and quality, meniscal degeneration, osteophyte formation, and adjacent capsular and synovial inflammation that progress gradually over years, causing generalized pain and disability.

MRI cartilage mapping techniques are rapidly developing for the quantification and qualification of cartilage damage in osteoarthritis.[61] In comparison, ultrasound currently has a limited role, although patellar and femoral cartilage can be assessed directly for thickness and qualitative surface changes such as loss of sharpness. Previous studies have shown reasonable correlation with arthroscopic[62] and MRI evaluation.[63] Secondary changes such as marginal osteophytes and neovascularity from associated synovitis can be detected and may correlate with severity of symptoms and be equivalent to MRI or radiography for this purpose.[64,65] Ultrasound may be useful in patients who present with symptomatic flares.

Calcium pyrophosphate deposition disease (CPPD) is a metabolic arthropathy of unknown etiology that is particularly common in the knee.[66] It may be asymptomatic or present with acute symptoms similar to gout or chronic symptoms similar to osteoarthritis. The diagnosis in acute cases is usually made by aspiration of joint fluid and detection of characteristic crystals by polarized light microscopy. However, CPPD crystals can also be detected by ultrasound as punctate or band-like hyperechoic foci in hyaline cartilage, that is, deep to the surface of the cartilage. Ultrasound is highly accurate, superior to radiography.[67]

NERVES

Neural lesions appreciable on ultrasound include post-traumatic neuromas and neoplasms. They produce focal thickening or enlargement of the nerve, often with a fusiform appearance that is usually elliptically elongated along the axis of the nerve (Fig. 7.40). They are particularly common after knee arthroscopy or arthroplasty.

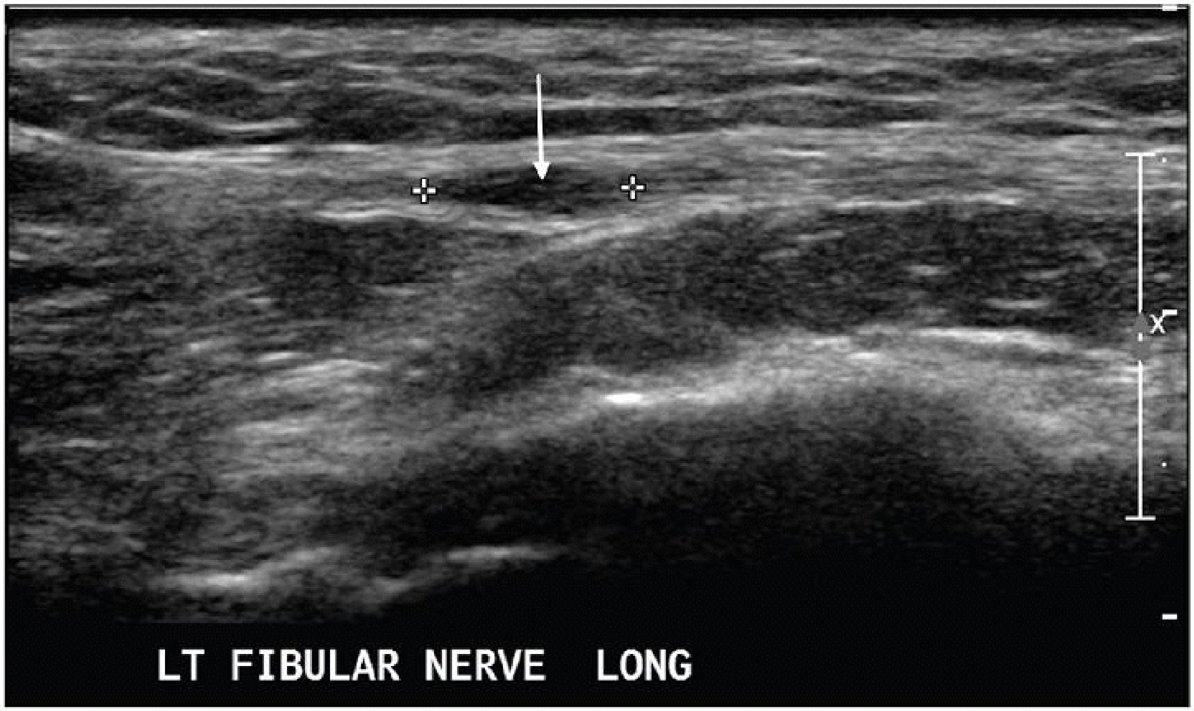

Figure 7.40. Longitudinal image of a small neuroma in the fibular nerve (arrow and calipers).

Compressive lesions of the nerves around the knee are also common. These include: Compression of the tibial nerve by popliteal artery aneurysm,[68] and compression or invasion of the common peroneal nerve by superior tibiofibular joint ganglion[69] (see also Chapter 9, p 206 and Chapter 12, p 288).

MUSCLES

Muscle tears around the knee most commonly involve the quadriceps (especially the rectus femoris) and gastrocnemius muscles. Tears of the medial gastrocnemius at the aponeurosis with soleus are termed "tennis leg."[70] The clinical presentation of a muscle tear is usually sufficient to make the diagnosis, but ultrasound is important to localize the injury to a particular muscle and quantify its severity. Clinically, muscle injuries are graded from I to III depending on the presence or absence of pain, weakness, or loss of function. Ultrasound shows hematoma, peri- and interfascial fluid, and discontinuity of muscle fibers[71] (Fig. 7.41). Tears most commonly occur at the myotendinous junction. It is important to look for associated tendinous injury, which can occur at the proximal and distal "free" ends of the tendon as well as at the intramuscular portion.[72]

BAKER CYST

A "Baker cyst" is a distended medial gastrocnemius-semimembranosus bursa. The bursa usually communicates with the knee joint. The communication may be congenital, or due to degeneration of the relatively thin joint capsule[73] that occurs with aging, possibly accelerated by degenerative conditions such as osteoarthritis. Baker cysts are extremely common. They are frequently found incidentally during deep vein thrombosis (DVT)

P. 144

scans[74] or present as asymptomatic popliteal masses, but they may present with acute, severe calf pain and swelling due to rupture or with local pressure effects causing pain, nerve compression (tibial or rarely common peroneal),[75] or vascular occlusion (popliteal vein or rarely artery).[76] They are markers for knee joint effusion, which is in turn a marker for knee joint pathology.[77]

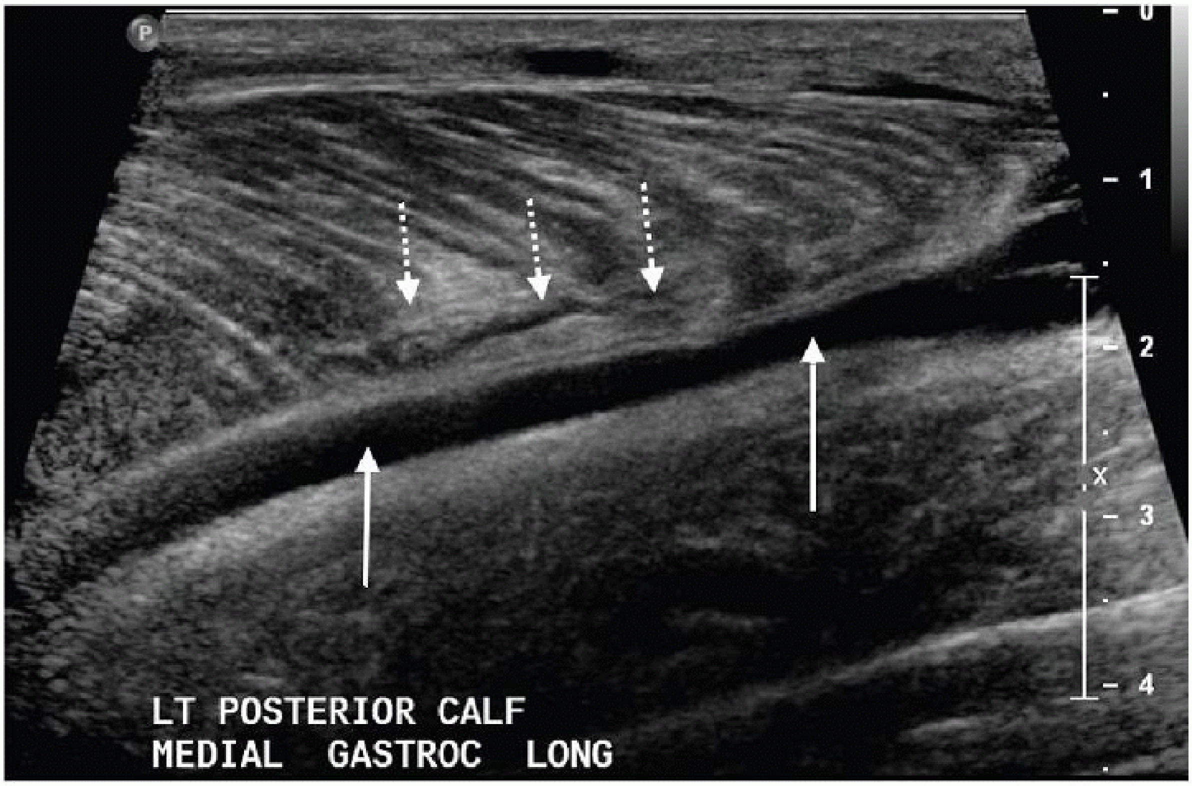

Figure 7.41. Longitudinal image of a medial gastrocnemius tear (tennis leg). Solid arrows, fluid (blood). Dashed arrow, myotendinous junction tear.

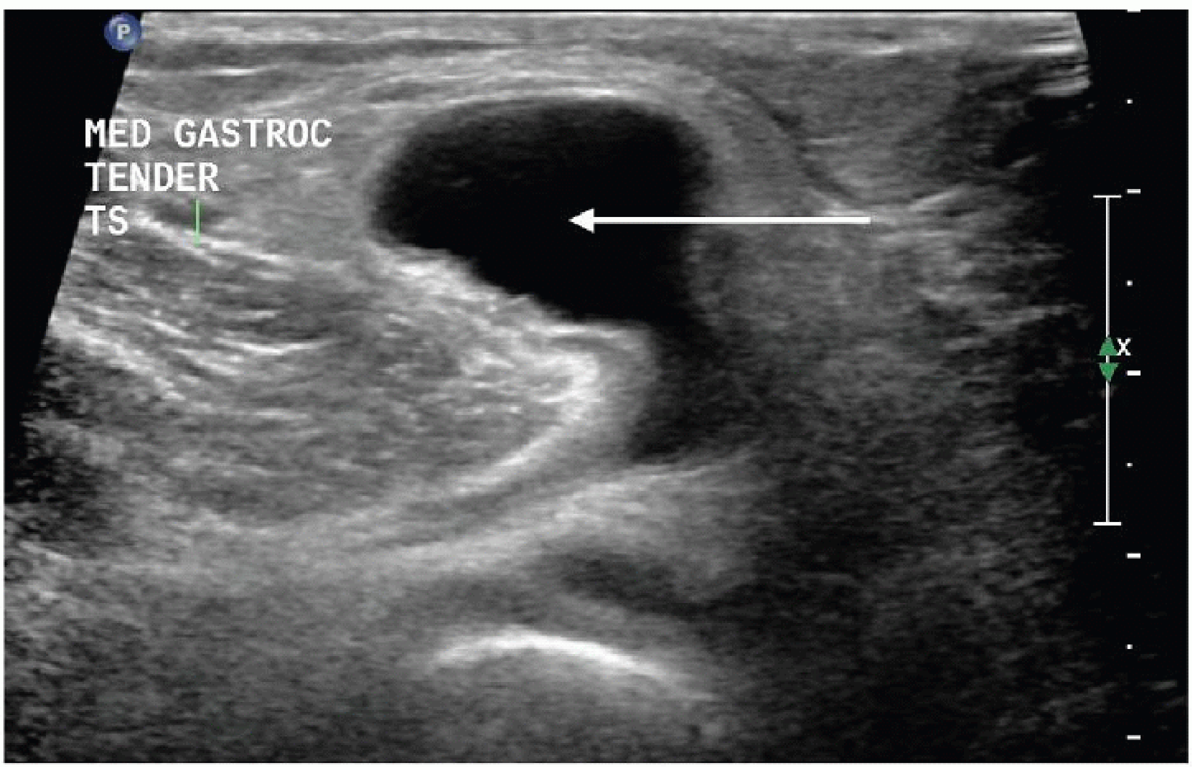

Figure 7.42. Transverse image of a simple Baker cyst. Arrow, anechoic fluid in the cyst. The echogenic and comma-shaped medial head of gastrocnemius marks the lateral margin of the neck of the cyst.

Usually, the bursa is an anechoic thin-walled round structure, filled with simple fluid (Fig. 7.42) and has a narrow neck or stalk between the medial head of gastrocnemius and the semimembranosus and more posterior semitendinosus tendons. However, when hemorrhage occurs in the joint or bursa, the fluid becomes echogenic and particulate. Inflammation causes thickening and indistinctness of the normally thin and sharply defined bursal wall, internal echoes due to synovial proliferation and hypervascularity (Fig. 7.43). Bursal rupture causes acute calf pain and swelling and can mimic gastrocnemius muscle tear, DVT, or even Achilles tendon tear. The ruptured bursa may deflate, but typically has an elongated inferior margin and extensive fluid tracks along fascial planes.

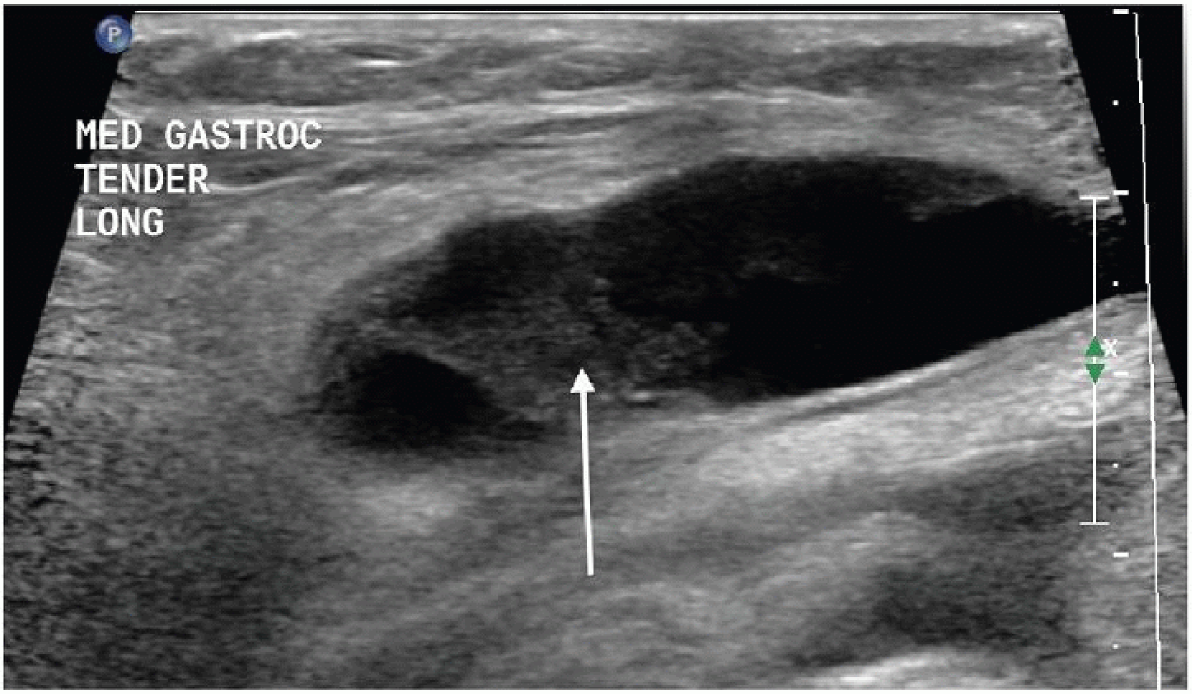

Figure 7.43. Transverse image of a Baker cyst. The internal echoes (arrow) are due to hemorrhage.

Tip:

The stalk of a Baker cyst lies between the comma-shaped medial head of gastrocnemius and the more medial semimembranosus and semitendinosus tendons.

PEDIATRIC KNEE

Ultrasound of the pediatric musculoskeletal system is described in more detail in Chapter 13.

The pediatric knee differs from the adult knee in several respects. The epiphyses, epiphyseal plates, apophyses, and apophyseal plates are not yet fully formed or fused, and are of variable appearance depending on their maturity. Tendon origins and insertions are not fully matured and have transitional zones of fibrocartilage (Fig. 7.44). The fibrocartilage and physeal echogenicity is quite variable in appearance depending on maturity, and ranges from totally anechoic to almost the echogenicity of tendon.

Tip:

The epiphysis and tendon insertions can be very echo poor and should not be mistaken for fluid or tears. Careful scanning should be performed when diagnosing fluid or a tear, including scanning of the opposite side.

The most common sonographic abnormality of the pediatric knee is traction apophysitis, an overuse injury at the osteotendinous junction. There are two eponymously named syndromes:

Osgood-Schlatter disease: this is a traction osteochondritis of the tibial tubercle, at the distal patellar tendon insertion. It is diagnosed clinically by swelling and tenderness at the tuberosity. Ultrasound in conjunction with plain radiographs determines severity and acuity by demonstrating color Doppler hyperemia at and around the fragmented apophysis (Figs. 7.45, 7.46, 7.47).

Sinding-Larsen-Johansson disease: this is a traction apophysitis of the inferior patella involving the tendinous attachment of the patellar tendon. It typically occurs in early adolescence in athletic children and manifests as tenderness and swelling. Ultrasound shows abnormal

P. 145

thickening of the superior part of the tendon, and irregularity and fragmentation of the adjacent inferior patella (Fig. 7.48).

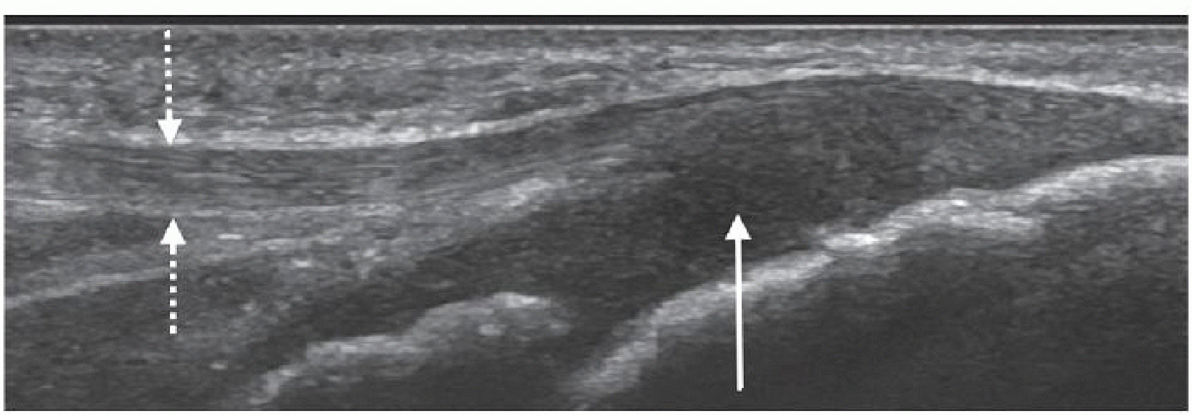

Figure 7.44. Longitudinal scan of the patellar tendon insertion of an adolescent. The epiphysis and the apophysis where the tendon inserts have not fully ossified. Solid arrow, fibrocartilage that will subsequently ossify. Dashed arrow, distal patella tendon.

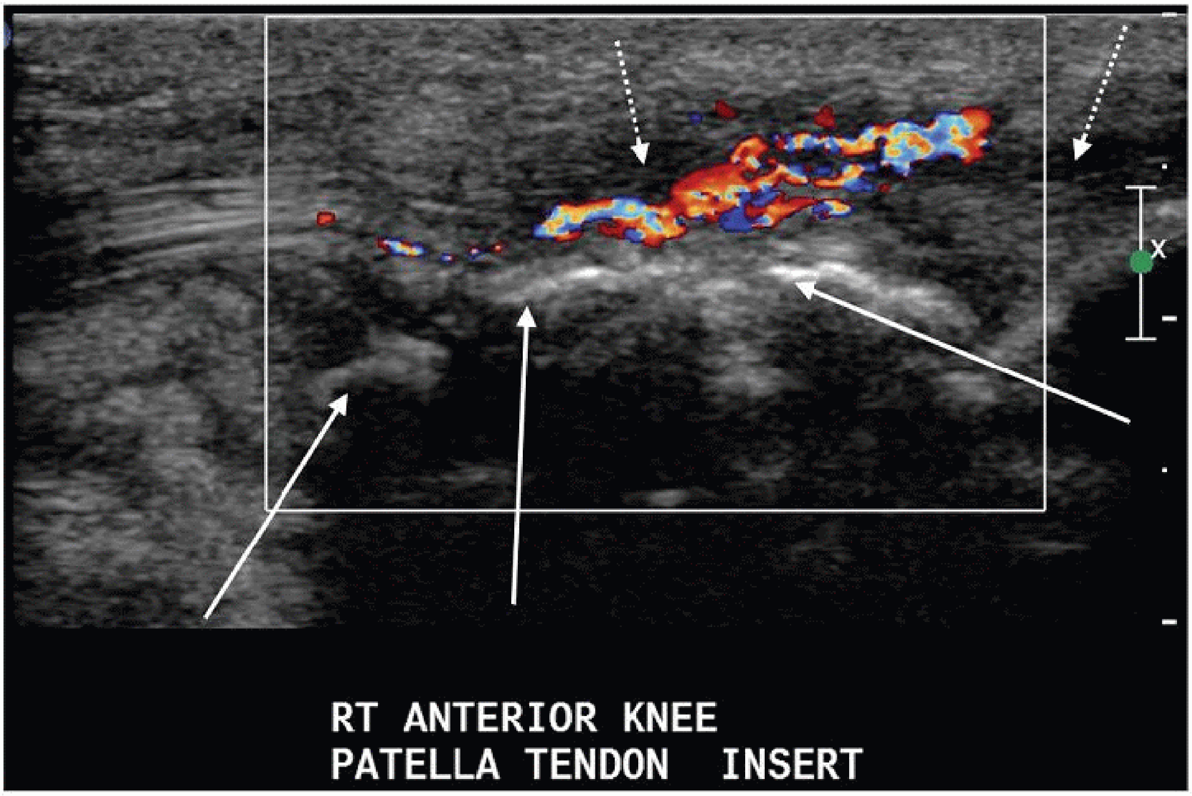

Figure 7.45. Longitudinal color Doppler image of the patellar tendon insertion in Osgood-Schlatter disease. Solid arrow, fragmented tibial apophysis. Dashed arrow, swollen tendon and hyperemia.

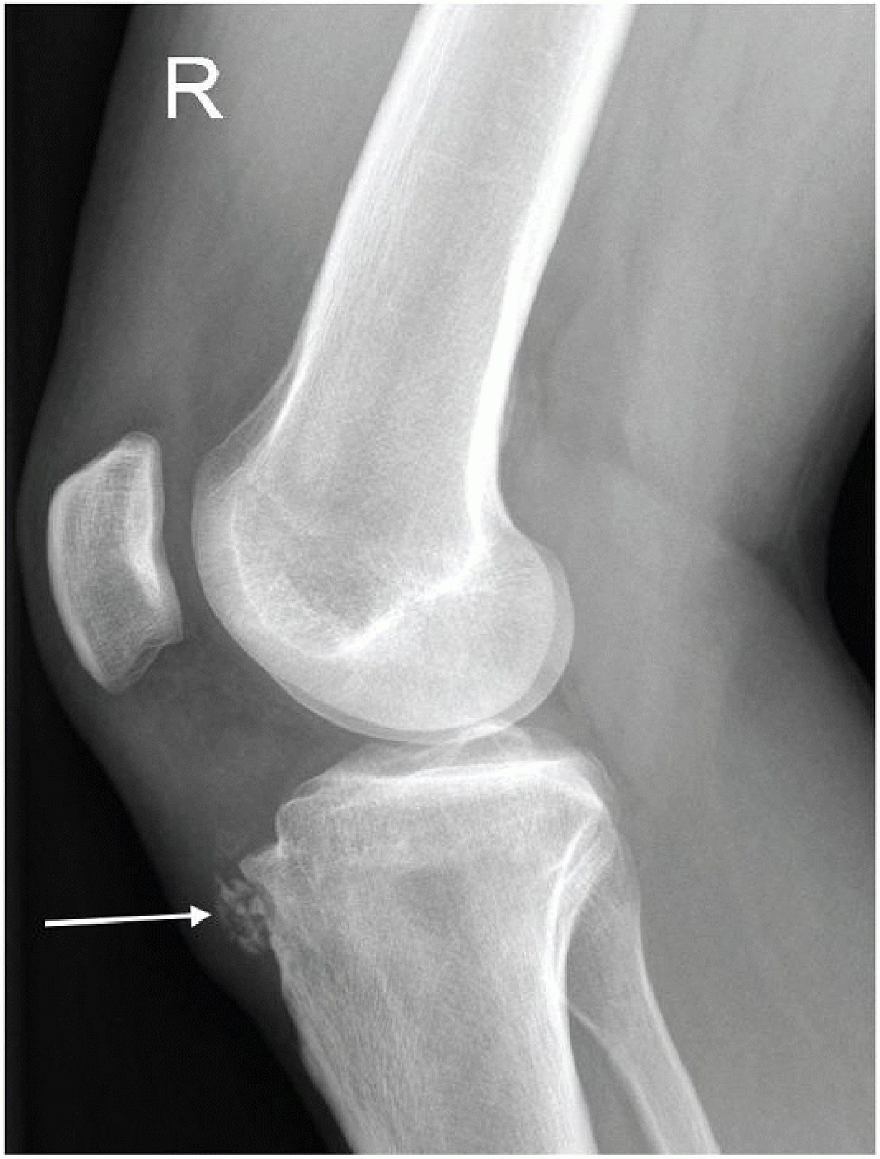

Figure 7.46. Same patient as in Figure 7.45; lateral radiograph demonstrating fragmentation at tibial apophysis (arrow).

Other pediatric knee conditions seen on ultrasound include joint effusions that are important in suspected sepsis; Baker cysts, which may be an early sign of juvenile rheumatoid arthritis but are also seen in otherwise normal pediatric knees; bursitis; and tendinopathy in athletic children.

VASCULAR ABNORMALITIES

Vascular abnormalities around the knee are few and are generally isolated to the popliteal fossa.

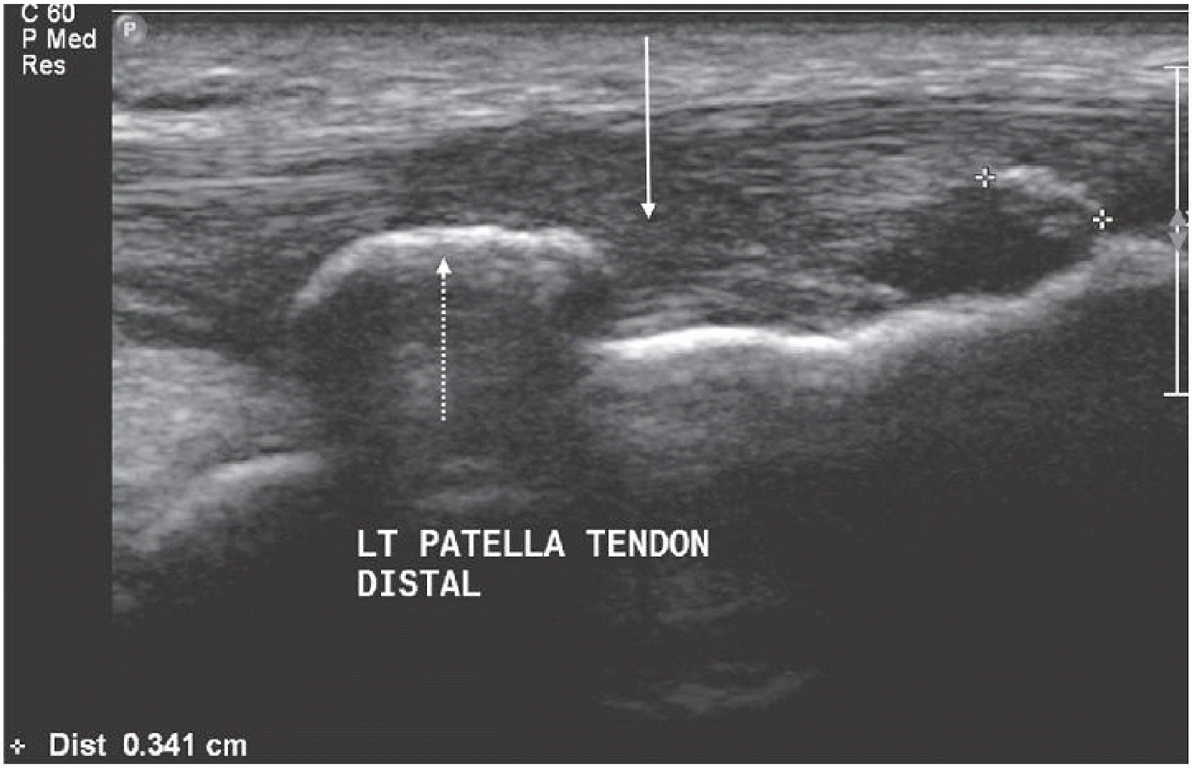

Figure 7.47. Longitudinal image of the patellar tendon insertion in Osgood-Schlatter disease. Solid arrow, tendon change with loss of echogenicity and architecture. Dashed arrow, fragmented apophysis. caliper, bony avulsion from tibia.

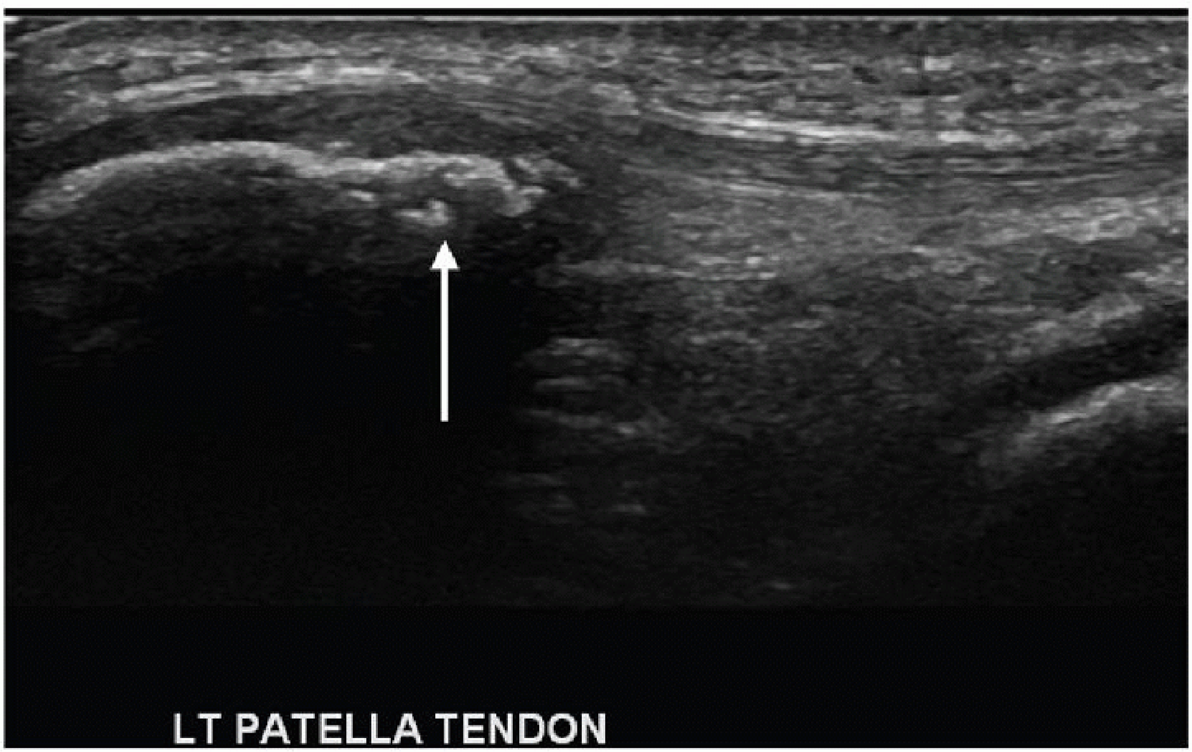

Figure 7.48. Longitudinal image of the patella apex and patella tendon origin in Sinding-Larsen-Johansson disease. Arrow, fragmentation of the patella apex. The adjacent patellar tendon is thickened and hypoechoic in keeping with tendinosis.

Popliteal Aneurysm

The ultrasound diagnosis of popliteal artery aneurysm is sometimes a surprise finding in what may have been clinically considered as a Baker cyst. The artery is dilated, shows turbulent flow on color Doppler, and may contain hypoechoic thrombus.

If an aneurysm is found, the opposite side and the aorta should be examined as there is a high incidence of coexistent aneurysms. Measurements should be taken and a note made of complications such as mural thrombus, dissection, or leakage. Large popliteal aneurysms can cause calf swelling from venous obstruction and may lead to DVT (Fig. 7.49).

Deep Vein Thrombosis

Some patients with calf pain may have a DVT, and the popliteal vein should be assessed for compressibility and for augmentation when the calf is squeezed.

P. 146

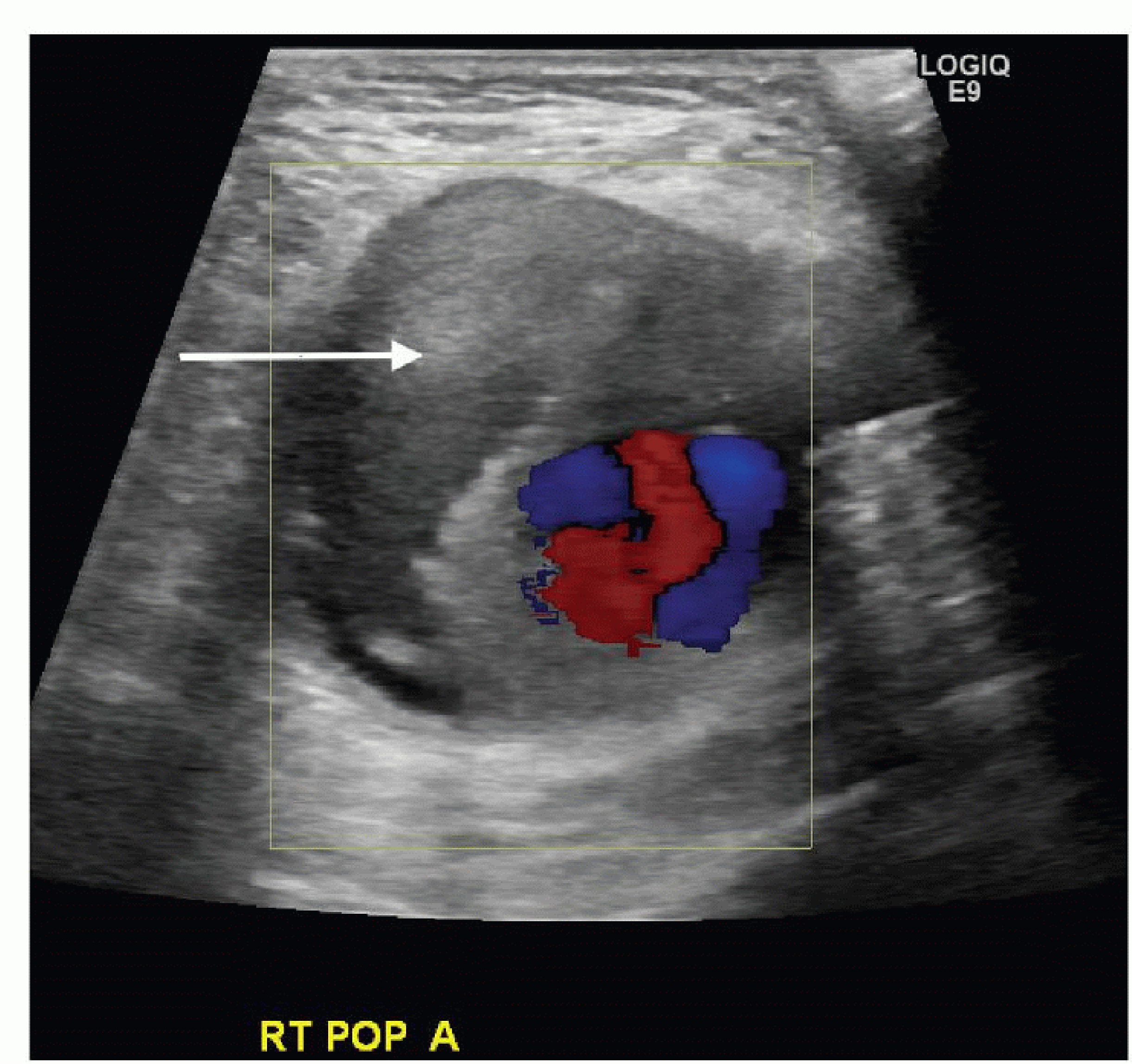

Figure 7.49. Transverse image demonstrating a large popliteal aneurysm with dissection. Arrow, region of dissection. Color Doppler demonstrates patent lumen.

Popliteal Artery Entrapment Syndrome

Popliteal artery entrapment syndrome (PAES) presents clinically with claudication symptoms during exercise in young, otherwise healthy patients (usually males). It is due to anatomical variation(s) in the popliteal fossa, either an abnormal course of the artery or abnormal slips of the medial head of gastrocnemius.[78]

PAES has been well described as a clinical entity, but anatomical abnormality can also occur in the absence of symptoms, and clinical correlation is required to make the diagnosis.

Although MRI/MRA or catheter angiography are usually employed, ultrasound may be superior.[79] It can be used dynamically and demonstrates the vascular stenosis and, with sufficient operator skill, the causal anatomical abnormality. The ultrasound examination commences with a full arterial study of the leg to ensure that the arterial supply is normal. With the patient prone and the knee slightly flexed by a bolster under the ankle, the popliteal fossa is scanned, noting the relative positions of the popliteal artery and the gastrocnemius and popliteus muscles. Comparison should be performed with the other side.

The patient is then asked to plantar flex the foot against resistance provided by an assistant. The resistance should be sufficient to prevent flexion beyond 90 degrees. As this is occurring, the sonologist should note the diameter of the popliteal artery and measure flow velocity. There is normally a small degree of narrowing of the artery with slight elevation of velocities. In PAES, the artery narrows or occludes (Fig. 7.50). The opposite leg should be examined for comparison.

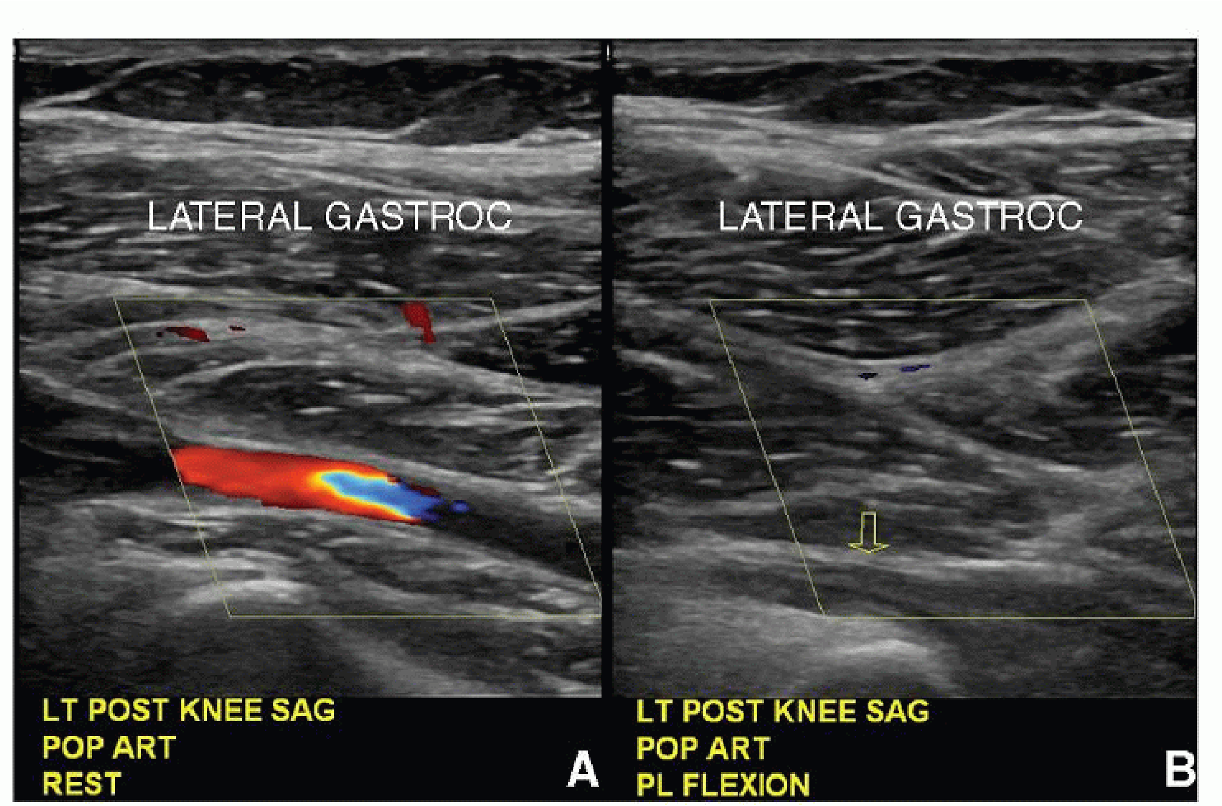

Figure 7.50. Color Doppler images demonstrating PAES. A: Color Doppler flow is seen in the popliteal artery at the level of the tibial plateau at rest. B: No flow is seen in the popliteal artery during resisted plantar flexion.

CONCLUSION

Proficiency and experience with ultrasound of the knee, a deceptively complex joint, is hard-earned but rewarding. Tendon, muscle, nerve, and intra-articular pathologies are common and well assessed with ultrasound.

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