Sonography of the Knee and Lower Limb

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INTRODUCTION

Ultrasound is an important adjunct to the clinical examination in the diagnosis of musculoskeletal disorders. Knee problems account for 10% of referrals to orthopedic surgeons. The technique has shown accuracy in the workup of soft-tissue and joint pathology. Knee ultrasound can be routinely used to evaluate traumatic and inflammatory disorders.

Nearly every kind of orthopedic disorder presents in the knee. In addition to vulnerability to blunt and penetrating injury, the spectrum of pathology of the knee is broad. In young patients, pathology may appear at birth, as in hypoplasia of the patella seen in Nail-Patella syndrome, or may become apparent later in life. The metaphysis around the knee is the part of the lower limb with the most active bone growth during adolescence; as a consequence of the unique anatomy and physiology of the growth plate, it is a common site of osteomyelitis and primary bone tumors. Young active patients usually present with traumatic injury of the bone and/or soft tissues, such as collateral ligament injuries or avulsion of the tibial tuberosity. Older and generally less active patients are more likely to present with degenerative joint disease. The knee may be affected by metabolic, inflammatory, noninflammatory, or neoplastic disease. It is prone to almost every kind of arthritis, particularly osteoarthritis. Moreover, it is the joint most commonly affected by osteochondritis dissecans and intra-articular loose body formation.

Surgeries are common in the knee. Surgical arthroscopy, widely used for the diagnosis of knee complaints, has become almost a routine investigation for any suspected intra-articular lesion. However, if arthroscopy of the knee can be avoided by the use of other diagnostic techniques, recovery and convalescence are greatly accelerated. Total knee replacement surgery, for the relief of disabling arthritis, whether rheumatoid or degenerative, has a high success rate. The different types of knee prostheses as well as the imaging features by radiography, computed tomography (CT), magnetic resonance imaging (MRI), and ultrasound have been described by.[1] The sonographer must be familiar with changes in knee anatomy after surgery in order to make diagnoses that are meaningful postoperatively.

Sonography provides considerable information about tumors and their relationship to surrounding tissues. In fact, ultrasound is useful as the first method for diagnosis of giant cell tumors of tendon sheaths[2] and the technique has also been useful in the diagnosis of pigmented villonodular synovitis in the knee joint.[3] The possibility of ready comparison between symptomatic and asymptomic knees, as well as direct correlation of sonographic findings to the patient's symptoms, are advantages of ultrasound. A focused knee study, i.e. using patients' guidance to the painful site, can usually be performed more efficiently with ultrasound than with MRI. Advantages of the former include greater availability, real-time examination, and reduced cost.

The main strength of knee ultrasound is its assessment of periarticular disease. Ultrasound precisely demonstrates the fibrillar microanatomy of tendons, muscles, and ligaments, and it reveals periarticular soft-tissue masses to those familiar with ultrasound knee anatomy. Ultrasound is also effective for joint effusions, synovial thickening, bursal fluid collections, intra-articular loose bodies, ganglia, ligament and tendon tears, tendonitis, and occult fractures.[4] This chapter reviews the scanning technique and role of ultrasound in the evaluation of traumatic injuries and chronic knee pain. Knowledge of the location of pain and the characteristics of the injury usually narrow the differential diagnosis. Therefore, this chapter will use a clinically oriented approach.

Magnetic resonance imaging and ultrasound are the modalities of choice for evaluation of soft-tissue pathology of the knee. Magnetic resonance imaging is typically preferred for evaluation of chronic symptoms of internal derangement. On the other hand, ultrasound is the

Table 20.1: Knee pathology: noninvasive imaging options.

Modality	*Advantages*	*Primary use*
Radiographs (weight-bearing films over 50 years of age)	Inexpensive	Initial study High accuracy in detecting fractures Sensitive in detecting joint space narrowing Excludes bone tumors (e.g. giant cell tumor)
MRI	Superior soft-tissue contrast Ideally suited for cartilage imaging	Diagnose internal derangement Occult fractures Staging of tumors
CT	Fast and accurate measurements of bone alignment Superior detail of cortex and calcification	Measurement of dysplasia of trochlear groove and placement of tibial tuberosity Osteoid osteoma Assessment of early cortical destruction
Ultrasound	Inexpensive Widely available Rapid Always right-left comparison Can be used at bedside Spatial/contrast resolution unaffected when metal is present No ionizing radiation	Differential diagnosis of anterior knee pain Differential diagnosis of a popliteal space mass First line examination for a suspected soft-tissue lesion Assessing effusion and synovial disease Guide aspiration or biopsy

Algorithm is based on the authors' personal practice experience.

preferred choice for initial imaging evaluation, or when clinical features suggest tendon disease, bursal inflammation, synovial abnormality, or capsular disease. A unique advantage of ultrasound in the examination of the knee is its ability to perform dynamic testing of ligaments and tendons, e.g. the stress loading of ligaments. Other benefits include the capacity for high-resolution imaging of internal tendon structure, and the capacity to accurately distinguish fluid collections from soft-tissue edema. Demand for knee sonography has increased recently due to its significantly lower cost compared to MRI (Table 20.1).

Diagnostic ultrasound is an invaluable technique in the management of a variety of musculoskeletal disorders. Technical innovations such as color-flow Doppler, three-dimensional surface reconstruction, and ultrasound contrast agents have already introduced new areas to clinical practice. As image quality improves, the role of diagnostic ultrasound in clinical orthopedic practice increases. Well-established professional societies for practitioners who specialize in musculoskeletal ultrasound currently exist, though their numbers are still limited. We hope that this chapter will increase the interest in this particular field.

Safety and availability are strengths of diagnostic ultrasound. Dependence on a skilled operator and the steep learning curve for acquiring musculoskeletal ultrasound skills are disadvantages. Inaccurate diagnoses may easily result from evaluation by an inexperienced sonographer. Since interpretation of ultrasound examinations is hard to standardize and image quality is patient dependent, images should be reviewed by a physician, while the patient is still present. The dynamic aspect of the examination is also important. Therefore, video clips should be recorded for later review when appropriate. Quality must be monitored by measuring outcome, by comparing with results of other methods of imaging, and by correlating with clinical findings. Institutions with this rigorous process of quality initiatives for musculoskeletal ultrasound in the United States should consider accrediting their program with the American Institute of Ultrasound in Medicine or the American College of Radiology. Further consideration should be given to employing sonographers who are registered in musculoskeletal sonography (RMSK, see www.ardms.org). Clearly, the organization of a musculoskeletal ultrasound service is quite demanding.

EQUIPMENT, POSITIONING REQUIREMENTS, AND SONOGRAPHIC TECHNIQUE

Ultrasound examination of the knee is first directed to the anterior aspect of the joint, followed by the medial and lateral aspects, and concludes with the study of the popliteal fossa (Table 20.2). Knee ultrasound requires a high-frequency linear array transducer (7.5 MHz or higher). In our clinic, a 12 MHz transducer is used most often. Structures in the posterior knee joint space deep in the popliteal fossa, however, may be best examined with a 5 MHz linear array transducer. Rarely, a 5 MHz curved array transducer may be of value in examining the popliteal fossa. The longitudinal view offers the best imaging plane for the anatomical structures shown at the anterior, medial, and lateral aspects of the knee. A few specific exceptions will be mentioned below. In the popliteal fossa, e.g. the transverse view is best for an initial survey.

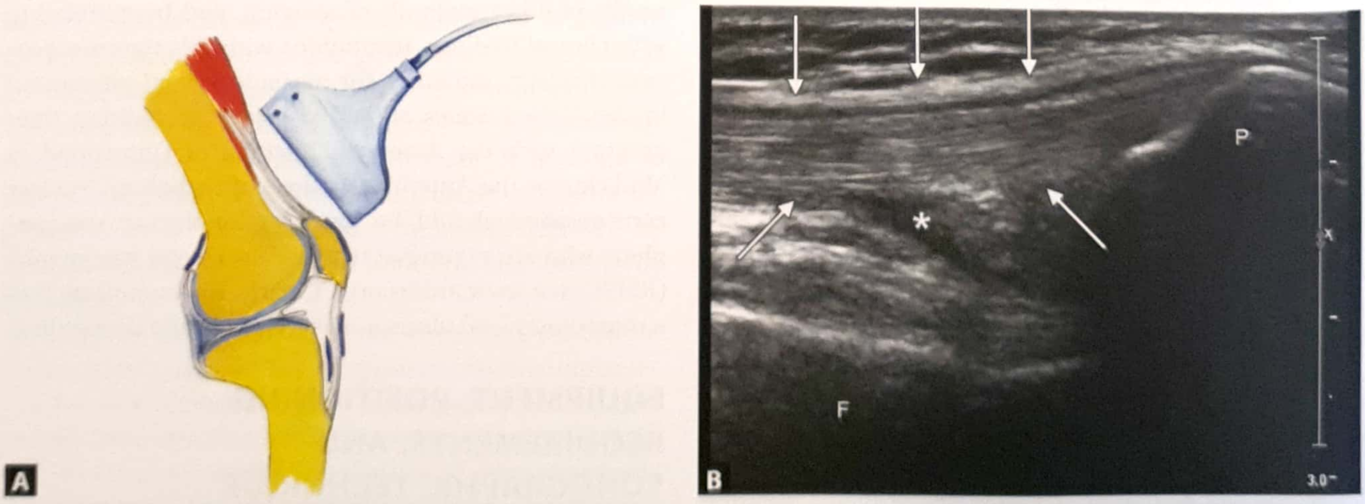
Table 20.2: Anterior, medial, lateral, and posterior examination of the knee.

Extension	*Flexion*
Anterior: Suprapatellar bursa, medial and lateral patellar recesses, quadriceps tendon	*Anterior*: Patellar tendon, Hoffa's fat pad, deep infrapatellar bursa
Medial: Medial collateral ligament, body of the medial meniscus, medial femorotibial joint space, pes anserine tendon insertion	*Lateral*: Iliotibial band, popliteal tendon, lateral collateral ligament, distal biceps femoris tendon, body of the lateral meniscus, lateral femorotibial joint space
Posterior with 7.5 MHz: Popliteal artery and vein [and nerve], gastrocnemius muscle, Baker's cyst (± calf distally)	*Posterior with 5 MHz*: Posterior cruciate ligament, posterior joint space, posterior horn of menisci

The entire routine examination of the knee can be completed in 20 minutes. The examination begins with the patient supine and the knee in full extension. Imaging of the anterior aspect of the knee allows identification and evaluation of the *suprapatellar bursa*, medial and lateral patellar recesses of the joint (transverse view), quadriceps tendon, distal muscle components of the quadriceps, and anterior horns of the medial and lateral menisci (Figs. 20.1A and B). The knee is then placed in moderate flexion (30°–45°) and the patellar tendon, Hoffa's fat pad, deep infrapatellar bursa, and subcutaneous soft tissue, including the prepatellar and superficial infrapatellar bursae, are studied (Figs. 20.2A to C). Complete flexion of the knee is utilized to examine the middle and distal portions of the anterior cruciate ligament (ACL), articular cartilage covering the intercondylar notch (femoral trochlea), and weight-bearing aspects of both femoral condyles (Figs. 20.3A to C).

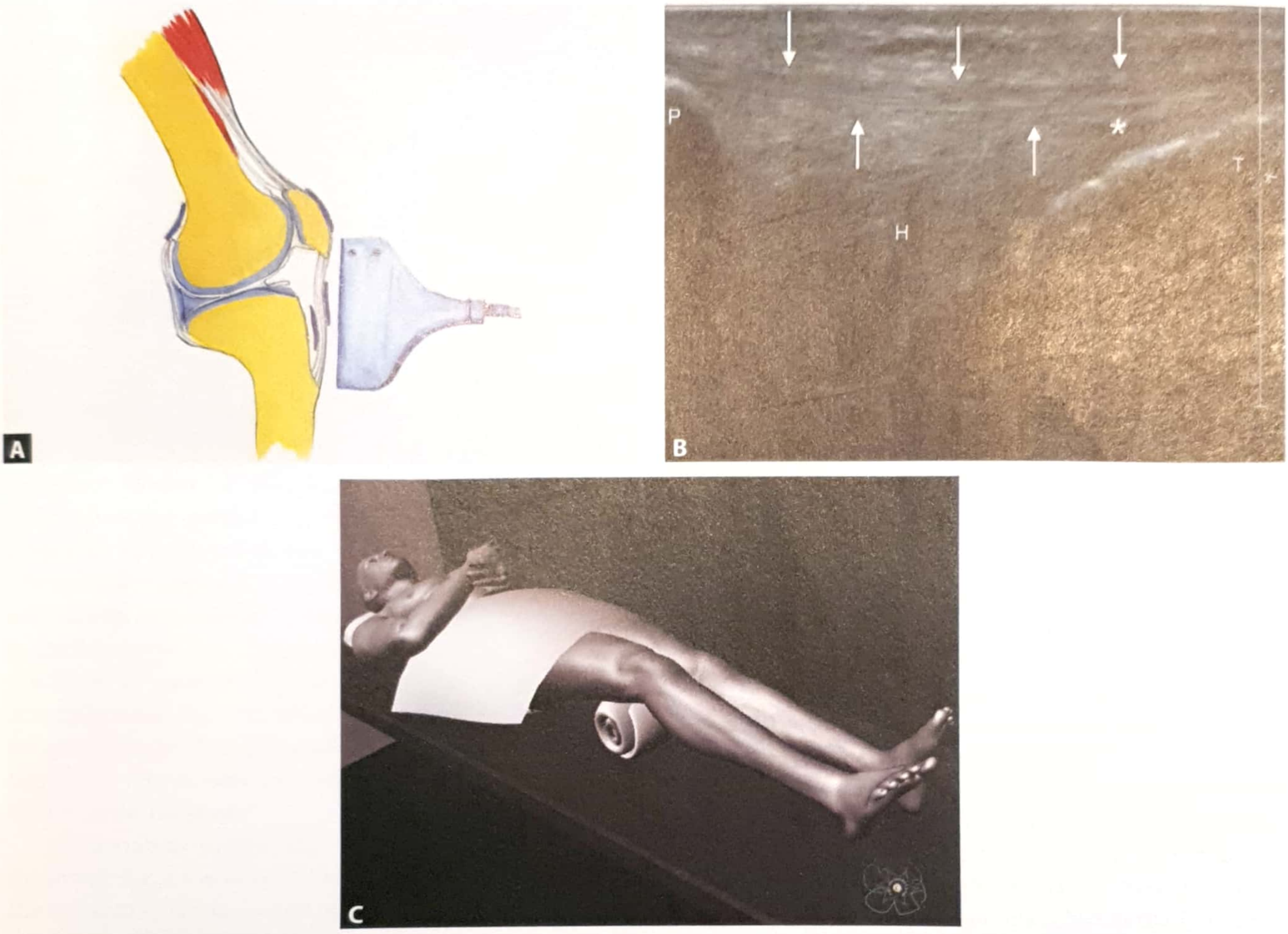
When the transducer is positioned anteriorly along the long axis in the midline of the distal thigh with the leg straight, both the quadriceps tendon and the suprapatellar bursa are examined (Figs. 20.1A and B). Moderate knee flexion is required for optimal filling of the bursa. The base of the patella is the inferior landmark of this image. Maintaining this longitudinal imaging plane, the

Figs. 20.1A and B: Ultrasound of quadriceps tendon and suprapatellar bursa.



(A) Schematic drawing. Lateral view of the knee with transducer placement over the suprapatellar tissues. (B) Ultrasound image obtained in the midline, demonstrating a longitudinal or long axis view of the anterior left knee. The layered structure of the quadriceps tendon (arrows) and its insertion on the patella (P) are noted between the subcutaneous and prefemoral fat. The suprapatellar bursa (*) of the knee joint separates the tendon from the prefemoral fat and the diaphysis of the femur (F).

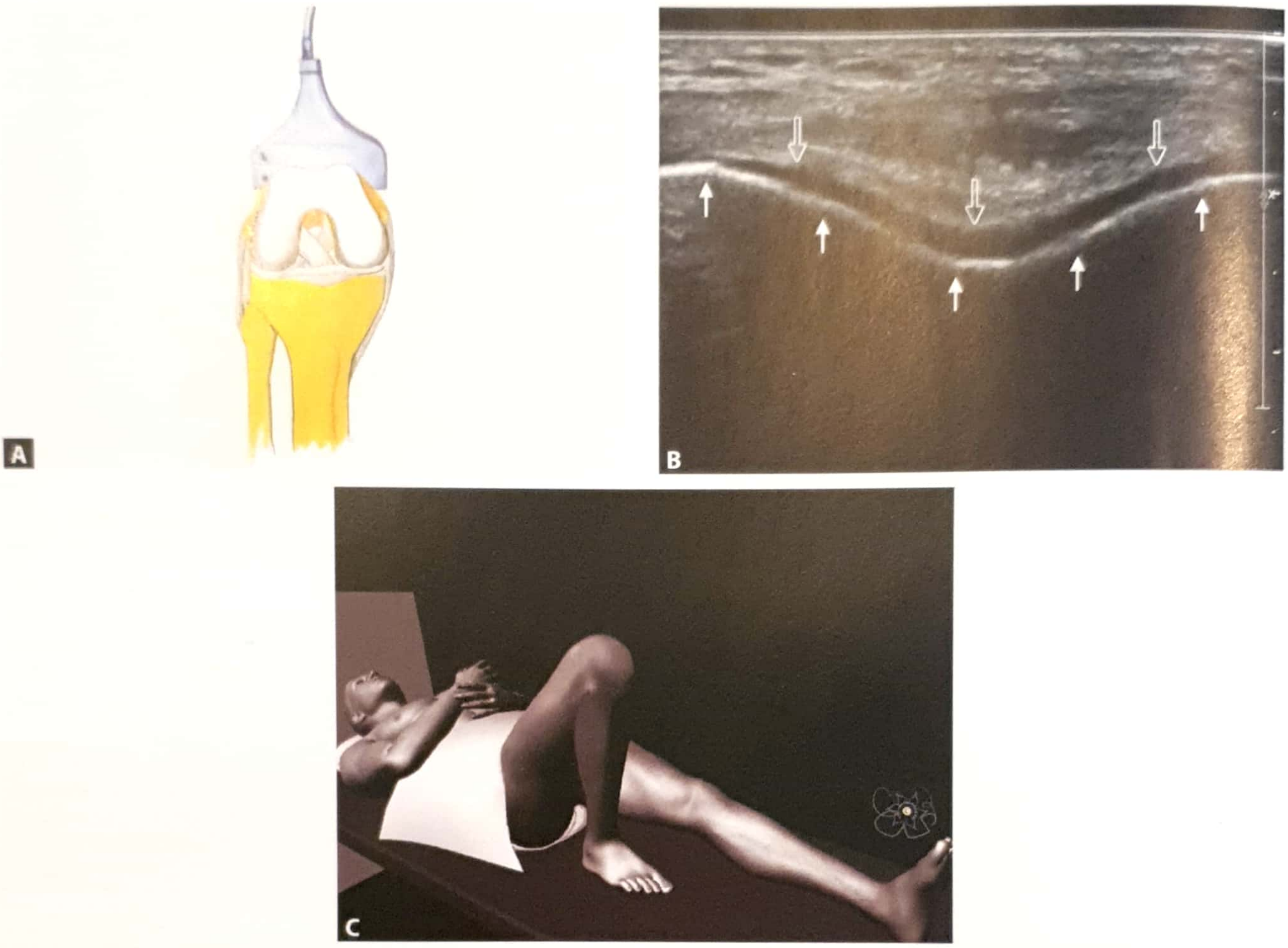
Figs. 20.2A to C: Patellar tendon.



(A) Lateral view of the knee with transducer placement over the patellar tendon. (B) Long axis view of the anterior aspect of the knee. Ultrasound image shows patellar tendon (arrows) from its origin from the patellar apex (P) to its insertion into the tibial tuberosity (T). The lobular structure of Hoffa's fat pad (H) is seen posterior to the patellar tendon. The deep infrapatellar bursa (*) cushions between the patellar tendon and the adjacent tibia. (C) This illustration shows the knee position required for this approach.

transducer should be moved gently from medial to lateral, encompassing the entire width of the suprapatellar bursa and the quadriceps tendon. The quadriceps has a trilaminar layered structure. The most superficial layer originates from the rectus femoris, the intermediate layer from the vastus medialis and lateralis, and the deep layer from the vastus intermedius. Only a thin film of fluid, no more than 2 mm thick, should be present in the normal suprapatellar bursa. As the suprapatellar bursa is not the dependent portion of the knee joint space in a supine patient, care should be taken to image both the medial and lateral patellar recesses for additional fluid. Fluid may be displaced from the medial and lateral recesses into the anterior suprapatellar bursa by manual compression, applied by the examiner's free hand. Any increase in suprapatellar fluid by this maneuver is considered abnormal. The medial and lateral patellar recesses are imaged on either side of the patella with the transducer held transversely, perpendicular to the long axis of the leg. Firm transducer compression of the suprapatellar bursa displaces any fluid into the adjacent joint space and allows accurate measurement of synovial thickness. This is especially valuable in the setting of hyperechoic blood or pus. It also demonstrates the communication between the suprapatellar bursa and the adjacent knee joint space. Since in the fetus the suprapatellar bursa is

Figs. 20.3A to C: Hyaline cartilage in knee.



(A) Schematic drawing of the knee in flexed position not showing the patella. Transducer placement in anterior short axis view above the patella. (B) Short axis view proximal to the base of the patella demonstrates trochlear cartilage over the anterior femoral condyles. The hyaline cartilage (open arrows) has a hypoechoic homogeneous structure with sharp margins, overlying the bright hyperechoic line of the subchondral bone (small arrows pointing up). (C) This illustration shows the hyperflexed knee position required for this approach.

initially sequestered by a suprapatellar septum, which should perforate by the fifth month in utero, confirmation of the communication is desirable (*see* Figs. 5.10A and B).

The anterior infrapatellar soft tissues are imaged with the knee in moderate flexion. A longitudinal midline transducer position at the apex of the patella enables imaging of the proximal and middle portions of the patellar tendon (Figs. 20.2A to C). Sliding the transducer distally, the inferior portion of the tendon is followed to its insertion on the tibial tuberosity. Medial-to-lateral translation of the transducer will ensure coverage of the full width of the tendon. Short axis imaging of the patellar tendon is then performed. The ultrasound beam should be perpendicular to the tendon surface to avoid anisotropy, which causes falsely decreased tendon echogenicity. The correct transducer angulation can be selected by gentle craniocaudal angulation of the transducer.

The patellar tendon is a broad flat echogenic fibrillar structure bridging the distal patella to the tibial tuberosity; it lies between the moderately echogenic subcutaneous fat anteriorly and the more hypoechoic Hoffa's fat pad posteriorly. The proximal insertion has a conical shape and is slightly larger than the remainder of the tendon. Images in this region also demonstrate the *prepatellar*