Sonography of the knee joint[☆]

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KEYWORDS

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Abstract The aim of this article is to review the sonographic appearances of common disorders involving the knee joint. Ultrasound is a sensitive method for diagnosis of tendon injuries. Injured ligaments appear swollen with mixed echogenicity. Meniscal injuries and muscle tears can be easily diagnosed. Ultrasound shows synovial thickening and effusion in inflammatory arthropathy and erosions of the articular surface in degenerative arthritis. It can be used effectively in the detection of rheumatoid arthritic activity and for grading degenerative arthritis lesions. Cystic lesions, as well as benign and malignant soft-tissue masses, are clearly delineated. Ultrasound is a safe noninvasive imaging modality that can be used for diagnosis of different disorders involving the knee joint.

Sommario Lo scopo di questo lavoro è fare una review riguardo l'aspetto ecografico delle patologie più frequenti che coinvolgono il ginocchio. L'ecografia è una metodica sensibile nella diagnosi della patologia tendinea. I legamenti danneggiati appaiono di dimensioni aumentate ad ecostruttura mista. Il danno meniscale e gli strappi muscolari sono facilmente diagnosticabili. L'ecografia è inoltre in grado di documentare l'ispessimento sinoviale ed il versamento nell'artropatia infiammatoria e le erosioni della superficie articolare nelle artriti degenerative. Può essere utile nello stabilire l'attività dell'artrite reumatoide ed il grading nell'artrite degenerativa. Le lesioni cistiche e le masse benigne o maligne dei tessuti molli sono ben documentate. Concludiamo che l'ecografia è una metodica d'imaging sicura e non invasiva che può essere d'aiuto per la diagnosi di diverse patologie del ginocchio.

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Introduction

Ultrasonography is a noninvasive imaging modality used for the assessment of the musculoskeletal system. It can provide clinically useful information on a wide range of

pathologic conditions affecting components of the knee joint, including the tendons, ligaments, muscles, synovial space, articular cartilage, and surrounding soft tissues. Color and power Doppler techniques can be used to measure neovascularization within the synovial lining of the joints, tendons, and soft-tissue masses. The advantages of ultrasound include low cost, portability, real-time assessment, and facilitated side-by-side comparisons. Its major disadvantage is its operator-dependence: it requires trained experienced hands with appropriate high-resolution equipment. Ultrasound examinations of the knee joint are usually performed using a high-frequency linear transducer

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(7.5–12 MHz). The patient lies supine on the examining table with both knees exposed. Findings can be correlated with the point of maximal tenderness and readily compared with those obtained in the contralateral joint [1–6].

The aim of this article is to review the sonographic appearances of common disorders involving the tendons, ligaments, muscles, menisci, synovium, cartilage, and soft tissues of the knee joint.

Tendon injury

Tendons may be involved in acute inflammation or more chronic degenerative processes (tendinopathy), such as jumper's knee. Distal patellar and quadriceps tendinopathies are less common and usually caused by trauma. Tendons cannot be assessed by arthroscopy because they are extra-articular structures. Ultrasound identification of the site and extent of tendinopathy has been used successfully in surgical planning [6–9].

Patellar tendinopathy (Jumper's knee)

This condition is caused by overuse of the knee extensor mechanism during activities such as jumping or running. It commonly affects the proximal patellar tendon at the apex of the patella and may also involve the distal patellar tendon. This tendinopathy is diagnosed sonographically in the presence of localized tenderness associated with thickening and decreased echogenicity of the tendon adjacent to the patellar apex centrally. The parallel fibrillar pattern of the tendon is disrupted. Increased flow on power Doppler sonography may help to localize the site of disease [7–9] (Fig. 1).

Osgood–Schlatter disease

This chronic tendinopathy of the distal patellar tendon is caused by a prominent tibial apophysis. A fragmented tibial apophysis is characterized by acoustic shadowing. The

distal patellar tendon is thickened and hypoechoic and may contain fragments from the anterior tibial tuberosity. There may also be subcutaneous edema, increased echogenicity of the infra-patellar fat pad of Hoffa, and deep infrapatellar bursitis [7–9] (Fig. 2).

Quadriceps tendon

Rupture of the quadriceps tendon is uncommon. Tears tend to be located at the musculotendinous junction or at the tendon's insertion into the patella. In partial tears, there is a hypoechoic defect representing hematoma. Gentle traction on the patella may increase the gap between the ends of the ruptured tendon, facilitating differentiation of full- and partial-thickness tears. The specificity and sensitivity of ultrasound in the diagnosis of quadriceps tendon tears have been shown to be 100% [10].

Ligament injury

Ligament injuries may appear as a complete interruption or replacement of the ligament by hypoechoic granulation tissue (complete tears); with partial tears, where there is focal hypoechogenicity [6]. In acute ligament injuries, the ligament is swollen with inhomogeneous echogenicity, whereas chronic injuries are associated with ligament swelling and hypoechogenicity. A complete tear of the ligament appears as a discontinuity; partial tears cause hypoechoic thickening. The collateral ligaments of the knee are easier to visualize with ultrasound than the cruciate ligaments due to their superficial location. Comparison with findings for the normal contralateral ligament is advisable to confirm the diagnosis [11–13].

Medial collateral ligament (MCL) injury

The injured ligament appears as a thickened, inhomogeneously hypoechoic structure due to edema and hemorrhage. Tears usually affect the deep fibers lying superficial

Fig. 1 Patellar tendinopathy. Longitudinal ultrasound scan along the anterior aspect of the knee joint shows a focal hypoechoic region in the distal portion of the patellar tendon that is devoid of the normal fibrillar pattern.

Fig. 2 Osgood–Schlatter syndrome. Longitudinal power Duplex scan along the anterior aspect of the knee joint shows a hypoechoic area in the distal part of the patellar tendon associated with a fragmented epiphyseal plate and increased vascularity within lower part of the patellar tendon.

Fig. 3 Medial collateral ligament injury. Longitudinal scan along the medial aspect of the knee shows thickened medial collateral ligaments with a hypoechoic area denoting acute injury.

to the medial femoral epicondyle. Pellegrini–Stieda disease is myositis ossificans within a chronic MCL injury which can be identified as an echogenic focus at the femoral attachment of the ligament, usually associated with acoustic shadowing and focal tenderness [3]. The sensitivity of sonography in the detection of MCL injuries is approximately 94% [11] (Fig. 3).

Lateral collateral ligament injury

Tears of this ligament present as focally tender, hypoechoic, thickened segments, usually adjacent to the fibular attachment [1–5] (Fig. 4).

Anterior cruciate ligament (ACL) injury

Anterior cruciate ligament injury can be detected with an oblique sagittal anterior approach with the knee flexed at least 60 degrees. This approach has its limitations, however, because most patients with acute hemarthrosis are unable to achieve this degree of knee flexion. In acute ACL injury, a hypoechoic fluid collection is seen along the

Fig. 4 Lateral collateral ligament injury. Longitudinal scan along the lateral aspect of the knee joint shows a heterogeneous mass replacing the LCL and displacing the biceps tendon anteriorly. The mass represents a hematoma and denotes acute injury.

lateral wall of the femoral intercondylar notch. It represents a hematoma at the femoral attachment of the ACL [3,12].

Posterior cruciate ligament (PCL) injury

The acutely torn PCL appears thickened (10 mm) and inhomogeneously hypoechoic with loss of its sharply defined posterior border [13].

Muscle injury

Muscle trauma is readily imaged with sonography. Focal muscle tears and/or hematomas may appear as simple or complex fluid collections; the age of a hematoma influences its appearance [3,14].

Gastrocnemius muscle injury (tennis leg)

Rupture of the medial head of the gastrocnemius is characterized by disruption of the normal, parallel, linear echogenic and hypoechoic appearance of the tendon at its insertion. The tapering distal end of the tendon at its insertion is also typically indistinct. Fluid collection is seen within the gastrocnemius muscle. The hemorrhagic fluid collection may be hyperechoic in the early stages; coarse echoes are generally observed during the subacute stage, and the collection is anechoic in the chronic stage [14] (Fig. 5).

Fig. 5 Gastrocnemius muscle injury. Sonogram of the medial aspect of the popliteal fossa shows disruption of the gastrocnemius muscle with a hyperechoic intramuscular hematoma denoting acute injury.

Fig. 6 Meniscal injury. (A) Ultrasound scan along the medial aspect of the knee joint shows a swollen meniscus with a linear hypoechoic cleft denoting meniscal degeneration. (B) Sonogram of the lateral aspect of the knee joint shows a hypoechoic meniscal cyst connected to a meniscal tear.

Plantaris muscle injury

This type of injury can mimic deep vein thrombosis and gastrocnemius tears. Ultrasound shows thickening of the muscle belly with intramuscular hematoma. However, in the presence of a chronic tear, a solid lucent mass of fibrous or granulation tissue is observed at the site of rupture [15].

Meniscal lesions

Ultrasound can demonstrate different types of injury in the peripheral part of the meniscus. However, magnetic resonance imaging is more sensitive than ultrasound for detection of meniscal lesions. A meniscal tear may appear as a hypoechoic cleft coursing within the meniscus. It can be seen extending to the femoral or tibial articulating surface of the meniscus. A degenerated meniscus appears swollen with decreased echogenicity. The edges of the meniscus bulge outward and are not compressible when pressure is applied with the transducer. Changes in the echogenicity and contour of the meniscus may reflect degenerative changes or an intrasubstance tear. Parameniscal cysts appear as rounded hypoechoic lesions related to the outer margin of the lateral meniscus and connected with the linear hypoechoic meniscal tear [3,4,16] (Fig. 6).

Synovial lesions

Synovial effusion

Sonography can detect joint effusions that include even a few milliliters of fluid. The fluid within the suprapatellar bursa should not be more than 2 mm. The fluid can be aspirated under ultrasound guidance. Simple effusions are almost always anechoic. Debris within a joint effusion may represent pus, blood clots, fat lobules, or osteochondral fragments [5,17].

Baker's cysts (popliteal cysts)

This type of cyst has a characteristic crescent shape and involves the medial border of the gastrocnemius muscle and

the semimembranosus tendon. The bursa may be divided into two compartments (the semimembranosus bursa and the gastrocnemius bursa) by a central septum. Complications include hemorrhage, ruptures, and loose bodies. Simple cysts are thin-walled with thin internal septa whereas complicated cysts have thick walls, multiple septa, and fluid containing echogenic debris. Upon rupture, the characteristic rounded inferior margin of a Baker's cyst becomes tapered, and fluid can be demonstrated within the calf, between the gastrocnemius muscle and the deep fascia. The patient may complain of sudden-onset pain radiating down the calf; the cysts can present with a clinical syndrome mimicking deep vein thrombosis. Doppler can play an important role in differentiating small cysts from

Fig. 7 Baker's cyst. Longitudinal scan of the medial aspect of the popliteal fossa shows a well-defined cystic lesion with a narrow neck. It contains echogenic debris and thick septa, which are characteristics of a complicated Baker cyst.

popliteal aneurysms. A Baker's cyst is frequently associated with meniscal tears, especially those involving the medial meniscus, or with degenerative and inflammatory arthropathy [18–20] (Fig. 7).

Pre- and infra-patellar bursitis

The prepatellar bursa is located superficial to the distal patella and the proximal third of the patellar tendon. The prepatellar and infrapatellar bursae are commonly predisposed to the development of frictional bursitis. Occupational kneeling may cause inflammation of the superficial bursa, a condition described as housemaid's or clergyman's knee. Ultrasound demonstrates a fusiform enlargement of the sac associated with an irregularly thickened synovium and punctate high-level speckles that may represent hypervascularity or clumped crystals. Foreign bodies appear as high-level echoes with posterior acoustic shadowing. Chronic prepatellar bursitis reportedly presents with focal thickening and hypoechogenicity of the prepatellar soft tissue without fluid. Sonography can aid in differentiating infrapatellar bursitis from patellar tendinopathy. These conditions may have similar clinical presentations. Sonography may be used to guide bursal injections of steroids [2–6] (Fig. 8).

Pes anserine bursitis

Pes anserine bursitis is a commonly observed condition that can be seen in athletes or obese patients. It may be secondary to arthritis or idiopathic. Ultrasound demonstrates a cystic mass adjacent and deep to the pes anserine tendon. Less commonly, ultrasound reveals inflammation of the bursa surrounding the semimembranosus tendon. The pes anserine bursa lies between the tibial insertion of the tibial collateral ligament and the conjoined distal tendons of the sartorius, gracilis and semitendinosus [2–6].

Rheumatoid arthritis

Ultrasound shows synovial thickening and effusion. The former appears as hypoechoic or heterogeneous proliferation

of the synovial membrane with poorly defined contours. The clinical status of a patient with rheumatoid arthritis depends upon the degree of synovial thickening and effusion. Patients with higher grades of effusion and synovial thickening have more severe symptoms. This correlation between ultrasound and clinical findings suggests that ultrasound is a useful method for monitoring the response to the treatment of rheumatoid arthritis. Power Doppler sonography depicts increased vascularity within hypertrophied synovium. There is markedly increased vascularity within synovia that presents a higher grade of thickening whereas in patients with smaller effusions and less synovial thickening, the synovial leaflets display low vascularity. Power Doppler ultrasound may thus be used to identify rheumatoid arthritis activity and to monitor responses to treatment [21–23] (Fig. 9).

Loose bodies

These may be the result of detached osteochondral fragments, osteoarthritis, or synovial osteochondromatosis. Loose bodies appear as focal echogenic structures separated from other structures, lying within the joint space [24] (Fig. 10).

Articular cartilage injury

Degenerative arthritis

Sonographic assessment of the extent of cartilage damage in patients with osteoarthritis is important for early diagnosis and for monitoring responses to therapy. The hyaline articular cartilage in the intercondylar notch is easy to evaluate with ultrasound, and it can be used as a marker of the activity of inflammatory arthropathy. Ultrasound shows thinning or disappearance of the articular cartilages. Blurring and poor visualization of the outer margin of the cartilage, loss of cartilage transparency, and increased echogenicity reflect structural alteration. Marginal erosions appear as hypoechoic-like defects along the edges of the articular cartilage. Osteochondral fragments may be

Fig. 8 Prepatellar bursitis. Longitudinal midline ultrasound scan shows distension of the prepatellar bursa with a sonolucent fluid collection with coarse internal echoes.

Fig. 9 Loose bodies. Ultrasound scan of the popliteal fossa shows two large loose bodies within a popliteal cyst with posterior acoustic shadowing.

Fig. 10 Rheumatoid arthritis. Longitudinal ultrasound scan shows a small effusion in the suprapatellar bursa with mild irregular thickening of the synovial membrane, which is indicative of inactive disease.

detected within the superior patellar pouch or within Baker's cysts [25] (Fig. 11).

Osteochondral defects

Osteochondral defects of the femoral condyles appear as thinning or absence of the hypoechoic hyaline cartilage or as irregularities or defects of the hyperechoic bone cortex. Focal pressure can be used to elicit movement of an osteochondral fragment [3,25] (Fig. 12).

Bone lesions

The cortex is an intensely hyperechoic interface with distal acoustic shadowing. Fractures appear as breaks or steps in

Fig. 11 Degenerative arthritis. Transverse ultrasound scan of the flexed knee shows loss of the normal hypoechoic pattern of the articular cartilage, marked irregularity of the cartilage–soft-tissue interface, and blurring of the bone–cartilage interface.

Fig. 12 Osteochondral defect. Defect and displacement are seen in the hypoechoic articular cartilage and hyperechoic bony cortex.

the hyperechoic cortex, often accompanied by a hypoechoic subperiosteal hematoma. Cortical irregularity and destruction can also be caused by tumors and acute or chronic inflammation. Subperiosteal abscesses are readily diagnosed in correlation with clinical findings. Sonography has been used to measure the thickness of the cartilaginous cap of an osteochondroma; otherwise it is of limited value in the study of bone lesions [26,27] (Fig. 13).

Soft-tissue masses

Ultrasound can differentiate cystic lesions from solid masses, but malignant and benign masses cannot be distinguished on the basis of their sonographic appearances. Standard characteristics such as size, shape, location, and echogenicity can be determined with ultrasound. Color and power Doppler sonography allow assessment of tumor vascularity, which may be helpful if malignancy is suspected. However, tissue biopsy is indicated for definitive diagnosis. Ganglionic cysts appear as well-defined oval anechoic septate masses with distal acoustic enhancement

Fig. 13 Osteochondroma. Ultrasound scan of the knee joint shows bony outgrowth from the upper end of the tibia. Ultrasound can be used to measure the thickness of the hypoechoic cartilaginous cap.

Fig. 14 Soft-tissue masses. (A) Intramuscular ganglion: longitudinal scan along the popliteal fossa shows a well-defined, thick-walled, multiloculated intramuscular cyst with mild flow within the septa with color Duplex examination. (B) Soft-tissue sarcoma: Sonogram shows a large mass in the popliteal fossa with mixed echogenicity and increased vascularity on the color Duplex examination.

and hyperechoic walls. Power Doppler sonography can reveal increased blood flow in the tissues surrounding a symptomatic ganglion. Certain benign tumors have specific ultrasound features. Hemangiomas have a variable inhomogeneous echogenicity with distal shadowing (due to the presence of phleboliths), and increased flow can be demonstrated with power Doppler sonography. A well-defined hypoechoic fusiform mass located along a nerve suggests a peripheral nerve-sheath tumor. Lipomas generally appear as hyperechoic masses. Soft-tissue sarcomas appear as complex mass with increased vascularity on color and power Duplex sonography [28,29] (Fig. 14).

Vascular lesions

Ultrasound can be used to measure an aneurysm of the popliteal artery; power Doppler sonography can identify the neck of the aneurysm and differentiate between patent and thrombosed parts [30] (Fig. 15). Color Duplex ultrasound can be used for the detection of deep vein thrombosis within the popliteal vein, which appears distended and noncompressible with an echogenic thrombus. No flow is detected within the vein with the color Duplex examination [31] (Fig. 16).

Fig. 15 Partially thrombosed popliteal artery aneurysm. Color Duplex examination of the popliteal fossa shows color signals within the patent central part of an aneurysm, which is connected to the popliteal artery by a narrow channel. The thrombosed part of the aneurysm shows no flow signal.

Fig. 16 Deep vein thrombosis. Color Duplex examination of the popliteal fossa shows a distended popliteal vein, a thrombus with mixed echogenicity, and no detectable blood flow.

Neural compression

The common peroneal nerve follows an oblique course through the popliteal fossa and then traverses the neck of the fibula in an exposed subcutaneous fibro-osseous tunnel. Ultrasound demonstrates the common peroneal nerve in the lateral portion of the popliteal fossa down to the fibular neck. Entrapment occurs as the nerve winds around the back of the fibular neck. Nerve compression may result from space-occupying lesions such as ganglionic cysts, soft-tissue tumors, bone masses, or a large fabella. It may also be caused by fractures, dislocations, application of skeletal traction, or a tight cast or bandage around the knee. In many instances, lesions probably result from pressure exerted on the nerve at the level of the fibular neck during sleep or from habitual leg crossing [32,33].

Summary and conclusion

Ultrasound is a reliable, noninvasive method for diagnosing injuries to the tendons, ligaments, and muscles of the knee. It can also be used for grading osteoarthritis, diagnosing osteochondral defects, and guiding fluid aspiration procedures. Ultrasound has been used effectively in the diagnosis and follow-up of patients with rheumatoid arthritis and in the evaluation of soft-tissue masses. It is important to recognize the limitations of this method for examining the menisci and bony lesions. In experienced hands, ultrasonography can play an important role in the assessment of pathologic conditions involving the knee joint.

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