MUSCULOSKELETAL ULTRASOUND SYMPOSIUM

USG of normal musculoskeletal structures

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Advances in high-resolution technology, have had the greatest impact on the use of USG for musculoskeletal imaging. Structures previously considered inaccessible can now be evaluated accurately using this imaging modality. Though MRI still remains the gold standard, USG has now emerged as the initial imaging modality in a large proportion of musculoskeletal disorders. Among the distinct advantages of USG, are the ability to perform a dynamic study to demonstrate the function of the structure under question and to have transverse as well as longitudinal sections. This is now aided by 3D technology, which is becoming popular. USG is more easily available and is cheaper than MRI. Its portablity and the ease with which follow-up examinations can be done are also big assets.

There are two major drawbacks with this technique. One is the long learning curve and the other is that there is very little tissue differentiation when it comes to the acoustic properties of various structures. A sound knowledge of musculoskeletal anatomy is a prerequisite.

Key words: Musculoskeletal, normal, ultrasound

Technical considerations

High-resolution equipment is mandatory and no compromise or alternative should be sought. A variety of transducers should be available, with a frequency range from 7.5 MHz to 10 MHz. This frequency range should suffice for most examinations, though certain situations demand higher frequencies. Standoff pads are helpful when scanning superficial lesions. Linear arrays are the ideal transducers for the musculoskeletal system since most of the structures are elongated or oval.[1] For the examination of deeper structures, especially in the calf, 3.5 MHz convex probes are useful. Often, one may have to use different frequencies in the same patient for the examination of the structure of interest.[1] An extended field of view can demonstrate the entire extent of the structure being examined and many clinicians prefer and appreciate these images.

Split screen images are necessary when one has to compare the structure with the contralateral normal side. Cine-loop facility is a must to assess muscle contractions. This dynamic capability is one of the strong points of USG assessment.
Color and power Doppler are now accepted as part of protocol for the evaluation of vascular lesions, infections, and tumors. In selected cases, Doppler can help select the correct site for a biopsy.[2] Current research shows that USG has plenty of promise and can be very rewarding, especially in sports injuries. One encouraging application is in differentiating between active and passive muscle segments, based on Doppler findings.[3]

Artifacts in the musculoskeletal imaging

Anisotropy is an artifact that is peculiar to the musculoskeletal system; it is commonly seen when the USG beam is oblique and not perpendicular to the structure of interest. An echogenic structure appears spuriously echo-poor, giving the false impression of an abnormality [Figure 1]. Tendons are the commonest structures in which this artifact is encountered and false positive diagnoses of tendinosis, and sometimes even of tears, may be made.[4]

Muscles

Muscles are composed of fibers which are separated by perimysium, which is fibroadipose tissue in the form of septae. The muscle is covered by connective tissue called the epimysium.

Based upon the architecture, muscles are divided into three types. In the first type the muscle fibers run parallel to the long axis. The second type is characterized by a fan-shaped arrangement of the fibers. In the third type, the fibers lie oblique to the long axis; this feathery pattern is called the pennate pattern, which is further subdivided into four types, which are unipennate, bipennate, multipennate, and circumpennate. The chief components of a muscle are the belly and the tendon. On imaging, the muscle bundles

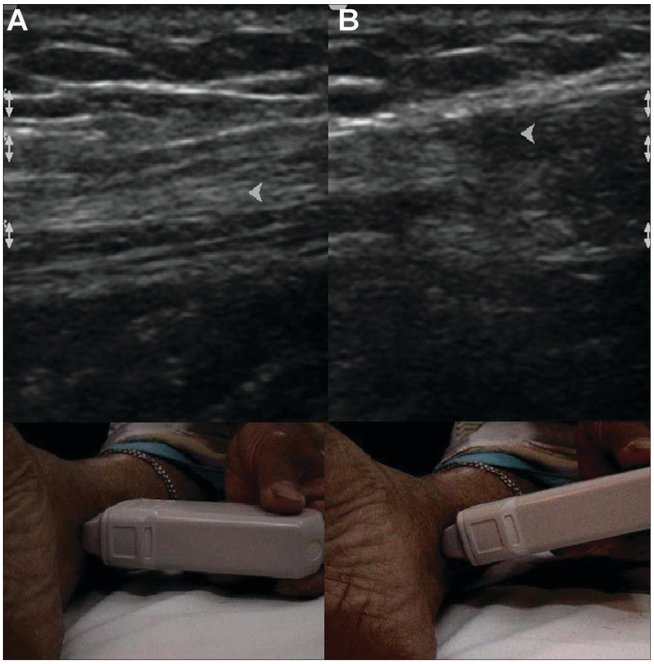

Figure 1 (A, B): Anisotropy. The transducer on the left (A) is correctly positioned and shows a normal appearance of the tibialis posterior tendon (arrowhead). With mild obliquity of the transducer (B), the tendon appears echo-poor, giving a false impression of pathology.

appear hypoechoic, whereas the perimysium, epimysium, and the fascia appear hyperechoic [Figure 2]. After exercise, muscles appear more hypoechoic and their size increases. Accessory muscles are not uncommon and are often misinterpreted as pseudotumors.[5]

In athletes, the muscles appear more hypoechoic under normal circumstances. With Doppler USG, increased vascularity can be observed following exercise, which is a physiological response. The ability to detect fine calcification and vascularity are areas where USG scores over MRI.[6]

Tendons

There are two types of tendons; those which have a synovial sheath and those which have dense surrounding connective tissue instead of a sheath. The tendon fibrils run parallel to the long axis. The ability to demonstrate the entire course of the tendon in a longitudinal plane, despite an oblique course in certain locations, is a distinct advantage of USG over MRI.[7] The graded compression technique, which is an asset when differentiating a tear from inflammation, is another advantage. Small ankle tendon tears may be missed on MRI, and USG is more sensitive in this location.[8]

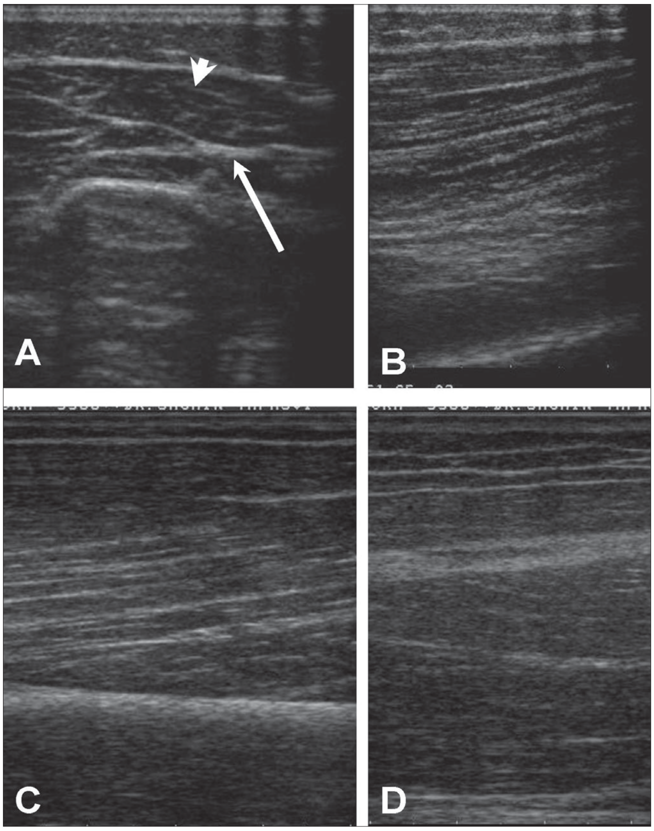

Figure 2 (A-D): Muscle fibers. Transverse (A) and longitudinal (B) scans through the biceps femoris and longitudinal scans through one of the calf (C) and thigh (D) muscles shows hyperechoic fibroadipose septae (arrow) standing out well against the hypoechoic muscle bundles (arrowhead).

Tendons are hyperechoic on USG and are usually the brightest amongst the musculoskeletal structures. Tendons with more than one muscular component have a brighter central thickened fibrillar pattern[9] [Figures 3 and 4]. On transverse scans, a tendon with a sheath demonstrates a peripheral hypoechoic ring whose thickness does not exceed 2 mm. Physiological fluid is often seen in the ankle tendon sheaths [Figures 5 and 6]. Knowledge of the common sites where physiological fluid may be seen is important. Even fluid in the ankle joint and its recesses is a normal finding.[10] USG can pick up morphological changes in tendons earlier than MRI.[11] The yield of fibrillar detail is greater with higher frequencies, being best at 15 MHz. This is because of the better axial resolution.[12] Tendon echointensity is independent of its intrinsic constituents such as water, collagen, glycosaminoglycans, and DNA.[13] Athletes can have variations in tendon shape, and this is better appreciated on transverse scans.

Ligaments

Like tendons, ligaments are also hyperechoic structures and are composed of dense connective tissue. The difference is that the internal structure is more irregular and the fibrillar pattern is less easily appreciated than in tendons [Figure 7]. On an average, ligaments are 2–3 mm thick. All the ligaments, except the medial collateral ligament of the knee, are homogenous and hyperechoic. The medial collateral ligament has a central hypoechoic zone that is due to the

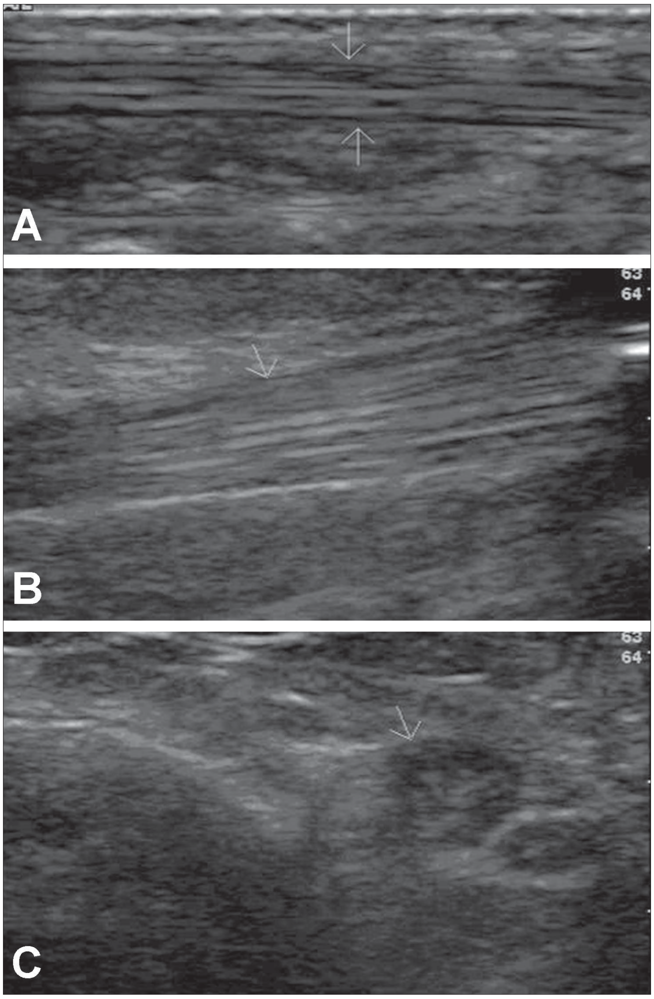

Figure 3 (A-C): Normal tendon. Longitudinal views (A, B) show echogenic, parallel fibrils (arrows). Transverse view (C) shows the echo-poor synovial sheath (arrow).

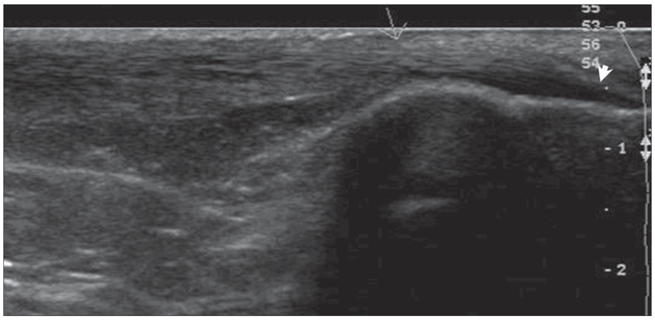

Figure 4: Achilles tendon. Longitudinal view shows the tendon (arrow) well, along with its calcaneal insertion (arrowhead).

presence of loose areolar connective tissue[14] between the superficial and deep parts.

Examination of ligaments requires a greater magnitude of experience. Since the examination is technically demanding, it is not surprising that MRI is often more commonly requested. Surgeons may prefer arthroscopic evaluation,

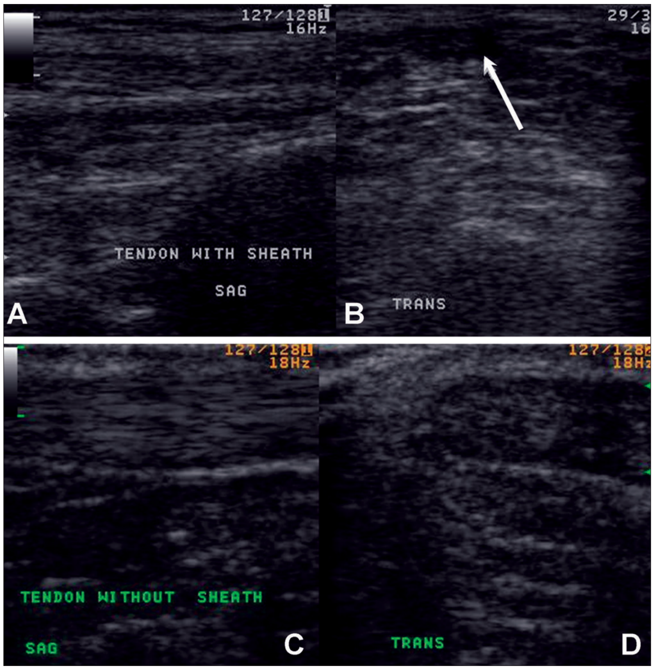

Figure 5 (A-D): Longitudinal (A) and transverse (B) images of a tendon with a sheath, showing a hypoechoic rim around the tendon. C and D are longitudinal and transverse images, respectively, of a tendon without a sheath.

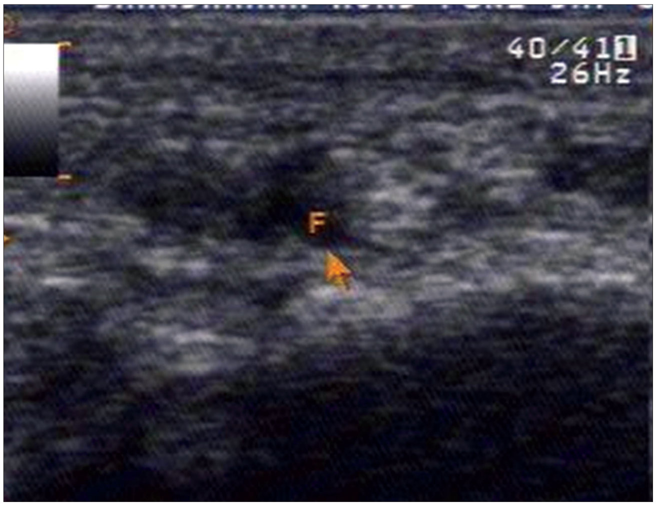

Figure 6: Fluid around a tendon sheath. Transverse view of the peroneal tendons shows anechoic fluid (arrow) around the tendon.

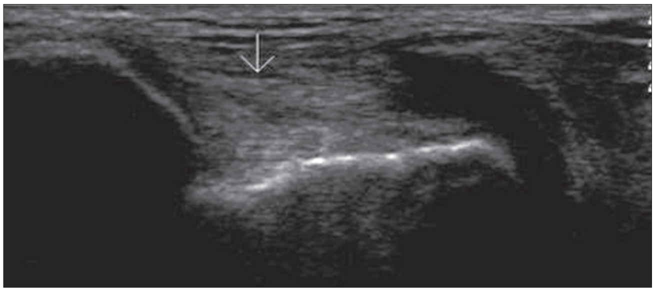

Figure 7: Tibio-talar ligament. Longitudinal image at the ankle joint shows the linear, hyperechoic ligament (arrow). Because of the small size, the internal architecture is not defined.

though this is mainly for intracapsular ligaments.

The request for ligament assessment is made most commonly in post-traumatic conditions. Real-time evaluation is the key factor in differentiating a partial tear from a complete tear. Being superficial in location, ligaments are best studied using very high-frequency transducers.

Bursae

These are sac-like structures with a hypoechoic appearance. The hypoechoic area usually does not exceed 2 mm in thickness [Figures 8 and 9]. A thin, peripheral hyperechoic line is seen, due to the tissue–fluid interface, between the bursa and the interposed fat between the soft tissues. Bursae are better defined on USG when distended with fluid. Some authors believe that if a bursa is visible on USG, it has to be abnormal.[15]

There are three types of bursae: the superficial bursae, the deep bursae, and the adventitial bursae, which are the acquired type. USG has its main role in the examination of deep bursae, which cannot be clinically assessed. Bursae may also be classified as communicating and non-communicating.

Like ligaments, superficial bursae are best examined using high-frequency probes. Deep bursae often require a 3.5 MHz transducer, depending upon the anatomical location.

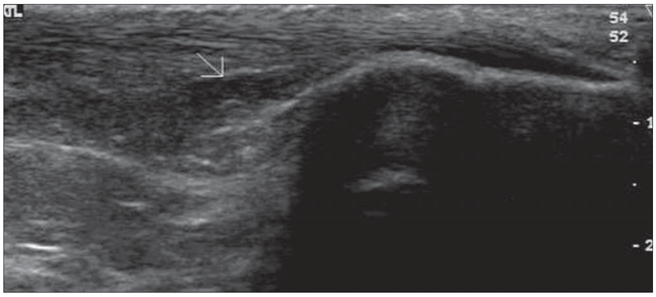

Figure 8: Retrocalcaneal bursa. Longitudinal scan shows the bursa as a hypoechoic space (arrow) between the Achilles tendon and the calcaneum.

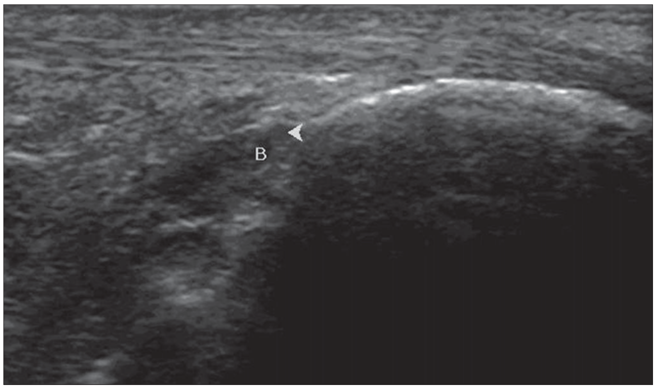

Figure 9: Retrocalcaneal bursa. Longitudinal scan shows the bursa as a hypoechoic space (arrowhead) between the Achilles tendon and the calcaneum.

The commonest bursal pathology is bursitis. Clinically, it is often not possible to differentiate between bursitis, a soft tissue mass, or nerve pathology. Perhaps, the bursa most commonly examined is the medial gastrocnemius-semimembranosus bursa (Baker's cyst). Other deep bursae which can be reliably evaluated are the subacromial-subdeltoid bursa, ilio-psoas bursa, and the deep trochanteric bursa. Olecranon, prepatellar, and the subcutaneous calcaneal bursae are the superficial bursae that commonly come for USG evaluation.

Cartilage

USG can only detect gross pathology of cartilage. A major limitation is the lack of a good acoustic window. Hyaline cartilage is hypoechoic [Figure 10] and is easier to demonstrate in children, who typically have a larger

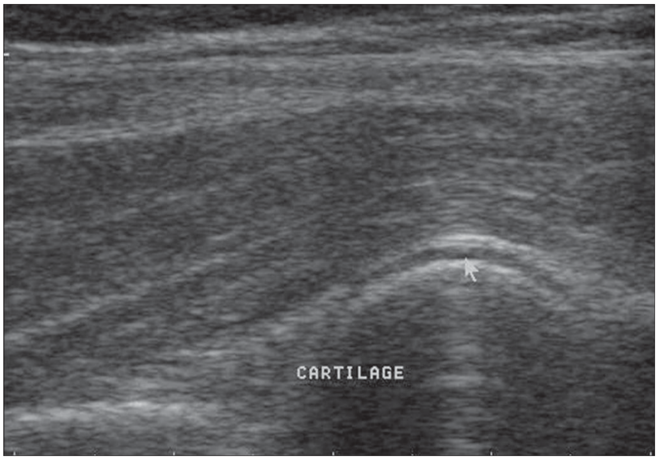

Figure 10: Hyaline cartilage. Longitudinal section of the lateral compartment of the elbow shows the cartilage as a linear, thin hypoechoic structure (arrow).

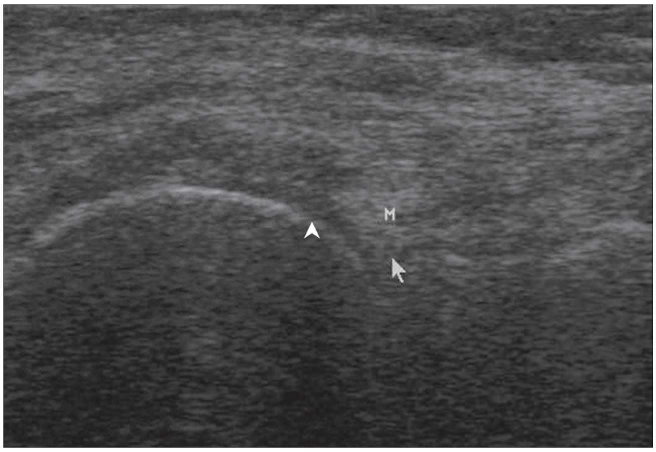

Figure 11: Knee meniscus. Longitudinal section along the medial aspect of the knee shows the fibrocartilagenous meniscus (arrow) as a hyperechoic triangular structure. Also seen is the hyaline cartilage of the femoral condyle (arrowhead).

acoustic window. Normal hyaline cartilage shows gradual tapering at the articular margins.[7] Fibrocartilage contains more collagen and hence appears hyperechoic, knee menisci being typical examples [Figure 11]. Comparison with the opposite side is of help whenever there is a need to differentiate edematous cartilage from normal.

Bone

For years, it was firmly believed that bone cannot be studied by USG. This still holds true, but mainly with regard to the medullary cavity. The surface of the bone especially the soft tissue–bone interface appears as a bright structure on USG and, consequently, bony contours are appreciated well. In addition to the contours, the fossae (for example, olecranon), tuberosities, and trochanters [Figure 12] are also well demarcated. However, a reliable comment on the periosteum is possible only in pathological conditions, mainly in children. USG can be superior to radiography for the detection of occult fractures, especially in the short tubular bones[16] and is also known to detect callus earlier than plain radiographs.[17]

Nerves

USG imaging of nerves is promising. Similar to the case with ligaments, examination of nerves, barring the median or the posterior tibial, is challenging. The main reason for this is the infrequency of requests for these examinations, which in turn results in inadequate experience and expertise.

Nerves fibers are grouped into fascicles. These are covered by two types of connective tissue: the inner perineurium surrounding the fascicles and the outer epineurium.

Nerves are also hyperechoic. The echogenecity is less than that of tendons and more than that of muscles. The nerves demonstrate a linear parallel pattern of bright echoes on longitudinal scans, while on transverse scans they appear oval with fine punctate echogenic dots [Figures 13 and 14]. A dynamic study helps differentiate a relatively immobile nerve from a mobile tendon or muscle. In certain anatomical locations such as the volar aspect of the wrist however, differentiation between the passive anterior displacement of the median nerve and active movements of tendons can be tough.[18] Currently, MRI has a clear edge in nerve evaluation.

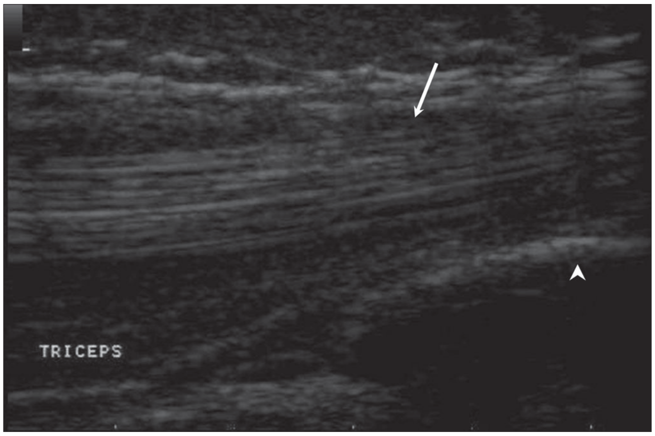

Figure 12: Olecranon fossa. Longitudinal scan through the elbow, showing the olecranon process (arrowhead) with the triceps insertion (arrow). The bony contours appear hyperechoic and sharp.

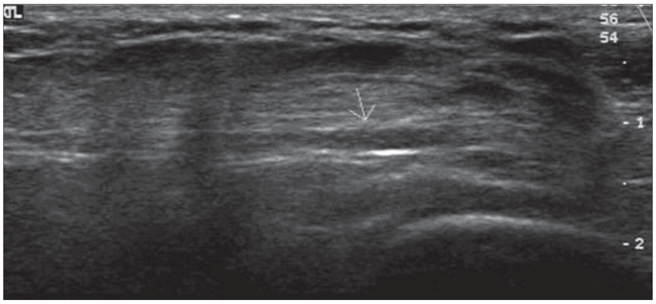

Figure 13: Posterior tibial nerve. Longitudinal section through the posterior tibial nerve shows its normal appearance (arrow).

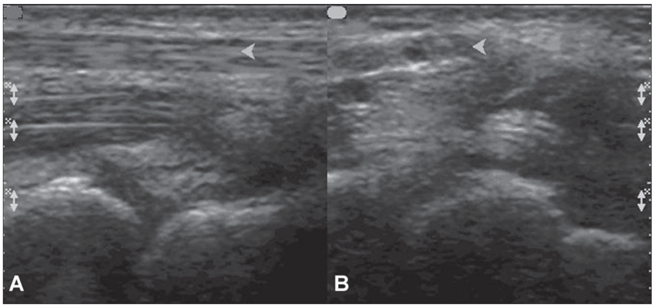

Figure 14 (A, B): Median nerve. Longitudinal (A) image at the wrist shows the normal fascicles of the nerve (arrowhead). The transverse (B) section shows the normal punctate echogenecities (arrowhead).

Identification of nerves and defining their continuity in the postoperative state can be difficult, because of scar tissue at the site of repair.[19]

Neonatal spine

USG demonstrates the anatomy of the spinal canal well [Figure 15]. The proportion of these examinations has decreased because of improvements in *in utero* assessment of pathologies of the neural axis, which has resulted in termination of a sizeable number of fetuses with these anomalies. Spinal dysraphisms are the main reason for referral for USG evaluation.

Miscellaneous

Subcutaneous tissue

Subcutaneous tissue is hypoechoic and almost isoechoic with muscle bundles. Unlike adipose tissue, the septae

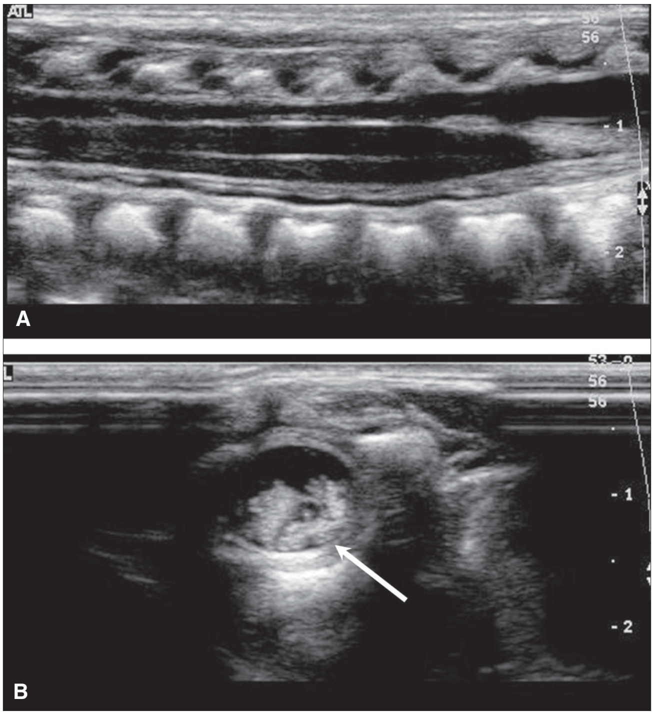

Figure 15 (A, B): Longitudinal (A) and transverse (B) sections of the spine. Note the demarcation of the vertebral bodies and the subarachnoid spaces (anechoic tubular structures between the echogenic arachnoid and the echogenic cord; arrow in B)

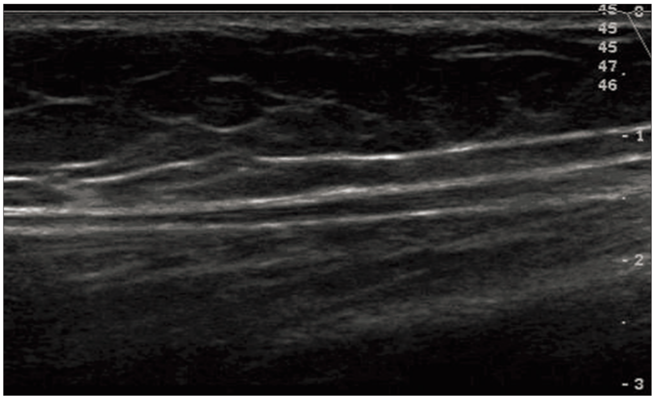

Figure 16: Longitudinal scan of the subcutaneous tissues. Hyperechoic anterior-most linear surface is the dermis, hypoechoic layer posterior to the dermis is the fat, while scattered hyperechoic structures in the fat are the fibrous septae. Fascia is the other linear hyperechoic structure posterior to the fat.

in the subcutaneous tissues are scattered in an irregular manner [Figure 16].

Fascia

Fascia is hyperechoic with a fibrillar pattern; it is seen surrounding muscles.

Interosseous membrane

This is not well seen. The interosseous membrane between the tibia and fibula appears as a thin hyperechoic structure.[20]

Summary

The contribution of USG to musculoskeletal system imaging is mainly the result of the current availability of high-resolution, high-frequency transducers and the real-time capability of USG. The ability to examine a structure in any plane is a boon. Assessment of function is difficult on MRI and this is one area where USG clearly scores over MRI. A thorough knowledge of anatomy and a meticulous technique are essential requirements for a successful examination. With experience, one can make the modality even more effective.

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