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MINISYMPOSIUM: SMALL PARTS AND MUSCULOSKELETAL ULTRASOUND

Normal and abnormal tendons in children: evaluation with ultrasound

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Abstract
Ultrasound (US) has emerged as an essential diagnostic tool for evaluating the entire musculoskeletal system in children. The spatial resolution of modern US technology offers unparalleled depiction of superficial anatomy, and motion and blood flow are demonstrated in real time allowing for the quick diagnosis of a wide variety of pathologies. US evaluation of tendons and their structure and function represents one of the best applications of musculoskeletal US. This article reviews some of the more common indications for US of the tendons in children. While not an exhaustive list, the anatomy and pathology examples described should help any pediatric radiologist confronted with a case of tendon pain or loss of function.

Keywords Anatomy · Children · Pathology · Tendon · Ultrasound

Tendinous anatomy

Tendons are strong but flexible cable-like structures that transfer the force generated by muscles to the bones they attach to, facilitating joint movement. Tendons can be rounded cords or flat bands, with varying length and size depending on their function. They consist of water (65–70% wet weight) and collagen type-I (70–80% dry weight), with elastin, proteoglycans and glycolipids making up the remainder. They are typically surrounded by a small potential fluid space contained within a synovial sheath, as in the tendons of the wrist and hand, or occasionally contained within a dense connective tissue (paratenon), as in the Achilles and patellar tendons, both of which can be affected in inflammatory conditions [1–4].

Tendons are similar in children and adults, but the normal adjacent cartilaginous structures of children can resemble pathology. In younger children, the origins and attachments of the tendon are unossified, and the chondro-tendinous attachments in areas such as the upper and lower patellar poles and the tibial tubercle are normally lucent. Areas containing abundant cartilage, such as the patella, contain multiple vascular canals detectable by Doppler sonography, and these might be confused with increased vascularity from enthesitis or tenosynovitis (Fig. 1).

Technique

Transducer selection

The optimal transducer for imaging musculoskeletal structures depends on the size, depth and location of the structure of interest. The surface of the selected transducer must be substantial enough to cover the structure but also large enough to visualize the surrounding structures. Extended field of view can be useful to evaluate longer anatomy in areas where two tendons interact, such as the quadriceps and patellar tendons around the patella. Larger structures such as the hip in adolescents might require a curved linear transducer in the range of 5–10 MHz.

A linear-array transducer in the range of 15–24 MHz should be used when a large field of view is necessary. This high-frequency large-footprint linear-array transducer is ideal for evaluating the shoulder, elbow, wrist, knee, foot and ankle. When imaging smaller superficial structures, the small-parts probe, or “hockey stick,” in the range of 15–22 MHz is optimal (Figs. 2 and 3). Its small footprint allows for navigation of the surface of bony structures and its high frequency depicts detail with very high resolution. The hand and foot tendons are ideally visualized using a high-frequency small-footprint linear-array hockey stick.

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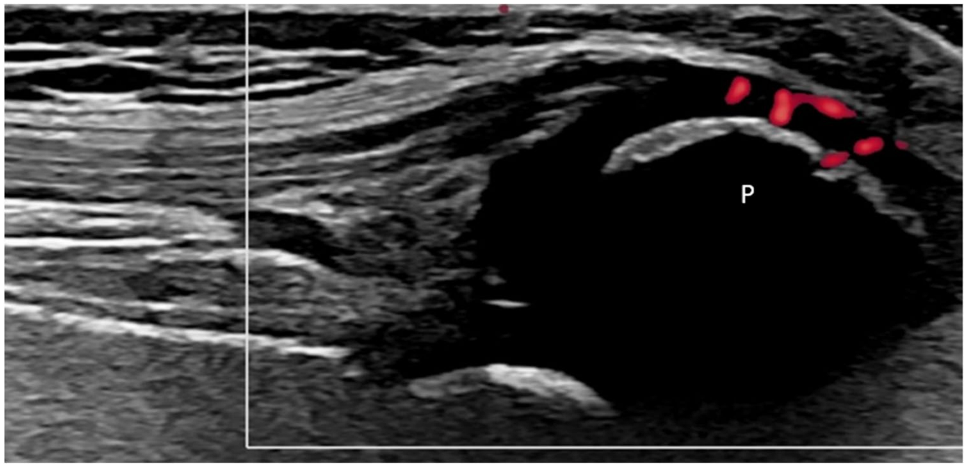


Fig. 1 Normal cartilaginous anatomy in a 7-year-old girl. Long-axis Doppler US image of the patella (*P*) shows flow within vascular canals in the cartilage anterior to the ossification center, which should not be confused with enthesitis or tendinitis

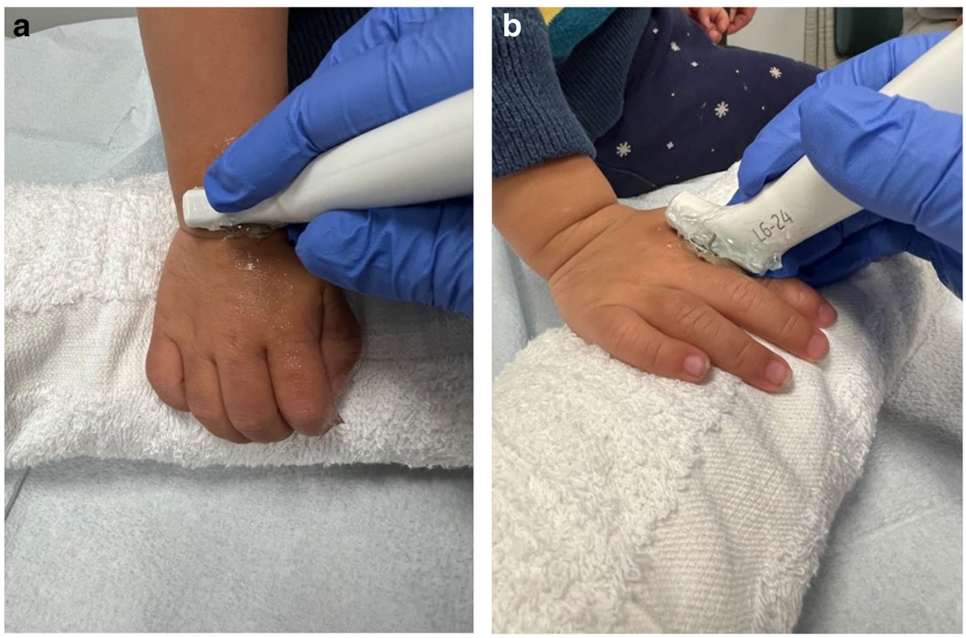


Fig. 2 Clinical image of scanning technique in a 5-year-old girl. **a** Scanning with a high-resolution US transducer for the extensor tendons of the wrist along the dorsal aspect. **b** Scanning with a high-resolution transducer for the extensor tendons of the finger along the dorsal aspect

Transducer placement

Transducer placement determines the imaging plane of the evaluated structures. The transducer should be joined to the skin with abundant acoustic transmission gel that allows transmission of the sound waves into the soft tissues. Holding the transducer like a pencil makes it possible to anchor the hand on the child and only use light pressure. Heavy pressure can move or compress any fluid and make it more difficult to image superficial structures.

Transducer orientation

The orientation should be described as long axis and short axis relative to the axis of the targeted anatomical structure being scanned, not relative to the location of the transducer on the child's body. Transducer orientation can greatly impact the US image. As an example, in the shoulder, the long head of the biceps tendon runs cephalad to caudal, while, just inferior, the subscapularis tendon runs medial to lateral. If the transducer is not properly aligned

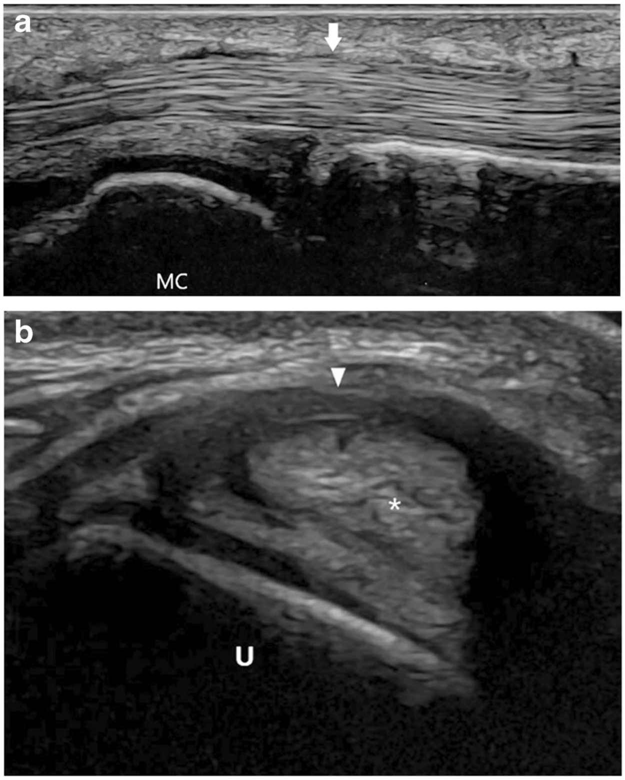


Fig. 3 High-resolution US of normal tendons of the hand in a 19-year-old woman with possible juvenile arthritis. The images were obtained with a 24-MHz transducer. **a** Long-axis image of the flexor tendons of the 3rd finger. The tendon (*arrow*) has a fibrillar appearance with multiple parallel echoes. *MC* metacarpal head. **b** Short-axis US of the medial wrist shows the extensor carpi ulnaris tendon (*) within the subsheath (*arrowhead*). On cross-section, the tendon has a speckled appearance. *U* ulna

with the fibers of these structures, then pathology could be missed or misinterpreted. It is paramount to know the orientation of the target anatomy in order to modify the transducer orientation to optimize visualization of the evaluated structure.

Transducer notch

In tendon US, the notch of the transducer should point toward the child's head when scanning structures in the long axis. It is acceptable to orient the transducer notch toward or away from the head when scanning the fingers and toes as long as the operator labels one side of the screen so that the orientation is clear on the images. For correct orientation when scanning in short axis from an anterior approach with the child supine or sitting, the transducer notch should point toward the child's right shoulder. When scanning in short axis from a posterior approach with the child prone or sitting, the notch should point toward the child's left shoulder. For short-axis right-handed scanning, the notch should face the examiner's thumb, and for left-handed scanning, the notch should face the pinky.

Optimization of the image

The depth is adjusted such that the structure of interest is located in the center of the screen. The depth of the focal zones is centered on the area of interest and the number of focal zones reduced to scan only this area.

Tendon imaging

Tendons are optimally studied with high-frequency transducers that allow for detailed visualization of the tendinous and peritendinous architecture. Tendons are examined in both axes, from the proximal myotendinous junction to the distal bony insertion. A normal tendon appears as cord-like hyperechoic structures with an internal fibrillar pattern in both long and short axes. The tendon is assessed for any thickening, hypoechogenicity or disruption of the fibers, and for surrounding fluid. Real-time US by the interpreting provider and video captures of moving tendons confirm appropriate function and location of a specific tendon. Cine images help differentiate small tendons from nerves and demonstrate areas of focal enlargement.

Power Doppler

Power Doppler sonography depicts increased blood flow to a tendon, important to detect active inflammation with hyperemia in pathologies such as tenosynovitis and enthesitis. We evaluate all the structures with power Doppler, which is ideal for imaging low-flow states, especially when the Doppler angle is not optimal.

Normal anatomy of commonly evaluated tendons

Flexor digitorum superficialis and flexor digitorum profundus

The 2nd through 5th fingers each have two flexor tendons, the flexor digitorum superficialis (FDS) and the flexor digitorum profundus (FDP). At the base of the proximal phalanx, the tendon of the FDS divides into two slips that pass on either side of the FDP tendon and insert onto the middle phalanx (Fig. 4) [5]. After crossing the superficialis, the FDP continues its straight course and inserts into the base of the distal phalanx. Sonographically, the tendons appear as two separate structures and can be made to move independently. Selective movement of the FDP is evaluated during passive extension and flexion of the distal

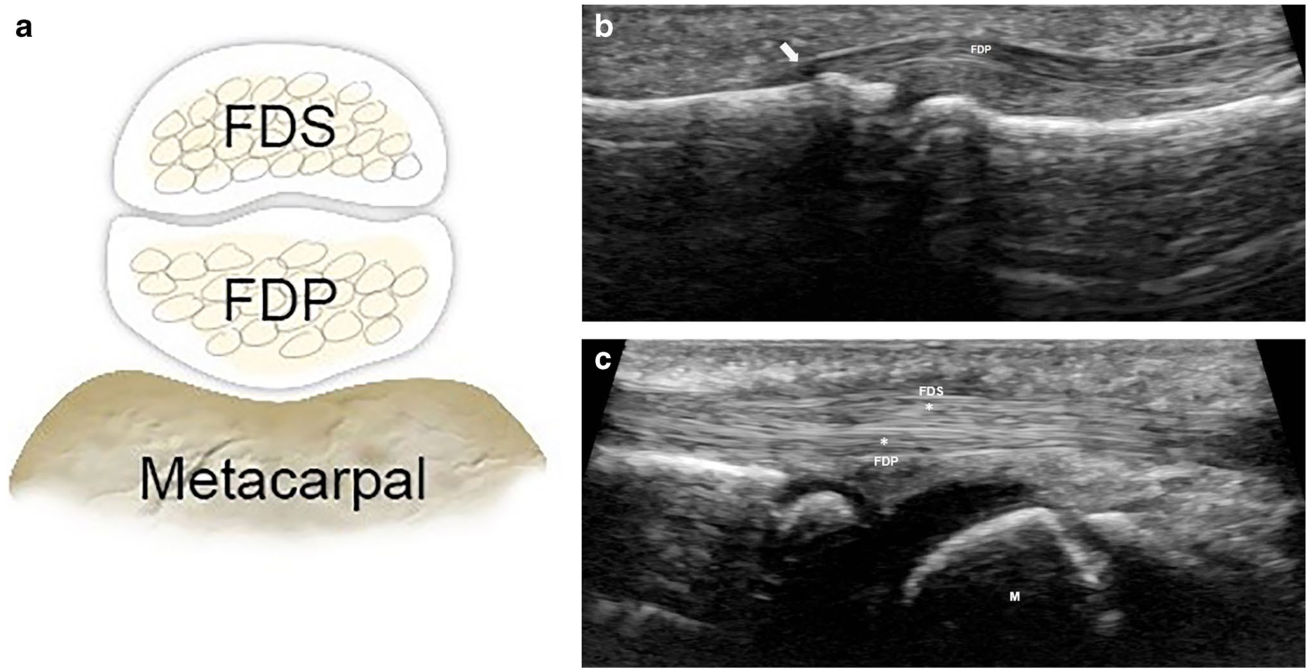


Fig. 4 Diagram of normal flexor tendons and images of the flexor tendons of the finger of a 10-year-old girl with pain but no history of trauma. **a** Diagram of the flexor tendons. The flexor digitorum profundus (*FDP*) lies between the flexor digitorum superficialis (*FDS*) and the metacarpal. Image used with permission from [5]. **b** Long-axis US image of the FDP shows the insertion (*arrow*) into the terminal phalanx. **c** Long-axis US image at the metacarpophalangeal joint shows two flexor tendons, the FDS and FDP. *M* metacarpal epiphysis

phalanx, while the examiner holds the middle phalanx in an extended position. Concomitant flexion of the distal and middle phalanges permits evaluation of the gliding movements of the two flexor tendons. A tear of the FDP at its insertion onto the distal phalanx ("Jersey finger"), is detected when the tendon is not demonstrated at its insertion and is retracted more proximally [6–9].

Wrist extensor compartments

The extensor retinaculum and dorsal tubercle of the radius (Lister tubercle) are two key structures that define the anatomy of the extensor surface of wrist. The extensor retinaculum is a fibrous band that extends obliquely across the dorsum of the wrist and has deep attachments along its course, dividing the extensor tendons into six compartments [5–7, 9] (Fig. 5). When scanning the extensor compartments, it is best to sweep from radial to ulnar, from I to VI.

Compartment I is over the radial styloid process and contains the extensor pollicis brevis and abductor pollicis longus tendons. The tendons in compartment I are affected in de Quervain tenosynovitis, which shows thickened tendons at the level of the radial styloid, increased fluid within the first extensor compartment tendon sheath, and peritendinous subcutaneous edema. Compartment II is located on the radial side of Lister tubercle, and contains the extensor carpi radialis longus and extensor carpi radialis brevis tendons. Compartment III is located on the ulnar side of the Lister tubercle and contains the extensor pollicis longus tendon. Compartment IV is the largest compartment and contains the tendons of the extensor digitorum communis, which are often involved with tenosynovitis related to inflammatory conditions such as juvenile idiopathic arthritis or psoriatic arthritis. Compartment V is dorsal to the interval between the radius and the ulna and contains the extensor digiti minimi tendon. Compartment VI, the most ulnar compartment, situated between the head and styloid process of the ulna, contains the extensor carpi ulnaris tendon surrounded by its subsheath [8] (Fig. 3). When the subsheath is torn, the tendon dislocates during supination.

Quadriceps and patellar tendons

The quadriceps tendon is a large multi-layer tendon that extends to the superior pole of the patella and is formed by contributions from the vastus intermedius, vastus medialis, vastus lateralis and rectus femoris muscles. The patellar tendon attaches to the inferior pole of the patella and the tibial tubercle of the proximal tibia (Fig. 6). The appearance of the insertions of the quadriceps and patellar tendons depends on age and the degree of ossification of the patella and the tubercle. In childhood, the tendons extend into the superior and inferior patellar cartilage and the non-ossified tibial

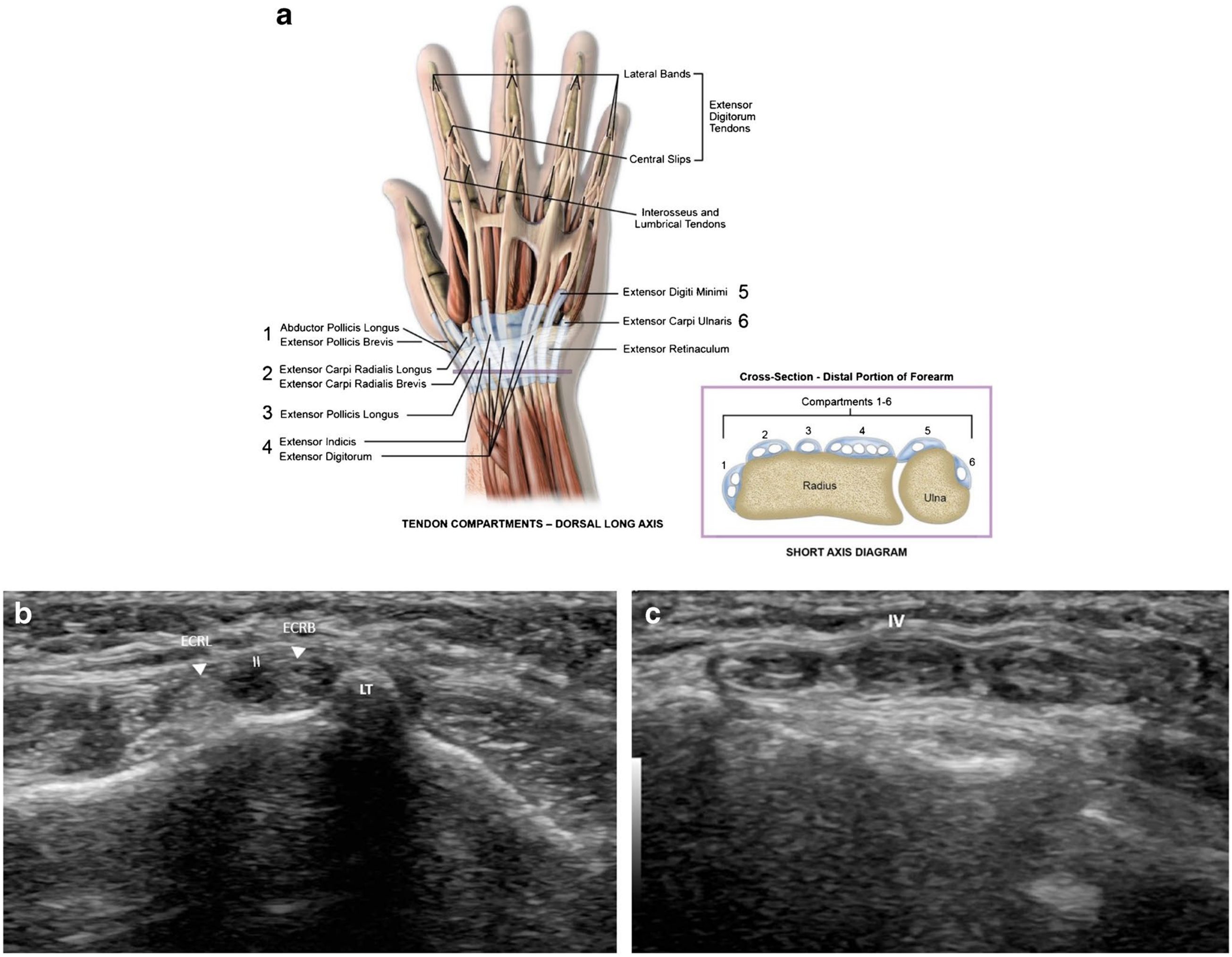


Fig. 5 Diagram of normal extensor compartment and short-axis US images of the extensor compartments in a 14-year-old girl with no wrist disease. **a** Diagram of the extensor compartments. Images used with permission from [5]. **b** The compartment II (*arrowheads*) is on the radial side of Lister tubercle (*LT*). *ECRB* extensor carpi radialis brevis, *ECRL* extensor carpi radialis longus. **c** Multiple extensor tendons are evident in compartment IV

tubercle, whereas in older children and adults they insert directly onto bone [10, 11] (Fig. 6).

Ankle tendons

Examination of the medial and lateral flexor tendons of the ankle is best performed in the axial plane, locating the tendons posterior to the malleoli (Fig. 7). Behind the lateral malleolus in the peroneal groove, the peroneus longus and brevis tendons are surrounded by the hypoechoic peroneal retinaculum. The peroneus brevis tendon abuts the fibula, is smaller, usually more echogenic and flatter, and runs anteriorly and inferiorly to insert on the base of 5th metatarsal, while the peroneus longus tendon is more superficial and runs obliquely to insert onto the medial cuneiform and first metatarsal.

On the medial side (Fig. 7), the large tibialis posterior tendon is easily located behind the medial malleolus. Just posterior to the tibialis posterior tendon is the smaller flexor digitorum longus tendon. The small flexor hallucis longus tendon is located farther posteriorly and deeper in the ankle, behind the posterior tibial artery and veins, and is easiest to identify where it sits in the groove of the sustentaculum tali, and it moves when the great toe is flexed. By US, the tendons can be remembered by the acronym "Tom, Dick and Very Nervous Harry."

Achilles tendon

The calcaneal tendon, commonly referred to as the Achilles tendon, is the largest tendon in the body and is formed by the merging fibers of the gastrocnemius and soleus muscles onto

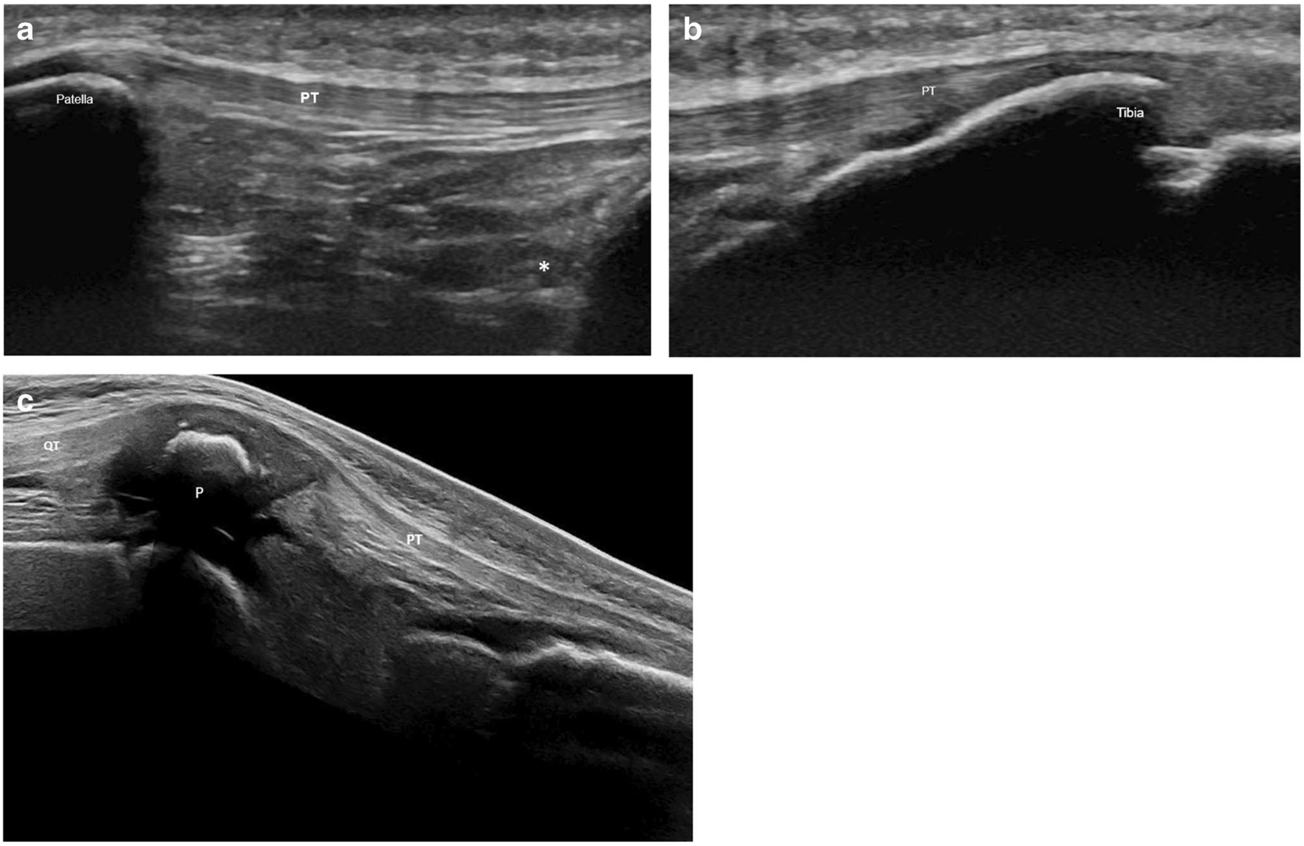


Fig. 6 Normal patellar tendon on US. **a, b** Long-axis imaging in a 12-year-old girl with knee pain. The origin of the patellar tendon (*PT*) in the patella (**a**); the patellar tendon is superficial to the infrapatellar bursa (*). In (**b**), the insertion of the patellar tendon into the tibial tubercle shows the tubercle extending above the proximal tibial growth plate. **c** Normal panoramic long-axis US in a 7-year-old with knee pain shows the partially ossified patella (*P*) with the quadriceps (*QT*) and patellar (*PT*) tendons

the calcaneal apophysis posterior to Kager fat pad. Similar to the patellar tendon, the sonographic appearance of its insertion changes with age as the calcaneus ossifies (Figs. 7 and 8). While the other tendons of the ankle are contained within their own synovial sheath, the Achilles tendon is contained within a tightly adherent paratenon.

Sonographic characteristics of tendons

The sonographic appearance of normal tendons reflects the linear parallel and densely packed arrangement of its collagen fibers. Tendons have a fibrillary pattern of parallel hyperechoic lines on long-axis images (Fig. 3) and appear as round to ovoid echogenic structures with bright stippled clustered dots on short-axis images. These lines and dots are caused by specular reflections at the boundaries of collagen bundles and septa.

Depending on the angle of the incident US beam, a typically hyperechoic tendon might appear hypoechoic because the organized fibrillar structure can reflect the sound beam away from the transducer. This property of tendons is known as anisotropy and can cause a tendon to appear artifactually hypoechoic. This should not be mistaken for pathology, and it can be corrected by changing the angle of the transducer (Fig. 9). Anisotropy can be useful to confirm the location of a tendon or distinguish it from a nerve [3, 4, 6, 7, 12].

When arising from more than one muscle, tendons exhibit a laminated appearance made of separate groups of fibers that overlie or twist on one another. Although the paratenon of the Achilles, quadriceps and patellar tendons appears as a thin hyperechoic line surrounding the tendon boundaries, synovial sheaths around most tendons are visible on US only when fluid fills the potential synovial space [4, 6, 7, 12].

Tendon pathology on ultrasound

Table 1 lists various tendon pathologies found on US in children. Here we describe tendinosis, tendon tears, tenosynovitis, peritendinitis, enthesitis and bursitis and their US findings.

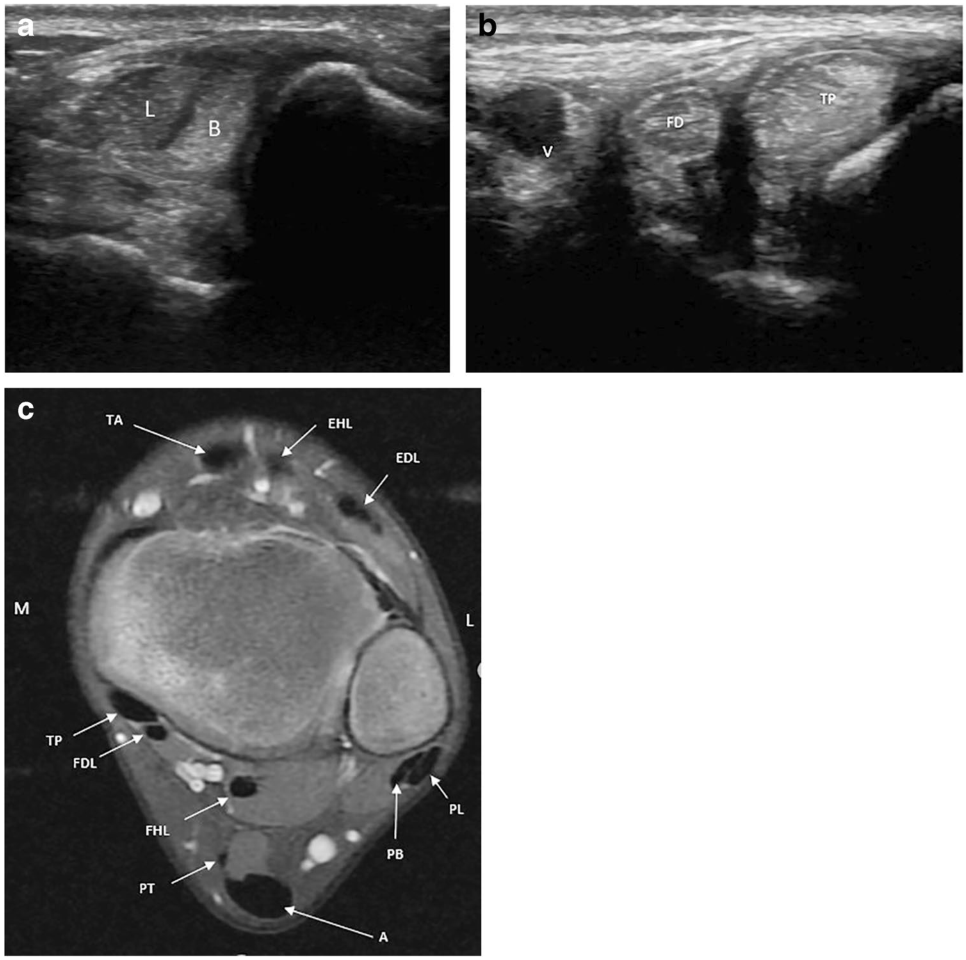


Fig. 7 Normal ankle tendons. **a, b** US in a 17-year-old girl with polyarthralgias. The short-axis images are oriented with the malleoli on the right side of the image. Lateral malleolus sonogram (**a**) shows the flat, echogenic peroneus brevis tendon (*B*) and the ovoid peroneus longus tendon (*L*), both surrounded by the peroneal retinaculum. Medial malleolus sonogram (**b**) shows the tibialis posterior (*TP*) adjacent to the medial malleolus. To the left are the flexor digitorum (*FD*) tendon and the posterior tibial vessels (*V*). **c** Axial fat-suppressed proton-density MR image of the ankle of a healthy 10-year-old boy shows the normal short-axis anatomy of the medial/flexor tendons (*TP*, flexor digitorum longus [*FDL*] and flexor hallucis longus [*FHL*], or "Tom, Dick and very nervous Harry"), the lateral/peroneal tendons (peroneus brevis [*PB*] and peroneus longus [*PL*]) and the extensor tendons (tibialis anterior [*TA*], extensor hallucis longus [*EHL*], extensor digitorum longus [*EDL*]). *A* Achilles tendon, *L* lateral, *M* medial, *PT* plantaris tendon

Tendinosis

The terminology used to describe overuse injuries in tendons has evolved, but inconsistencies in the use of terms still causes confusion. "Tendinopathy" is the generic term for a painful or swollen tendon and has largely replaced the term "tendinitis." The suffix "is" implies inflammation that might not exist in tendinosis but can be present in an immune-mediated condition such as in tenosynovitis or enthesitis. The term "tendinosis" is now the more accepted term to describe tendon over-use injuries because even though some form of inflammation likely plays a role in the pathophysiology of overuse injuries, inflammation is not a hallmark of the disease [2, 13]. Tendinosis is characterized by pain and reduced mobility, caused by repetitive strain of the tendon. Excessive loading leads to microscopic failure of the collagen matrix, fiber disruption and disorientation, generally with an absence of inflammatory cells [2].

Sonographically, there is hypoechoic or heterogeneous thickening of the affected tendon caused by disorganization of the normal parallel arrangement of its fibers. Affected tendons might also show increased vascularity on Doppler imaging, reflecting neovascularization and not inflammation within the normally avascular tendon (Fig. 10). However, no consistent correlation is known between tendon neovascularity and pain or clinical outcome [1, 14, 15].

Tendon tear

Partial- or full-thickness tendon tears occur in both acute and chronic injuries, though tears of normal tendons are rare and require severe force. Tears are more common when traumatic or inflammatory tendinopathy weakens the tensile strength of the tendon. Partial tears appear as a focal hypoechoic cleft or partial defect, either perpendicular to or along the long axis of a tendon, with or without intervening fluid (Fig. 11); complete tears are generally easier to diagnose because they typically show fully separate or retracted tendon margins with intervening fluid or hematoma. There is dynamic separation of the torn tendon margins with passive motion of the underlying joint [16].

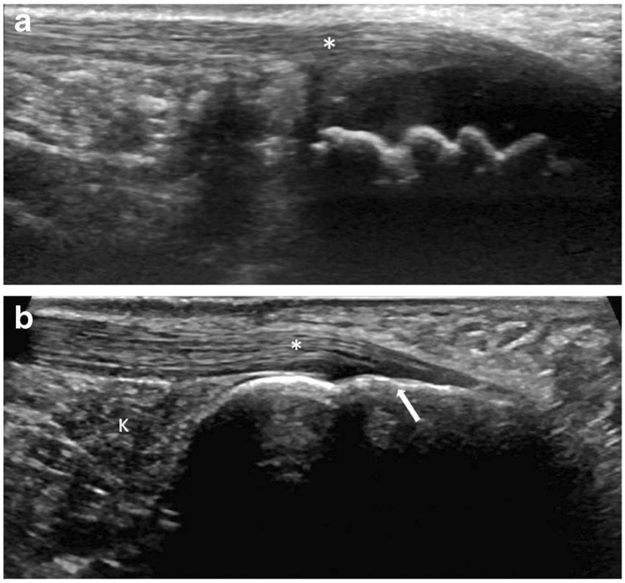


Fig. 8 Normal changes in Achilles tendon insertion with age. **a** Normal insertion in a 6-year-old boy on long-axis US. The Achilles tendon (*) inserts into the unossified calcaneal apophysis. The border of the ossified calcaneus is irregular. **b** Normal insertion in a 16-year-old boy on long-axis US. The Achilles tendon (*) inserts in the ossified calcaneus (*arrow*). The Kager fat pad (*K*) is the echogenic area deep to the tendon

Peroneal tendon tear and subluxation

Longitudinal split tears of the peroneal tendons appear as hypoechoic or anechoic longitudinal clefts. The separated tendon at the level of the split can be visualized best in cross-section. Occasionally, when the peroneus brevis has a longitudinal split, the peroneus longus passes through the two bundles of the torn peroneus brevis (Fig. 12), but only the anterior bundle of the peroneus brevis dislocates. Trauma to the lateral ankle can result in rupture or laxity of the superior peroneal retinaculum that confines the peroneal tendons, resulting in subluxation of the peroneal tendons out of their bony groove behind the lateral malleolus. This subluxation can be elicited with dynamic maneuvers including with dorsiflexion and eversion of the foot, resulting in transient peroneal tendon subluxation anterior and lateral to the fibula [17], and can be seen dynamically with US (Online Supplementary Material 1).

Tenosynovitis

Tenosynovitis represents nonspecific inflammation of the synovial sheath that encases a tendon or tendons. Edema of the paratenon of some tendons, such as the patellar and Achilles tendons, represents a similar process. Inflammation of the tendon sheath or paratenon can be seen in the setting of localized trauma or overuse injury, but it occurs more commonly with inflammatory conditions such as a juvenile idiopathic arthritis (JIA). In JIA, tenosynovitis can be part of the early stages of the disease, either as an isolated finding or in parallel with joint inflammation. Tenosynovitis appears as increased fluid within a thickened tendon sheath surrounding the tendon, with or without associated increased vascularity on Doppler imaging and peritendinous subcutaneous edema. Some tendon sheaths, such as those surrounding the proximal long head of the biceps and the flexor hallucis longus tendon, communicate with adjacent joint spaces and can be normally filled with a small amount of fluid that should be distinguished from true tenosynovitis. US is very helpful in differentiating between arthritis and tenosynovitis in cases

Fig. 9 Anisotropy in an 18-year-old woman with a normal study on long-axis US. The study showed anisotropy in the flexor tendon of the 3rd finger. **a, b** The apparent hypoechoic area in the tendon (*arrow* in **a**) can be corrected (*arrow* in **b**) by changing the angulation of the transducer. This results in homogeneous echogenicity

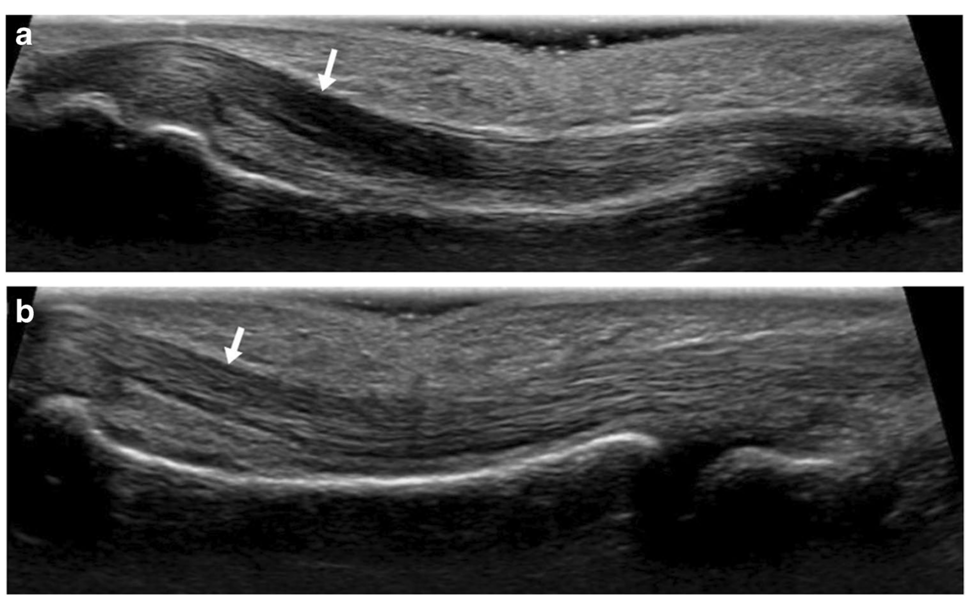


Table 1 Various tendon pathologies in children

Classification	Specific pathology
Congenital	Missing or short tendon
Inflammatory (JIA, psoriasis)	Tenosynovitis, enthesitis, longitudinal tendon tears, peri-tendinitis, cysts of the tendon sheath, bursitis
Infectious	Infectious synovitis
Traumatic	Partial or complete tendon tear, tendinosis (chronic trauma)
Tumoral	Ganglion cyst, fibroma
Degenerative	Tendinosis

JIA juvenile idiopathic arthritis

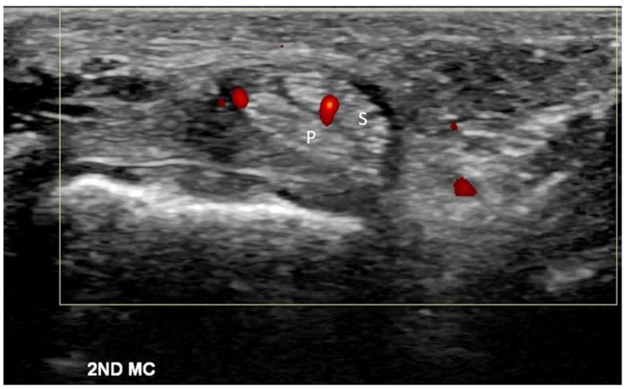


Fig. 10 Tendinosis in a 17-year-old boy with tendinopathy related to juvenile idiopathic arthritis**.** Transverse power Doppler US image shows increased vascularity within the flexor tendons of the 2nd finger. *S* flexor superficialis, *P* flexor profundus

of a painful swollen joint by distinguishing joint inflammation from an inflamed tendon sheath (Fig. 13). Prolonged tenosynovitis can lead to tendinopathy, where the tendon might show swelling, decreased echogenicity and neovascularization [18].

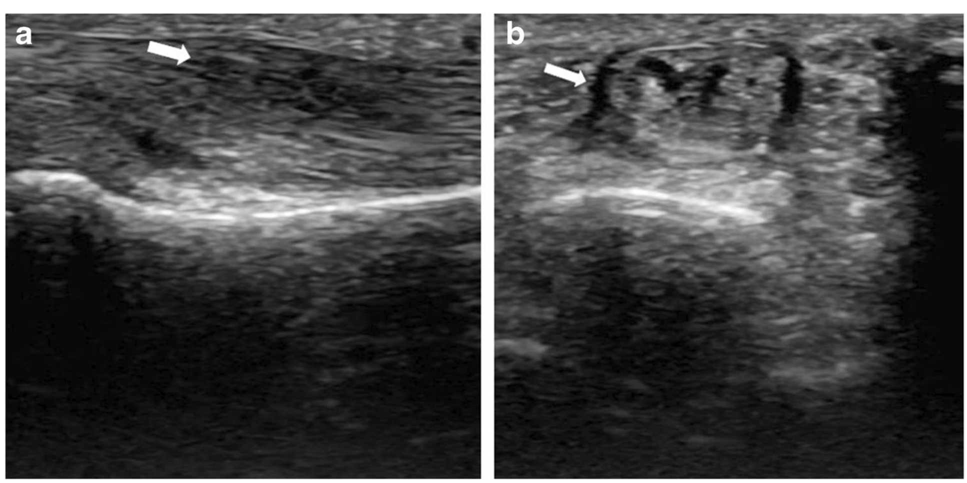
Enthesitis

Enthesitis represents inflammation at the bony insertion sites of ligaments and tendons, often occurring in children with JIA, particularly with the enthesitis-related arthritis (ERA), undifferentiated and oligoarticular-extended categories. Enthesitis should be distinguished from enthesopathy, an osseous proliferation caused by chronic stress at an enthesis that is commonly seen in adults. In enthesitis, there is loss of the normal fibrillar echotexture and thickening of the distal tendon as well as increased Doppler flow as it joins the bone (Fig. 14). In children, enthesitis must be differentiated from normal mild physiological vascularity on Doppler sonography. Although variation in the Doppler settings results in differences in entheseal vascularity, normal tendons should not show more than one or two internal vessels on Doppler imaging [19–21].

Bursitis

Bursae are synovial-lined fluid-filled sacs that act as cushions between bones and tendons and around muscles and adjacent joints. They sometimes communicate with a joint space and therefore they are sometimes normally filled with

Fig. 11 Partial tear of flexor tendon of the 2nd finger in a 15-year-old girl with juvenile idiopathic arthritis. **a** Long-axis US shows an area of thickening and decreased echogenicity of the tendon (*arrow*). **b** Long-axis US shows hypoechoic areas of discontinuity within the substance of the tendon (*arrow*), consistent with a partial tear



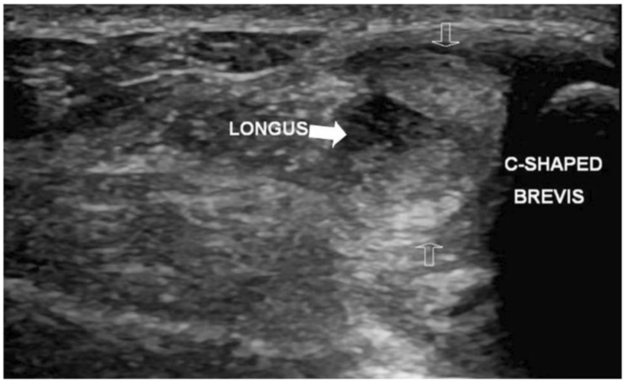


Fig. 12 Peroneal brevis tendon split in a 16-year-old girl. Long-axis US during plantar flexion shows that the peroneus longus (*white arrow*) insinuates itself between the split peroneus brevis (*gray arrows*), which has the shape of an inverted "C"

synovial fluid. Bursitis presents as bursal effusion, synovial thickening and sometimes synovial hyperemia and is commonly seen with JIA. Inflamed bursae are often discovered during the investigation of tendinous pathology (Fig. 15). One of the most frequently inflamed bursae in JIA is the deep infrapatellar bursa, which in the most severe cases extends to involve the superficial infrapatellar bursa. Inflammation of the Achilles tendon bursa (Kager fat pad bursitis, Fig. 15) is seen as a sonolucent area just anterior to the tendon and superior to the calcaneus. Continued inflammation can lead to erosions of the superoposterior calcaneal surface [18].

Peritendinitis in psoriatic arthritis

Juvenile psoriatic arthritis is more correctly called psoriatic juvenile idiopathic arthritis (PsJIA) to reflect its presence within the spectrum of JIA and enthesitis-related arthritis. Early onset PsJIA is more common in girls, while late-onset PsJIA occurs similarly in boys and girls. In PsJIA, enthesitis in tendons and ligaments might be the only musculoskeletal symptom. Inflammation of the distal interphalangeal joints of hands and feet with simultaneous destruction (erosions) and proliferation of bone is characteristic of more advanced disease. In the course of juvenile psoriatic arthritis, inflammation of flexor tendon sheaths, in conjunction with involvement of proximal and distal interphalangeal joints or soft tissues of the fingers, leads to the formation of sausage-shape digits (Fig. 16). US shows abnormal echogenicity of the tendons, fluid in the synovial sheath, and edema and hypervascularity of the surrounding soft tissues [18, 22].

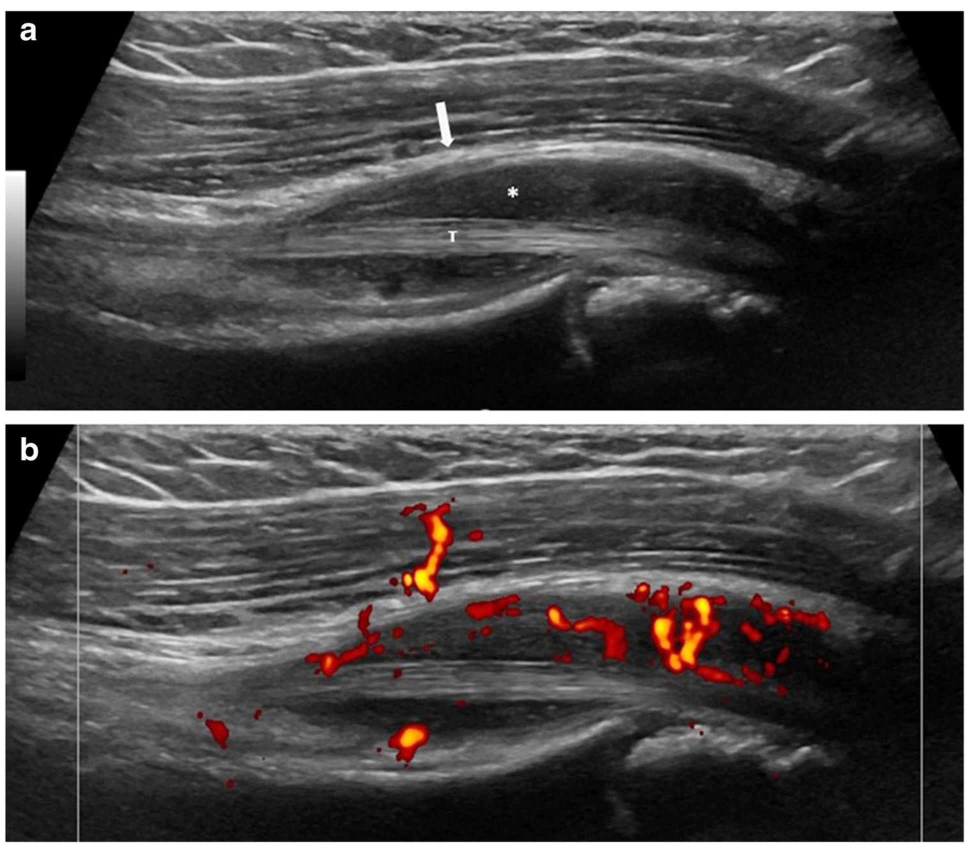


Fig. 13 Bicipital tenosynovitis and bursitis in a 10-year-old girl with juvenile idiopathic arthritis and shoulder pain. **a** Long-axis sonography of the shoulder at the level of the long head of the biceps shows the tendon (*T*) surrounded by fluid (*). A thick synovial sheath (*arrow*) surrounds the tendon. **b** Long-axis power Doppler sonography shows increased vascularity within the enlarged fluid-filled bicipital bursa, presumably representing vascularization of the synovial cavity from an inflammatory process

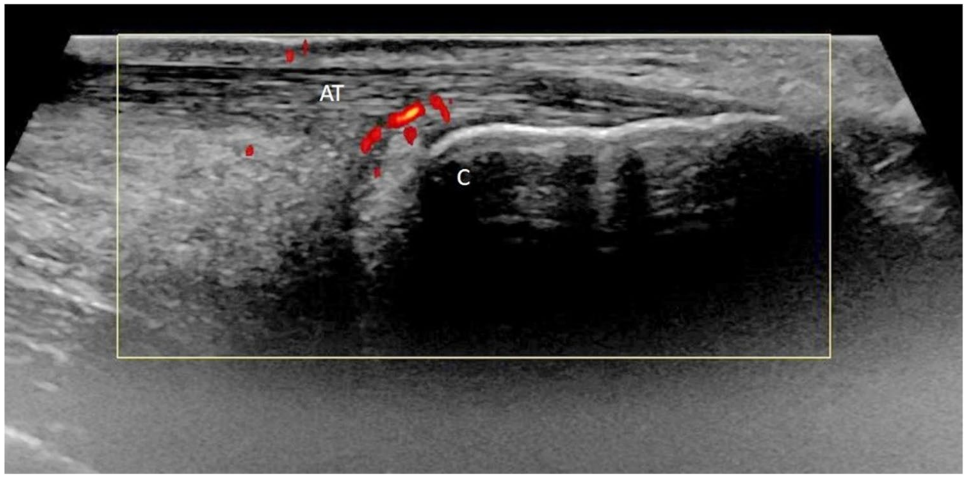


Fig. 14 Enthesitis in a 17-year-old boy with polyarthralgias and heel pain. Long-axis Doppler US shows increased flow at the insertion of the Achilles tendon (*AT*) in the calcaneus (*C*), indicative of enthesitis

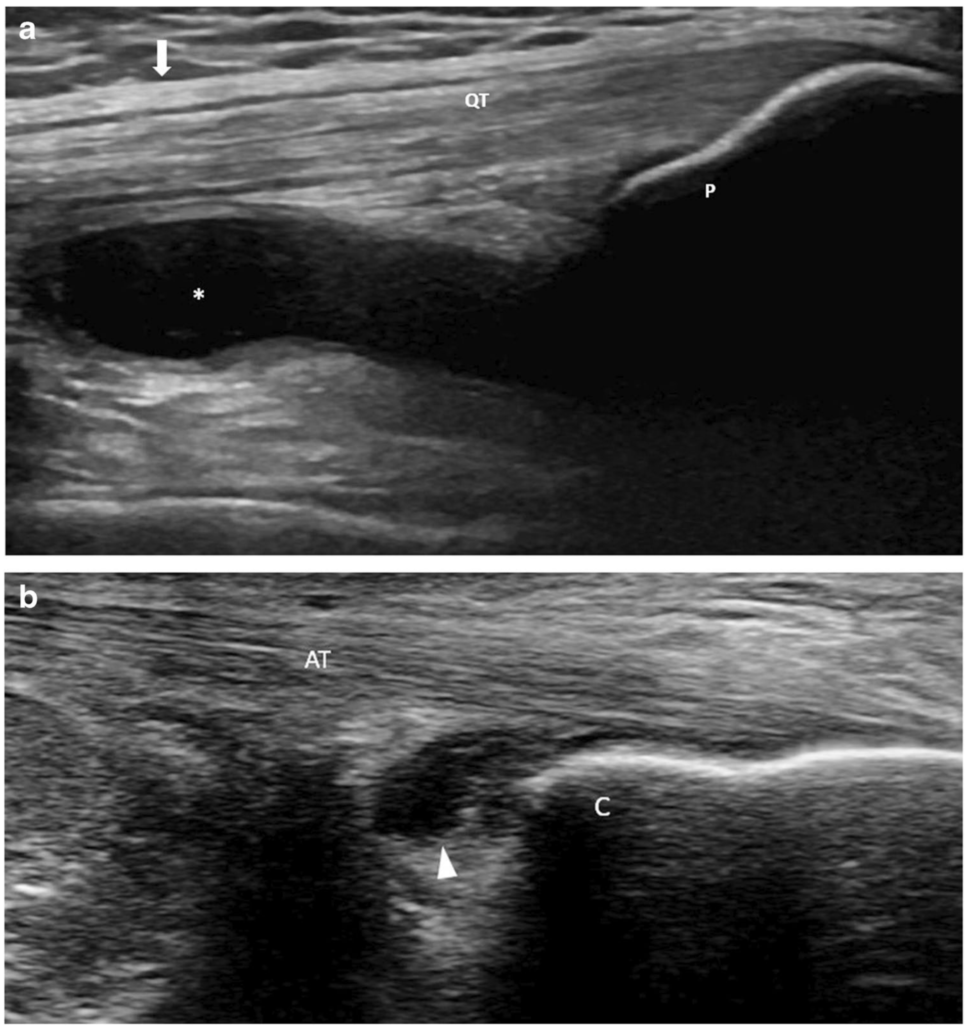


Fig. 15 Examples of inflamed bursae in two girls with juvenile idiopathic arthritis (JIA). **a** Long-axis US shows fluid in the suprapatellar bursa (*), just deep to the quadriceps tendon (*QT*) in a 13-year-old girl with JIA. The synovium and paratenon (*arrow*) are thick. *P* patella. **b** Long-axis US in a different 13-year-old girl with JIA shows the retrocalcaneal bursa (*arrowhead*) just superior to the calcaneus (*C*) and deep to the Achilles tendon (*AT*). Any fluid in this region suggests bursitis

Ganglion cyst of tendon sheath

Ganglion cysts are fluid-filled soft-tissue lesions associated with a joint capsule or tendon sheath (Fig. 17). Although they commonly occur as benign lesions in adults, particularly along the dorsum of the hand and wrist, ganglion cysts are much less common in children and can be associated with synovitis. The exact etiology of ganglion cysts is

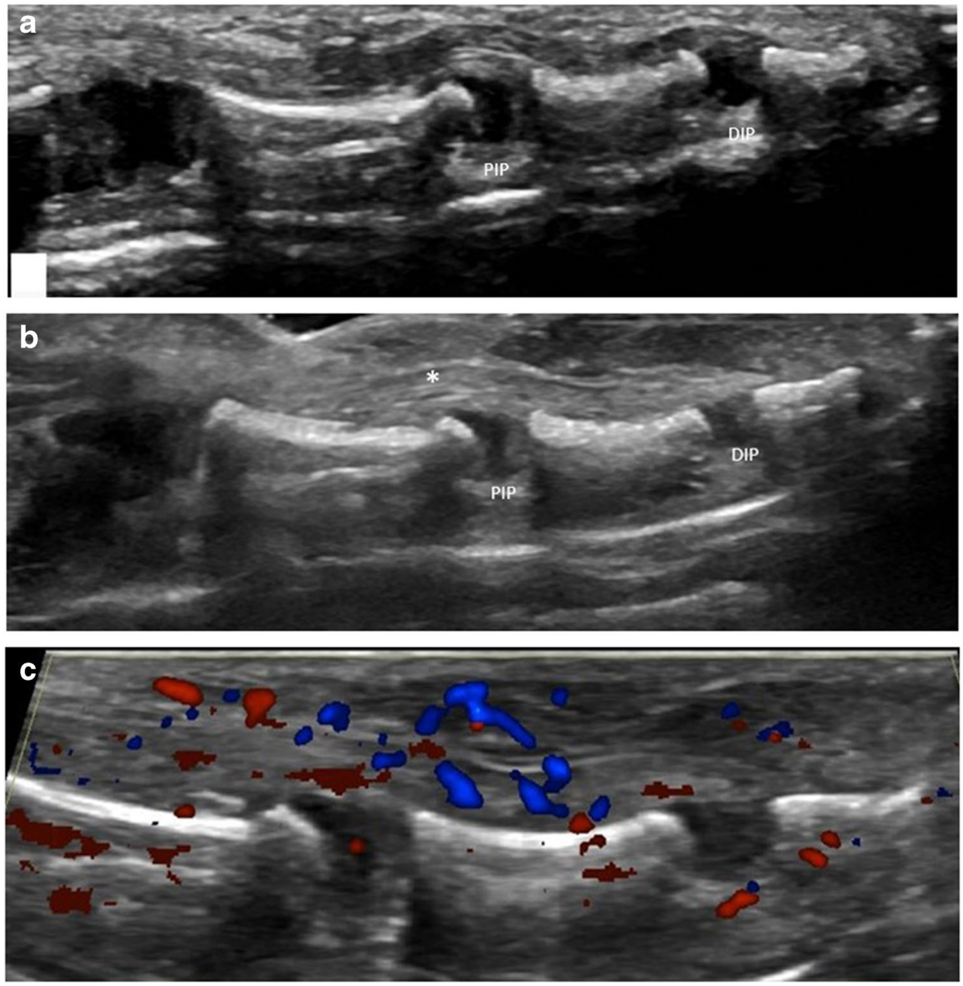


Fig. 16 Psoriatic arthritis in a 2-year-old girl with a "sausage finger" of the 2nd digit. **a** Long-axis US shows normal image of proximal (*PIP*) and distal interphalangeal (*DIP*) joints in the unaffected 2nd digit. **b** Long-axis US of the inflamed finger shows that the flexor tendon (*) is thick and hyperechoic. **c** Long-axis color Doppler US shows increased blood flow at the site of inflammation

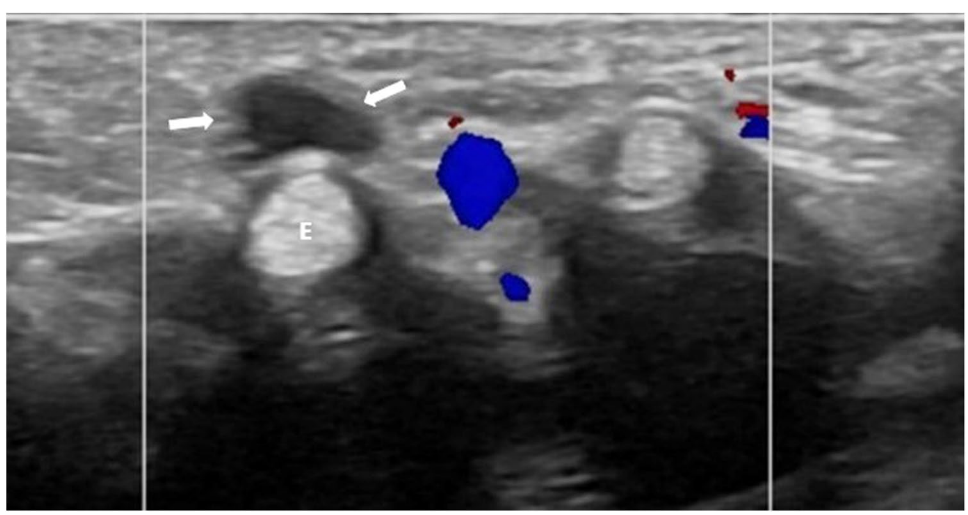


Fig. 17 Ganglion cyst in a 15-month-old boy who presented with a lump in the dorsum of the hand. Short-axis Doppler US image shows an anechoic, avascular synovial tendon cyst (*arrows*) just superficial to the echogenic extensor tendon (*E*)

unknown but thought to be related to cystic degeneration of the joint capsule or tendon sheath. Most are found along the volar aspect of the hand and wrist in children younger than 10 years. In children older than 10 years, the distribution is the same as adults [23–26].

The US appearance of ganglion cysts is variable, although most appear as a well-defined unilocular or septated anechoic to hypoechoic fluid-filled cysts, with or without posterior acoustic enhancement. Ganglion cysts arising from joints more commonly feature thick walls and locules, whereas they are less complex when they involve tendon sheaths (Fig. 17).

Conclusion

Ultrasound offers high-resolution dynamic imaging of tendons that is unparalleled, and it has become increasingly routine in the diagnosis of traumatic and inflammatory tendon pathologies in children including tendinosis, tenosynovitis, enthesitis and bursitis. An understanding of the basic anatomy of all tendons and their related structures along with a recognition of their normal and abnormal sonographic appearances can be applied to many tendon pathologies in the pediatric population. Although there are many tendons within the human body, all with different explicit functions of movement, they share a common architecture and pathological spectrum that is exquisitely revealed on US.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s00247-022-05414-7.

Declarations

Conflicts of interest None

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