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Musculoskeletal Ultrasound in the Emergency Department: Is There a Role?

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Introduction

Once only reserved for Focused Assessment with Sonography in Trauma exams, and abdominopelvic pathology in the emergency department (ED), ultrasound (US) is increasingly used to evaluate many urgent or emergent musculoskeletal (MSK) indications in the United States. The recent growth of MSK US is related to several factors: increased clinical demand; improved US equipment and technique; speed and low cost of examination; incorporation of MSK US into residency and fellowship training of radiologists, emergency physicians, family medicine physicians, sports medicine specialists, physical medicine and rehabilitation physicians, and orthopedic surgeons; improved training of US technologists; and acceptance of the sonographic diagnosis of superficial tendon and other soft tissue injury as being equal to MRI.[1-4] As training programs further integrate MSK US into their diagnostic imaging education, US utilization and breadth of application will increase.

Increased clinical demand for MSK US is a major driver of MSK US expansion in the ED setting. Musculoskeletal complaints account for 20% of ED and primary care visits in the United States.[5] Since the superficial MSK structures lend themselves so well to imaging with US, it is a natural development that MSK complaints would also be readily assessed by US in the ED.

US is already commonly used in the emergent setting at the bedside to look for fluid collections in the soft tissues and to differentiate cellulitis from abscess, or joint effusion from bursitis.[6-11] This type of examination is typically performed either by general US sonographers or by ED physician sonologists. However, widespread adoption of MSK US to assess tendon or ligament injury in the ED setting is limited by lack of subspecialty expertise and by the lack of adequately trained personnel. This review will discuss common benefits and uses of MSK US in the urgent or emergent setting, areas of potential utility, and some of the drawbacks inherent to US as a modality.

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US in the Emergency Setting

In the fast-paced setting of an ED, immediate image acquisition and the ability to make a prompt diagnosis are important for expediting patient management.[12-14] Emergency physicians are becoming increasingly comfortable with sonography and now more frequently perform bedside evaluation, or point-of-care US in the ED as an extension of the physical exam.[6,15-27] The emergency physician has the benefit of direct correlation of US exam findings to the patient's concurrent history and physical exam findings in real-time, during the encounter; thus the emergency physician is more inclined to perform a focused, goal-oriented evaluation.

Focused exams tailored to answer a specific clinical question are undoubtedly quicker than comprehensive exams, an important reason why emergency physicians may prefer to do their own sonography rather than to consult a radiologist.[15] In the specific case of pediatric patients, US is used whenever possible in order to reduce ionizing radiation, with its potential deleterious long-term effects.[18,22,23,28-31]

Joints

Radiography and computed tomography are the mainstays of imaging in the setting of polytrauma. However, when a patient arrives at the ED with a painful, swollen joint, US is useful to make a quick diagnosis of joint effusion, bursitis, or cellulitis, especially when the clinical exam is limited.[6,7,9,11,16,32-36]

Septic arthritis occurs in 5-12 patients per 100,000 ED visits per year. In the United States, about 16,000 ED visits per year involve the primary diagnosis of septic arthritis.[37] Although septic joints are uncommon, the consequences of a missed diagnosis are dire, including joint destruction, permanent impairment of function, sepsis and even death.[38]

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The most commonly infected joints in the ED setting are the knee and hip joints. A simple joint effusion appears as anechoic fluid distending the joint, without synovial hypertrophy or increased flow on color Doppler imaging. Findings concerning, although not specific for septic arthritis include the following: anechoic to complex fluid distending the joint, with synovial hypertrophy and increased color Doppler flow consistent with synovial hyperemia or synovitis[8] (Fig. 1). Of note, a joint can be infected without demonstrating increased color Doppler flow in the synovium.[39] Because this same appearance can also be seen in the setting of inflammatory arthropathy and crystalline arthropathy, arthrocentesis is required in order to differentiate among them. Using US guidance, bedside arthrocentesis can then be performed.[36] One can almost always exclude septic arthritis in the absence of a joint effusion.[40]

Hip pain is a common complaint in the emergent setting. The sudden onset of hip pain, or groin pain, with the inability to bear weight, in the absence of trauma or fall, is concerning for septic arthritis or possibly fracture, if the patient is osteopenic. If radiography does not detect a fracture, then the next step is either cross sectional imaging to assess for occult fracture, or US if effusion or septic arthritis are suspected. US of the hip, however, can present many challenges. If the patient is obese, it can be difficult to get adequate resolution at the depth required to visualize the joint and to guide aspiration. The depth of the hip joint can also make it difficult to distinguish sonographically among the joint capsule, synovial hypertrophy, or a joint effusion; all may appear hypoechoic (Fig. 2). Several parameters have been published for determining a hip effusion on US, for instance, symptomatic hip joint distention of ≥1-2 mm than the asymptomatic hip; or total capsular thickening/distention from the femur greater than 7 mm.[41-43] As with any effusion, it is important to remember that echotexture, complexity and color Doppler imaging cannot discriminate between septic and nonseptic effusions.

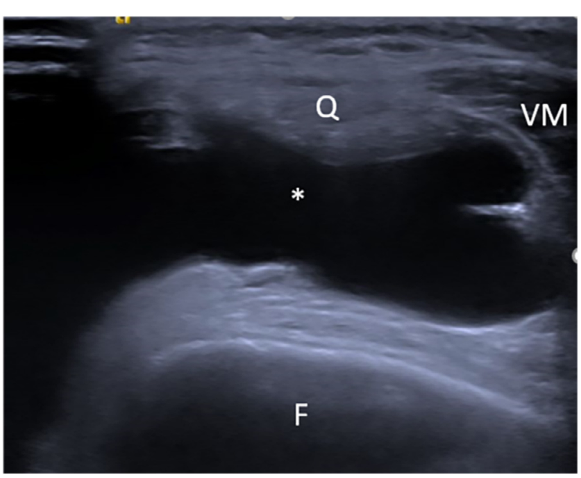

Figure 1 Knee joint effusion in an 8-year-old boy with sudden knee swelling. US of the knee joint in short axis (SAX) with transducer placed transversely across the suprapatellar recess, shows a large, anechoic effusion (*). F, femur; Q, quadriceps tendon; VM, vastus medialis. Bedside aspiration yielded no bacteria; subsequent diagnosis was toxic synovitis.

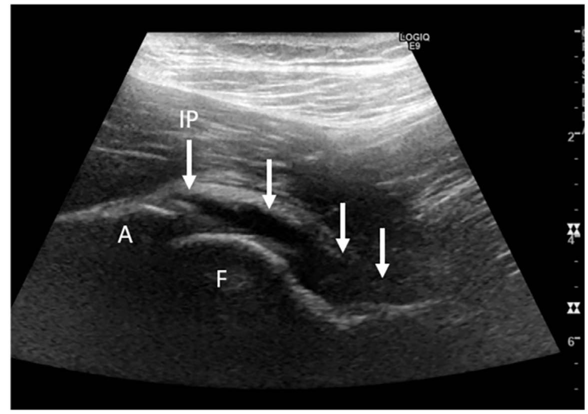

Figure 2 Hip effusion in a 19-year-old woman with sudden hip pain and inability to bear weight. US of the hip joint with the transducer placed in long axis (LAX) to the femoral neck shows a hypoechoic joint effusion (arrows). F, femur; A, acetabulum; IP, iliopsoas muscle. Note that the effusion is seen at a depth of 3.5-5.5 cm.

Glenohumeral joint effusions can cause sudden pain and prompt a visit to the ED. In our experience, crystalline arthropathy and rheumatoid arthritis flares, rather than septic arthritis, account for most of the painful joint effusions we have aspirated in the emergent setting. All of the above entities can present with complex effusions, synovial hypertrophy and hyperemia on color Doppler imaging, necessitating aspiration to make the definitive diagnosis.

The acutely painful acromioclavicular joint can result from osteoarthritis, septic arthritis or inflammatory arthritis. Osteophytes, synovial hypertrophy and joint distention are readily detected with US.[33] Immunocompromised patients and intravenous drug users have increased risk of developing septic arthritis of the acromioclavicular joint; US findings may still be equivocal, though US-guided aspiration of the joint can be easily performed for definitive diagnosis.[44]

Acute swelling of the joints of the hands and feet can cause clinical uncertainty if the patient has a history of gout or rheumatoid arthritis but high clinical concern for infection remains. All etiologies can cause joint swelling and effusion. Monosodium urate crystal deposition in the form of a gouty tophus appears as an amorphous, echogenic, heterogeneous intra-articular lesion, sometimes seen extending into a bony erosion. This finding may correlate to increased radiodensity on radiography, and so can be differentiated from infection (Fig. 3). In the absence of a tophus, the joint capsule may appear echogenic, due to urate crystal deposition within the synovium, also known as the “double contour” or “urate icing” signs.[45] Although extremely rare, infection can co-exist with gout. Therefore, US-guided aspiration is required to differentiate among infectious or inflammatory etiologies.

Bursae

Bursitis is a common musculoskeletal complaint in the ED. Approximately two-third of bursitis cases are nonseptic, being caused by trauma or overuse.[46,47] Septic bursitis is most commonly seen following direct penetrating trauma to

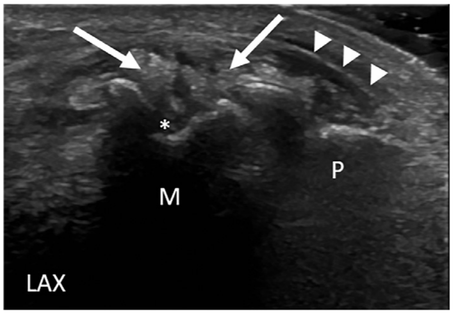

Figure 3 Gout in the first metatarsophalangeal joint. US (LAX) shows an erosion (*) in the first metatarsal (M) head, with an amorphous, echogenic tophus (arrows) distending the joint capsule. The joint capsule is also lined with echogenic urate crystals (arrowheads), in keeping with the "urate icing" appearance of gout. P, proximal phalanx.

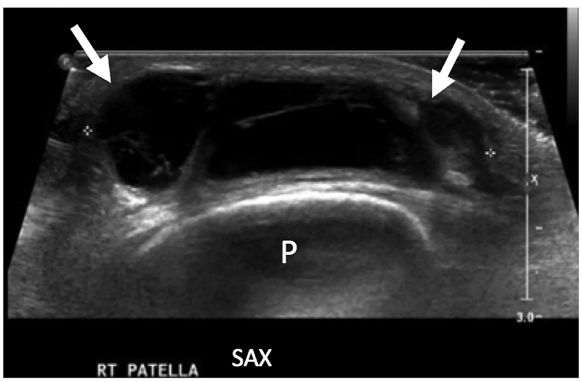

Figure 4 Prepatellar bursitis. US SAX image with transducer placed transversely over the patella (P) demonstrates a mostly anechoic fluid collection (arrows) with internal septations within the subcutaneous tissues anterior to the patella.

the bursa. It is also noteworthy that septic olecranon bursitis occurs four times more often than septic prepatellar bursitis.[46,47]

Bursitis can be easily differentiated from a joint effusion with US, and potential communication with the joint can be evaluated. US may show simple to complex fluid distending the bursa, with or without synovial hyperemia. Because US alone cannot determine septic from nonseptic bursitis, aspiration is required to make the diagnosis.[48] US can also be used to guide the beside aspiration.

Prepatellar bursitis often presents as pain, swelling, and erythema at the anterior aspect of the knee, and there may be a history of a direct blow or repetitive injury. The prepatellar bursa resides within the subcutaneous tissues anterior and inferior to the patella, and can be contiguous with the superficial infrapatellar bursa. The bursa is normally decompressed, containing only minimal fluid, and does not normally communicate with the knee joint. Accumulation of fluid within the bursa is indicative of bursitis, which can be readily identified sonographically (Fig. 4). The fluid can be simple and anechoic, echogenic, or mixed echogenicity. The bursa may also contain hemorrhage and blood products and there may be hyperemia in the bursal wall.

The semimembranosus-medial gastrocnemius bursa communicates with the knee joint. Also known as a popliteal cyst or Baker cyst, this bursa can cause painful swelling in the popliteal fossa behind the knee, especially when it ruptures. Baker cysts are reported to exist in 10%-41% of the population.[49] Acutely ruptured Baker cysts are a common cause of ED visits for popliteal fossa pain. The presentation may be confused for venous thrombosis or infection, as both entities may present with painful swelling, warmth, and erythema. US can reliably diagnose a Baker cyst, identifying the communication with the knee joint that extends between the semimembranosus tendon and the medial head of the gastrocnemius[50] (Fig. 5). Baker cysts have many different appearances, ranging from simple to complex fluid, with thin or hypertrophied synovium, with or without color Doppler flow in the thickened synovium. Baker cysts may also contain internal septations, hemorrhage, echogenic debris, or ossified intra-articular bodies.[50] US can detect ruptured Baker cyst fluid extending distally into the calf, extending in a crescentic fashion between the medial head of the gastrocnemius and the overlying subcutaneous fat.

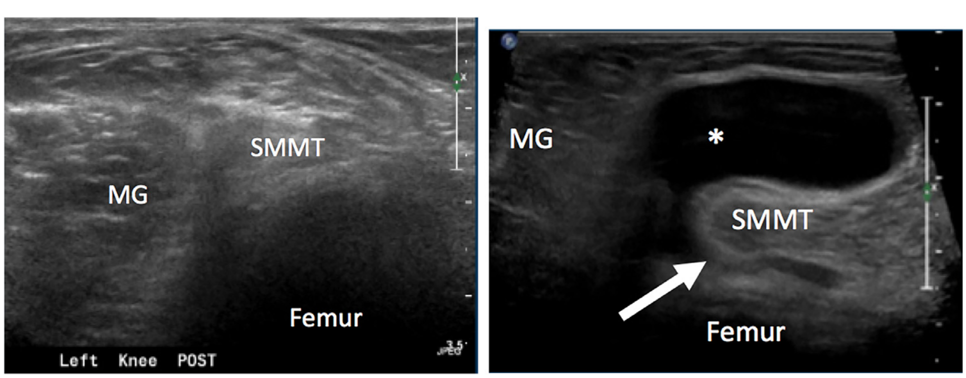

Figure 5 Baker cyst assessment. US SAX image (A) of the posterior medial aspect of the popliteal fossa shows the normal relationship between the medial head gastrocnemius (MG) and semimembranosus tendon (SMMT) posterior to the femur. US SAX image of a different patient (B) with a Baker cyst shows anechoic fluid (*) extending between the MG and the SMMT, with a neck connecting it to the joint (arrow).

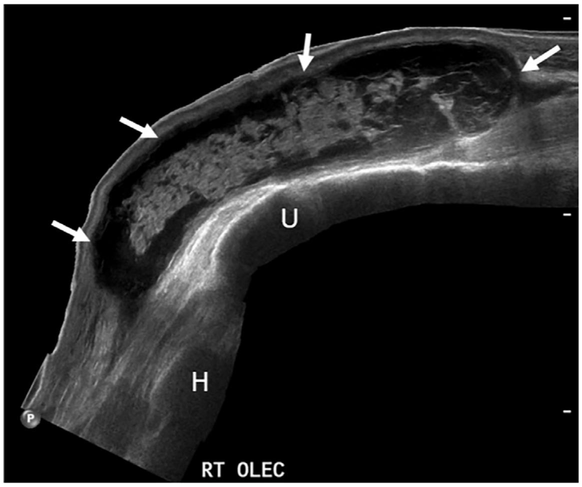

Figure 6 Olecranon bursitis. US panoramic view of the elbow shows a large, complex fluid collection distending the olecranon bursa (arrows), superficial to the elbow and separate from the elbow joint. U, ulna; H, humerus.

In patients with acute swelling of the elbow, a clinical history is particularly important. Beyond traumatic injury to the elbow, pain may be caused by olecranon bursitis, septic arthritis, or soft tissue abscess; US easily distinguishes among these entities. Similar to the Baker cyst, olecranon bursitis has many different sonographic manifestations, from simple to complex, with or without color Doppler flow (Fig. 6). When bilateral, olecranon bursal distention raises suspicion for gout, and US may demonstrate echogenic tophi within. In patients with high risk of infection, including intravenous drug users, there may be high clinical suspicion of both septic arthritis and soft tissue abscess in the antecubital fossa. In these cases, a subcutaneous abscess can be differentiated from elbow joint effusion sonographically.

The subacromial/subdeltiod bursa has long been established as a source of shoulder pain,[35] although bursal thickening and distention can be seen in up to 78% of asymptomatic patients.[51] Bursal fluid communicating with the glenohumeral joint is diagnostic for a full-thickness rotator cuff tear.

Subcutaneous Tissues

Cellulitis and Abscess

Characteristic US findings of cellulitis include skin thickening, increased echogenicity of the normally hypoechoic subcutaneous fat, with obscuration of the normal, linear, echogenic internal septations, and with hyperemia.[10] While subcutaneous edema appears similar to cellulitis on grayscale imaging, the key difference is that cellulitis shows hyperemia on color Doppler imaging while edema does not[7,8,10] (Fig. 7). Cellulitis can also demonstrate a "cobblestone" appearance on US, where hypoechoic to

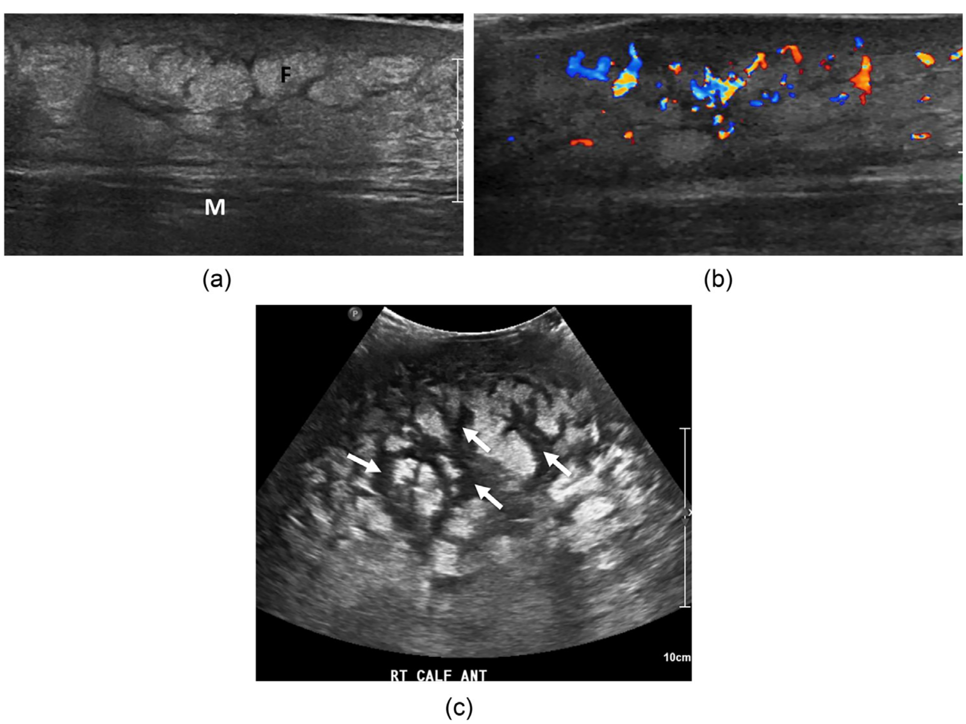

Figure 7 Cellulitis. LAX US image of a patient's forearm demonstrates echogenic subcutaneous fat with obscuration of the normal internal septations (a); this appearance is nonspecific and can be seen in the setting of cellulitis or edema (M = muscle). However, the addition of color Doppler in the same patient (b) shows hyperemia within the echogenic subcutaneous fat, consistent with cellulitis. US of the anteromedial calf in a different patient with cellulitis shows anechoic interstitial fluid interposed among the echogenic subcutaneous fat lobules (arrows), consistent with the "cobblestone" appearance. This finding can be seen in both cellulitis and edema.

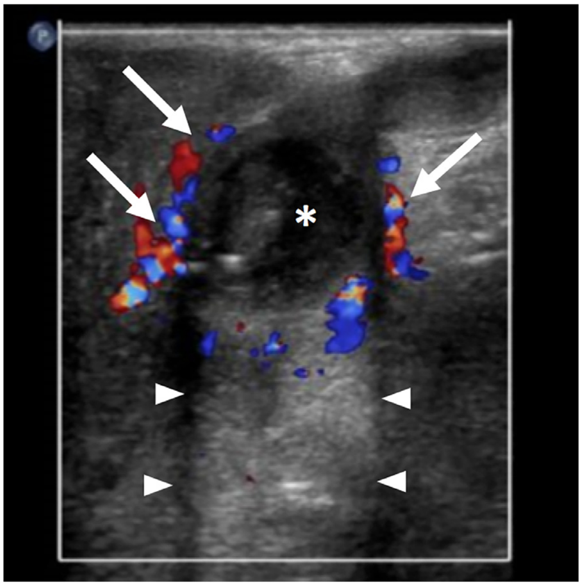

Figure 8 Subcutaneous inner thigh abscess. The abscess (*) is complex and mostly hypoechoic, with a thickened rim and peripheral hyperemia (arrows). Note the posterior acoustic enhancement (arrowheads).

anechoic interstitial fluid interdigitates among the echogenic fat lobules.[7]

If left untreated, cellulitis may progress to abscess formation; US is very useful to differentiate cellulitis from soft tissue abscess.[10] The fluid of an abscess may range from hypoechoic to heterogeneous, or mixed echogenicity. The abscess may have well-defined or ill-defined borders, with or without peripheral hyperemia on color Doppler imaging.[52] Abscesses usually demonstrate increased posterior acoustic enhancement (Fig. 8). Transducer pressure may also cause the abscess contents to swirl[8,10]; however, it is important to note that abscesses can be extremely painful and some patients may not tolerate the transducer pressure required to cause swirling of abscess contents. Percutaneous aspiration or drainage of superficial soft tissue abscess can easily be performed with US guidance.

Foreign Bodies

US can be useful for detecting foreign bodies, especially those that may not be visible on radiography such as wood, plastic, thorns, or small foci of glass[53] (Fig. 9). Foreign bodies appear sonographically as foci of increased echogenicity, depending upon their composition, with deep acoustic shadowing. There may be hypoechoic soft tissue reaction about the foreign body with peripheral hyperemia.[54,55] One advantage over radiography is that US can guide the removal of the foreign body under real-time sonographic visualization.[56] A caveat is that US can miss some wood, glass and gravel foreign bodies.[57] Therefore, it is prudent to assess a patient with a suspected foreign body with both US and radiography.

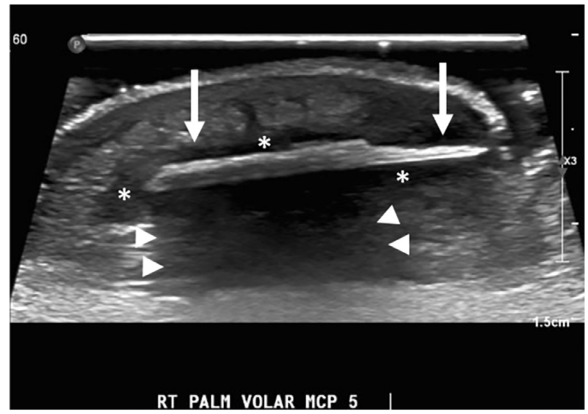

Figure 9 Foreign body in the soft tissues at the volar aspect of the fifth metacarpophalangeal joint. US LAX centered at the volar aspect of the fifth metacarpal head shows an echogenic, linear shard of glass (arrows) with posterior acoustic shadowing (arrowheads) deep to the glass. In addition, hypoechoic granulation tissue (*) surrounds the glass.

Morel-Lavallée Lesion

US provides useful assessment of focal soft tissue abnormalities after blunt trauma. A Morel-Lavallée lesion, or closed degloving injury, is caused by a shearing blow that separates the subcutaneous tissues from the underlying fascia, allowing the space to fill with blood, lymph and necrotic fat.[58] Morel-Lavallée lesions occur most often around the pelvis or proximal thigh, but they can also occur around the knee.[58]

The Morel-Lavallée lesion can be diagnosed by US as effectively as MRI (Fig. 10).[59] The sonographic appearance is that of fluid layering between the deep subcutaneous fat and underlying fascia at the site of injury. The fluid may be anechoic or heterogeneously hypoechoic with echogenic islands of fat, depending upon its complexity, with or without peripheral hyperemia.[59] Percutaneous aspiration of the fluid and subsequent injection of sclerosant may be performed under US guidance, although the recurrence rate of fluid re-accumulation is high.[48]

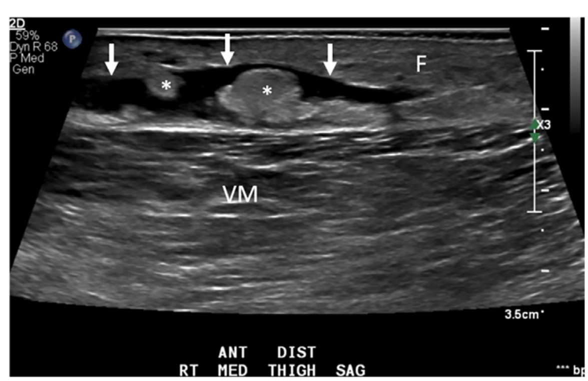

Figure 10 Morel-Lavallée lesion. US of the medial thigh of a man who had blunt trauma, experienced painful swelling and soft tissue mass. There is a heterogeneous fluid collection (arrows) with internal echogenic fat (*) occurring in the characteristic location between the deep subcutaneous fat (F) and the underlying vastus medialis muscle (VM).

One caveat is not to mistake a Morel-Lavallée lesion of the knee with prepatellar bursitis. It is important to note that Morel-Lavallée lesions of the knee occur in the suprapatellar region and extend proximally into the mid-thigh, either medially or laterally in the mid-coronal plane. Prepatellar bursitis, on the other hand, is isolated to the soft tissues anterior to the patella and does not extend proximally or far medially or laterally.[60]

Tendons

The most commonly encountered tendon ruptures in the ED in our practice occur in the Achilles, quadriceps, patellar, biceps and rotator cuff. US provides accurate information about superficial tendon anatomy and associated pathology.[4,61] US has been validated as equivalent to MRI in diagnosis of tendon rupture or injury.[3,4] Dynamic evaluation of tendon rupture allows for the assessment of tear extent and distance of stump retraction, valuable information for surgical planning. The sonographer can also scan for the presence of a hematoma as a sign of acute muscle trauma.[31]

In actuality, the availability of personnel with proper training and confidence to perform these types of tendon-focused US exams in the ED is limited, and thus complete workup commonly occurs after initial assessment and splinting in the ED. Follow-up with orthopedic surgery or sports medicine, and any additional dedicated sonographic imaging, can be performed in the outpatient setting.

The Achilles tendon is readily evaluated with US with the unique added benefit of dynamic imaging. The normal Achilles tendon is echogenic, with a fibrillar pattern, and demonstrates uniform thickness throughout. Tendinopathy appears as diffuse or localized hypoechogenicity, with thickening of the tendon. A full thickness tear, or tendon rupture, appears as a hypoechoic to hyperechoic gap, with no discernible tendon fibers.[62] Partial-thickness tears are reliably differentiated from full-thickness tears sonographically.[63] In the case of complete rupture, the patient can be imaged at 20 degrees and 40 degrees of plantar flexion to see how closely the stumps approximate to one another.[62] If the distance between the stumps is less than 1 cm, the patient will usually do well with conservative treatment; if the stumps are greater than 1 cm apart, then the patient may benefit from surgery[64] (Fig. 11). One potential pitfall is to mistake, in the setting of a complete Achilles rupture, an intact plantaris tendon (which inserts medially on the calcaneus), for a partially torn Achilles.[65] If one sees intact tendon at the medial calcaneus, one can follow it proximally to confirm that it is, indeed, the plantaris tendon, and not the Achilles.

The extensor mechanism in the knee is well-assessed with US. US has been proven sensitive for partial-thickness tears of the distal quadriceps tendon, and also allows dynamic evaluation.[66] Determination of the thickness of the quadriceps tendon tear is important in order to differentiate surgical cases of complete rupture from nonsurgical partial-thickness tendon tears, which are typically managed conservatively.[67] If not evaluated immediately, clinical examination for complete rupture as a palpable gap in the tendon may be obscured by intervening granulation tissue or scar. Similar evaluation of the patellar tendon can be performed.

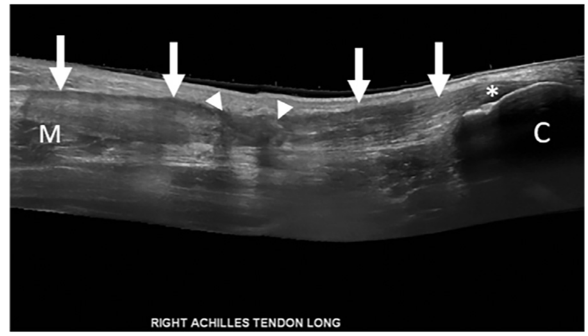

Figure 11 Achilles tendon rupture. US LAX panoramic image shows a markedly thickened and hypoechoic tendon, with abnormality extending from the myotendinous junction (M) through the mid tendon (arrows), consistent with severe tendinopathy. There is focal, hypoechoic discontinuity at the site of rupture (arrowheads) where refraction artifact is also noted at the tendon stumps. The distal insertion (*) on the calcaneus (C) is normal. Upon plantar flexion, the stumps approached within 1 cm of one another, so the patient was treated in a boot and avoided surgery.

Acute shoulder pain is a common presentation to the ED, with rotator cuff disease being one of the more common causes. Dedicated US for rotator cuff tear is most often performed in the nonacute, outpatient setting, using a standard protocol. The protocol requires the patient to move their arm into various positions, including behind their backs. Most patients, when acutely injured and in a great deal of pain, are unable to comply with this examination. However, a brief US in the ED with the patient's arm at their side in neutral position, can gain useful information, allowing triage of patients without acute radiographic findings for conservative therapy and deferred full sonographic assessment.

Emergent or urgent assessment of tendon rupture in the finger can be performed with dynamic US, which has been shown to have greater sensitivity and specificity than physical exam, while being quicker to perform than MRI.[61] US can identify the proximal stump of a completely ruptured tendon, information that is important for surgical planning.[68] Annular pulley disruption can also be diagnosed with dynamic US.[69] That said, these types of exams require a high level of expertise and are likely best deferred to the outpatient setting.

Nerves

According to some authors, US is the preferred first-line modality to assess for traumatic nerve transection and entrapment syndromes.[70,71] While MR neurography can provide high resolution detail, the length of time required for image acquisition and need for the patient to remain still for the duration of the exam may limit its utility in the emergent setting. However, it may be similarly difficult to assess the integrity of a nerve in the presence of an open wound

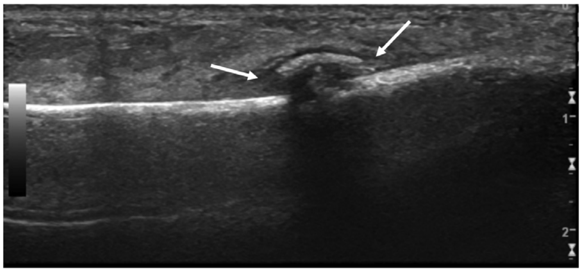

Figure 12 Distal radial fracture in a 5-year-old boy. US LAX of the distal radius shows cortical discontinuity consistent with acute fracture (arrows). US was obtained after radiographs were negative and the patient continued to experience pain.

containing air, foreign bodies, or debris, that cause extensive artifact and obscuration of the nerve. In any case, many peripheral nerve injuries can be addressed later on an outpatient basis once other limb threatening injuries are treated.

Fractures

While radiography is the first-line modality of choice for diagnosis of fracture, there is a potential role for US in cases for which either anatomy is difficult to image radiographically or when clinical suspicion remains high despite negative diagnostic radiography. US is particularly useful in imaging traumatic musculoskeletal injury to the thorax. Compared to conventional radiography, sonography has greater sensitivity and specificity for diagnosis of sternal fractures.[72] There are higher sensitivities for both rib fractures and costal cartilage fractures as well, since the examination can be focused to the area of pain.[73,74]

US is particularly useful to diagnose fractures in the pediatric population, given its lack of ionizing radiation. It has been shown to be accurate in diagnosis of fracture in long bones, particularly in the diaphysis[75] (Fig. 12). US can also be used as a screening tool for elbow fracture.[28,29] Additionally, US has been found to be more sensitive than radiography in the diagnosis of nondisplaced clavicular fractures.[18,23]

Limitations of US

In the hands of highly skilled practitioners, the performance of MSK US in the assessment of superficial soft tissue and tendon injury is equal to MRI. A barrier to the performance of MSK US in the ED is the high degree of training that is required of personnel, both to scan and to interpret the images. Sonographers must be able to recognize the artifacts inherent to MSK US and must be able to manipulate the various parameters in order to optimize image quality. It is vital to have a sophisticated understanding of MSK anatomy and the varied sonographic appearances of tissues such as skin, subcutaneous fat, muscle, tendon, ligament, and synovium, both when normal and abnormal. Without this high level of understanding, the resulting images can be confusing at best, and cause missed diagnoses at worst.

Sonographic evaluation of deep structures comes at the expense of image resolution. Particularly in patients with large BMI or those unable to cooperate with positioning, detection of hip joint effusion, deep abscess, fluid collection, or hematoma may be extremely limited.

Because bone attenuates sound, it is not recommended that US be used as the primary means for detecting fractures. US has shown low sensitivity for fracture detection in the epiphyses and metaphyses of long bones of the extremities and in the scaphoid.[17,76] However, the modality is useful as a troubleshooting method for radiographically occult fractures in which there is high clinical suspicion, especially in children.

Typical US artifacts seen in other body regions exist in the musculoskeletal system as well. One of the most important artifacts is anisotropy. If a tissue containing directional fibers, such as tendon or ligament, is not imaged at 90 degrees to the sound beam, then the tissue may appear hypoechoic, or abnormal, when it is actually normal. Experienced sonographers automatically correct for this artifact by toggling or "heel-toeing" the transducer to confirm whether a finding is pathologic or due to anisotropy. However, an inexperienced practitioner unfamiliar with anisotropy may miscall a normal finding as pathologic or vice versa, leading to potential misdiagnosis or unnecessary follow-up imaging.[77]

Conclusion

In the hands of experienced operators, US is an important adjunct to the clinical exam in the ED, enabling clinicians to rapidly diagnose a painful joint, differentiating joint effusion from bursitis, or cellulitis from abscess. As a problem-solving tool, US is a useful and versatile adjunct to radiography for certain fractures and foreign bodies. US, in experienced hands, also allows the diagnosis of tendon rupture with similar accuracy to MRI. Given that MSK complaints account for a large number of ED visits annually in the United States, it is expected that MSK US will continue to play a vital and expanded role in patient care.

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