Skin, Soft Tissue, and Musculoskeletal Ultrasound

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KEYWORDS

- Ultrasound • Skin • Soft tissue • Cellulitis • Abscess • Musculoskeletal
- Arthrocentesis

KEY POINTS

- Point-of-care ultrasound (POCUS) is an efficient and easy tool to assist in the diagnosis of skin, soft tissue, and musculoskeletal conditions at the bedside.
- POCUS may be used for the evaluation of cellulitis, abscess, necrotizing fasciitis, foreign bodies, and hematomas.
- POCUS may also be used to assist in procedures, such as foreign body removal, hematoma blocks, and arthrocentesis as well as in the evaluation of musculoskeletal complaints including fractures, dislocations, and tendon ruptures.

INTRODUCTION

The landscape of medicine has been reshaped by the advent of ultrasound imaging, with evergrowing importance and usage. The focus on skin, soft tissue, and musculoskeletal ultrasound has emerged as a growing modality, driven by the need for precise, real-time diagnostics in various fields of medicine, including emergency medicine and critical care. There are an estimated 6.8 million emergency department (ED) visits for skin and soft tissue infections (SSTIs) in the United States, while 8% of ED encounters in the United States and Canada are due to musculoskeletal concerns, highlighting the importance of prompt diagnosis and management.[1,2] Traditionally, many of these relied upon radiography (eg, radiographs, computed tomography [CT], magnetic resonance imaging [MRI]), which can increase radiation exposure, costs, and length of stay. Ultrasound can provide a rapid diagnosis and guide management of these patients directly at the bedside. This article will discuss the use of ultrasound in the diagnosis and management for various skin, soft tissue, and musculoskeletal pathologies frequently encountered in the ED.

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DISCUSSION

Skin and Soft Tissue

It is important to understand the normal sonographic findings of skin and soft tissue structures to identify pathologic findings on ultrasound. The normal epidermis and dermis appear as a thin, hyperechoic layer of tissue closest to the ultrasound probe. Beneath it lies the subcutaneous tissue, which appears more hypoechoic due to greater fat content and houses superficial nerves, arteries, and veins. Deep to that is the fascial layer which is a linear hyperechoic layer that surrounds muscles and bones. Other important structures to note are lymph nodes, which appear reniform or oval-shaped and have a fatty echogenic hilum with hypoechoic cortex.

Cellulitis

Cellulitis has an annual incidence ranging from 22 to 50 per 1000 persons, with more than 14 million cases in the United States every year.[3] While cellulitis is often a clinical diagnosis, it can be challenging in some cases to differentiate cellulitis from abscess based only on patient history and physical examination alone, as both can have erythema, tenderness, and induration.[4] Point-of-care ultrasound (POCUS) can be used as an adjunct to assess the extent of the pathology and look for evidence of an underlying abscess.

Data have shown that POCUS can change management in approximately half of patients who present to ED with clinical signs and symptoms of cellulitis by preventing invasive procedures, detecting occult abscesses, and guiding the need for further imaging or consultation.[5] POCUS has also been shown to decrease ED length of stay when used in the evaluation of SSTIs, such as cellulitis.[6]

To evaluate for cellulitis, use the linear probe to evaluate the area of interest in both long and short axes. A curvilinear probe may be used if there is concern for deeper infections. The depth should be far enough to see the subcutaneous tissue and underlying fascial layer. Cellulitis will appear as hyperechoic fat lobules separated by fluid in the subcutaneous tissue, often described as "cobblestone" appearance, thought to mimic a cobblestone street (**Fig. 1**). It is often helpful to scan slightly distal from the area of interest first to see the "normal" appearance of the patient's skin and then compare it to the findings at the area of interest. It is important to note that POCUS

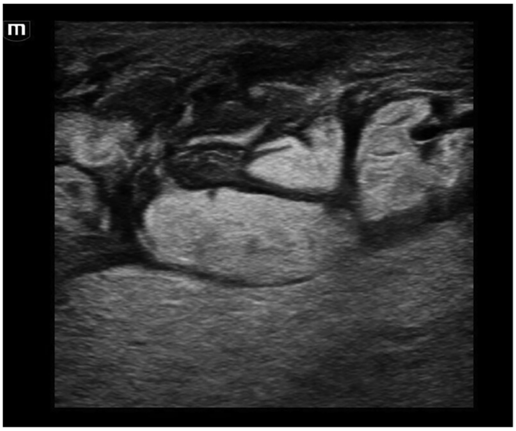

Fig. 1. Cellulitis appears as hypoechoic fluid in the subcutaneous tissue often separating fat lobules, often termed as "cobblestoning."

must be used in conjunction with the clinical examination, as many other pathologies that cause edema can mimic cellulitis on ultrasound (eg, congestive heart failure, lymphedema, deep venous thrombosis).

Abscess

ED visits for abscesses had increased from 1.2 to 3.2 million from 1996 to 2005.[7] Abscesses can be challenging to diagnose, particularly when they are smaller in size or deeper to the skin surface, with data suggesting poor inter-rater reliability for diagnosing abscesses using physical examination alone.[8] Ultrasound has also been shown to be more accurate than clinical examination in both adults and pediatrics for diagnosing abscesses.[9]

One recent systematic review and meta-analysis including both pediatric and adult patients found that POCUS was 93% sensitive and 87% specific.[10] Another study found that POCUS correctly changed the management in 10.3% of cases involving abscesses and incorrectly changed management in only 0.7% of cases.[11] They found that ultrasound was particularly useful in clinically uncertain cases, where it outperformed physical examination.[11]

The sonographic approach to abscesses is similar to cellulitis, utilizing a linear or curvilinear array probe and scanning in both the short and long axes over the area of interest. An abscess cavity will appear round or irregularly shaped with an anechoic or hypoechoic center and posterior acoustic enhancement (**Fig. 2**). Often, there will be debris seen internally with echogenicity that may represent purulence or loculations. Graded compression of the abscess may cause the internal debris to shift, often described as the “swirl sign.” Ultrasound can also establish the extent and depth of the abscess cavity, as well as locate the best area for incision and drainage. The use of color Doppler is important to assess for vascularity, in order to avoid surrounding vasculature and potential mimics (eg, pseudoaneurysms). Abscesses are avascular internally, whereas vascular structures will have constant or pulsatile color flow throughout the cavity. For example, the use of color Doppler on a normal lymph node will show hilar vascularity as compared to an abscess where color flow will be absent within the structure itself. Finally, ultrasound may aid in the management of abscesses by determining the overall size to inform the decision for antibiotics versus incision and drainage.

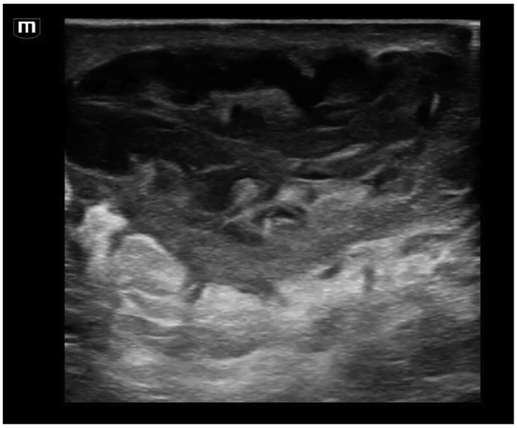

Fig. 2. Abscesses are hypoechoic or isoechoic fluid-filled cavities often with internal debris and surrounding hyperemia with posterior acoustic enhancement.

Necrotizing fasciitis

Necrotizing fasciitis (NF) is a life-threatening, severe SSTI that requires prompt diagnosis and surgical intervention. One study found that the mortality ranges between 25% and 75%,[12] with delays in diagnosis significantly increasing both morbidity and mortality.[13] A systematic review found that ultrasound for NF had a sensitivity of 85% to 100% and a specificity of 45% to 98%.[14]

The technique is similar for other skin and soft tissue examinations described earlier. Ultrasound findings of NF can include thickening of deep fascia, diffuse thickening of the overlying fatty tissue, and a fluid layer along the deep fascia (**Fig. 3**) and commonly, the STAFF mnemonic has been used to describe the ultrasound findings of NF, which includes subcutaneous thickening, air. and fascial fluid.[15] One study found that fluid accumulation along the fascial plane was the most sensitive ultrasound finding at 85.4%, while subcutaneous emphysema was the most specific ultrasound finding at 100%.[16] Gas in NF often appears as hyperechoic with posterior dirty shadowing; however, this can also be mimicked in the case of recent procedures or open wounds where air can become trapped beneath the skin surface.

Foreign bodies

Any patient presenting to the ED with a wound should raise concern for a potential retained foreign body (FB). Retained FBs are found in 7% to 15% of wounds in the ED with up to 38% missed on initial physician evaluation.[17] Retained FBs should also be considered in intravenous (IV) drug users (IVDUs), as 1 study found that up to 20% reported a needle break on one or more occasions while injecting.[18] Retained FBs are associated with wound complications and high medicolegal risk.[19] Radiographs are commonly ordered to evaluate for retained FB, but not all FBs are visualized on X ray—most notably wood, plastic, and organic matter.[20] A systematic review and meta-analysis reported POCUS was 72% sensitive and 92% specific for FB detection.[17] When performed by a trained emergency medicine physician, another study found the sensitivity may be as high as 97%.[21]

To visualize for an FB, place a high-frequency linear probe over the wound or area of interest. If the wound is open, a probe cover should be utilized to protect the

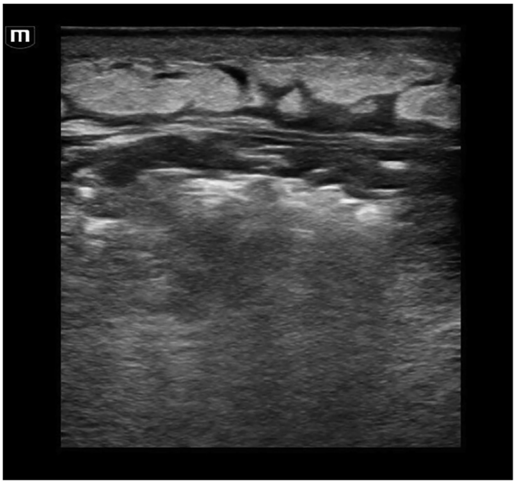

Fig. 3. Necrotizing fasciitis with hyperechoic air with posterior "dirty" shadowing with fluid along the fascial planes.

ultrasound probe from bodily fluids and contamination. The operator should use a water bath or a saline bag to improve the proximal image resolution if there is concern the FB is close to the surface of the wound. FBs often appear hyperechoic compared to the surrounding tissue. The depth of the object should be measured to assist with FB localization and removal. Most foreign objects have posterior shadowing, while metal may also demonstrate reverberation or comet tail artifacts (**Fig. 4**).[22]

When used for real-time guidance in FB removal, first identify the FB and visualize it in the long axis. Then, anesthetize the overlying skin and make an incision parallel to the FB. Insert a hemostat under the ultrasound toward the retained object. If the object is a solid structure (eg, needle), a small incision can be made and the object retracted along its path; if the object is at risk of splintering (eg, wood), the incision should follow the entire length of the object and it should be lifted vertically from the wound.

Bones

Fractures

Long-bone fractures are a common reason for ED presentation. Globally, there were 178 million new fractures in 2019, which is a 33% increase from 1990.[23] Radiographs are commonly ordered; however, these can increase radiation exposure, length of stay, and health care costs.[24,25] POCUS has arisen as an alternate modality that can be rapidly performed at the bedside for initial diagnosis and reassessment after reduction. Moreover, some investigators have proposed using POCUS for assessing Salter-Harris I fractures by visualizing the growth plate and correlating this with the area of pain.[26]

Data are variable for upper and lower extremity fractures in adults, with sensitivities of 42% to 100% and specificities of 65% to 100%.[27] Among pediatric patients, 1 meta-analysis found that POCUS was 95% sensitive and specific.[28] A recent randomized control trial comparing radiography with POCUS for pediatric distal forearm fractures reported no difference in outcomes, but POCUS reduced ED length of stay by 30 minutes.[25]

To perform this technique, utilize the linear probe to visualize the bone in short and long axes through the entire length of the bone (**Fig. 5**). Make sure to visualize across multiple imaging planes (eg, anterior, posterior, medial, and lateral sides). If a fracture is identified, determine the degree of alignment and any angulation present. If visualizing a growth plate, compare with the contralateral side for appearance and width.

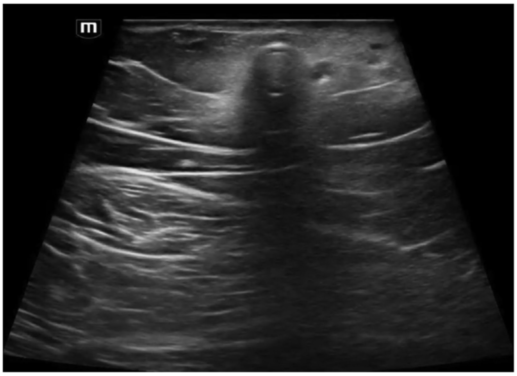

Fig. 4. Retained metal foreign object with posterior shadowing.

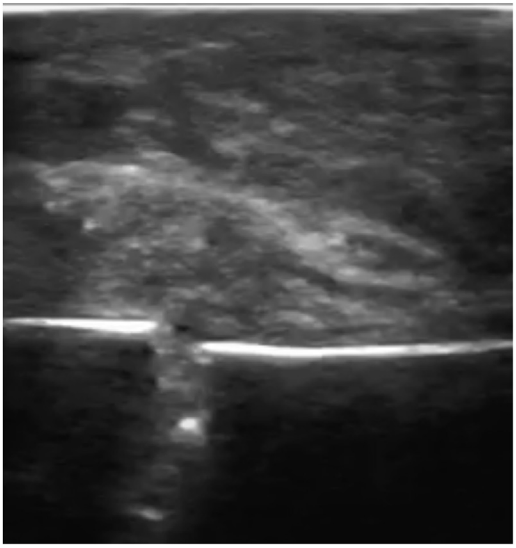

Fig. 5. Hyperechoic bone with cortical interruption representing fracture.

Osteomyelitis

Osteomyelitis should be suspected in patients presenting with cellulitis and evidence of systemic infection, nonhealing ulcers, or fistulous tracts.[29] While radiography is often ordered for patients with suspected osteomyelitis, plain radiographs and CT have limited accuracy.[30] Advanced imaging modalities, such as MRI and PET, have higher accuracy but are time consuming, not universally available, and can be significantly delayed.[30] POCUS could allow rapid diagnosis at the bedside and identify findings before they appear on X ray.[31]

Multiple case reports and studies have demonstrated a role for early identification using POCUS, with sensitivity ranging from 76% to 100%.[32–39] Two case reports have even described using ultrasound for real-time guidance of aspiration under local anesthesia.[34,40] Importantly, POCUS can be falsely negative early in the disease process, so a repeat examination should be considered if the initial POCUS is negative but a clinical suspicion remains.[41] One study of 37 patients reported 76% sensitivity on admission, which increased to 84% at 4 to 7 days post-admission.[38] Another study reported 85% sensitivity if performed within the first week, but increased to 90% with daily POCUS examinations.[37]

To perform this technique, begin by visualizing the affected area with a high-frequency linear probe in both the long and short axes to evaluate for periosteal elevation. The earliest finding is typically swelling of the overlying muscle or subcutaneous tissue overlying the bone (days 1–3).[36,39,42] The next finding is thickening of the periosteum with hypoechoic zones both superficial and deep to the periosteal layer, referred to as the ‘periosteal sandwich’ sign (days 4–6)[35,36,39,42] (**Fig. 6**). Later findings can include a hypoechoic fluid collection (typically $\geq$2 mm) with a hyperechoic rim, which may or may not include cortical erosion (days 7–14).[35,36,41,42] When present, this latter finding may be more predictive of the need for surgical intervention.[36] When unclear, compare the findings with the contralateral side, particularly in pediatric patients, where findings can be mimicked by growth plates.[41] Color Doppler can also assist with the diagnosis by assessing for hyperemia. Two studies reported that

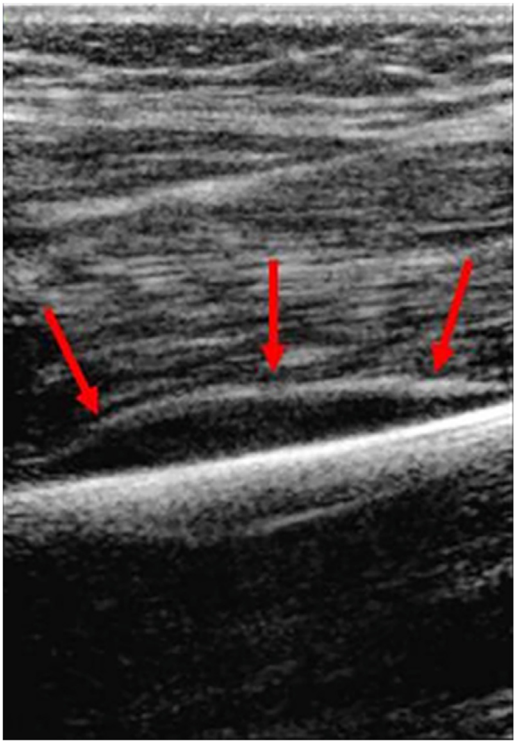

Fig. 6. Thickening of the periosteum with hypoechoic zones both superficial and deep to the periosteal layer, referred to as the 'periosteal sandwich' sign (*red arrows*). (Image courtesy of Inusa et al (Inusa BP, Oyewo A, Brokke F, Santhikumaran G, Jogeesvaran KH. Dilemma in differentiating between acute osteomyelitis and bone infarction in children with sickle cell disease: the role of ultrasound. PLoS One. 2013 Jun 6;8(6):e65001. https://doi.org/10.1371/journal.pone.0065001. PMID: 23755165; PMCID: PMC3675051.)

hyperemia was present in 100% of cases of proven osteomyelitis, but it may not be present in the first several days of symptoms.[35,43,44] Hyperemia on color Doppler may also predict a greater likelihood of requiring surgical intervention in pediatric patients.[39,44]

Confirming intraosseous line placement

Intraosseous (IO) lines are performed when medications or fluids need to be given rapidly and IV access is limited. Studies have reported variable success rates with anatomic placement of IO lines, ranging from 45% to 97%.[45–51] Moreover, it can be challenging to confirm adequate placement clinically, particularly in patients with increased soft tissue or pediatric patients. IO needle dislodgement or accidental placement through the bone with the needle entering the soft tissue posterior to the bone can cause compartment syndrome if excess fluid is infused into the compartment instead of the bone.[52]

Several case reports have demonstrated the role of POCUS in the confirmation of IO placement.[52,53] A cadaveric study of POCUS reported it was 100% sensitive and 100% specific, compared with standard evaluation (ie, assessment of the flow of IV fluid) which was 87.5% sensitive and 25% specific.[54]

To perform this technique, place a linear probe just distal or proximal to the insertion site. Turn on color or power Doppler and place the Doppler region over the bone and just below the cortex. Inject saline and assess for fluid entering bone. Some experts have suggested using agitated saline and visualizing the heart as an alternate confirmatory technique.[55]

Ultrasound-guided hematoma block

Hematoma blocks are commonly performed for anesthesia prior to reduction of long-bone fractures. The landmark-based approach relies upon palpation of a cortical deformity and inserting the needle into the fractured area; however, this can be more challenging in patients with increased soft tissue edema or less-displaced fracture fragments, often requiring multiple needle passes to locate the hematoma site. POCUS allows real-time guidance for tracking the needle, which can improve accuracy, reduce the number of needle passes, and even allow smaller needles to be used (as it does not require the needle to track along the bone as with the landmark-based technique). The ultrasound-guided approach is particularly beneficial for smaller fracture sites, such as the ulnar styloid with complicated distal radius fractures.[56]

Multiple case reports have demonstrated successful ultrasound-guided hematoma blocks for fractures of the distal radius and ulna,[56–58] proximal humerus,[59] clavicle,[60] sternum,[61,62] and femoral neck.[63] One study of 143 adult distal radius fractures randomized patients to ultrasound-guided hematoma blocks versus procedural sedation and found no difference in pain scores, patient satisfaction, or physician satisfaction.[64] In the POCUS group, there was also a shorter time to discharge and fewer complications.

To perform this technique, first identify the fracture site in the long axis. Create a skin wheal and then advance the needle toward the fracture site using the in-plane technique (ie, needle parallel to the ultrasound probe). Once the needle enters the fracture site, visualize for fluid entering the hematoma site or widening of the hematoma site in real-time.

Joints

Acromioclavicular joint

The acromioclavicular (AC) joint consists of the distal clavicle and acromion process of the scapula (see **Fig. 5**). Injury to the AC joint accounts for 40% of shoulder injuries with residual pain affecting 30% to 50% of patients.[65,66] While often assessed via X ray, POCUS allows for rapid diagnosis, as well as aspiration or injection at the bedside.

Begin by positioning the patient sitting upright with their arm resting at their side. Place the linear probe on the superior shoulder in a coronal plane parallel with the clavicle. An anechoic joint space between the curved surfaces of the acromion and distal clavicle should be visualized and measured.[67] Based upon radiographic data, a normal joint space is about 3 to 4 mm and becomes smaller with age.[68,69] Diagnosis of an AC joint separation is supported by a difference of 2 to 3 mm when compared with the unaffected joint space (**Fig. 7**).[70] Some have proposed a dynamic evaluation of the joint distance comparing the neutral shoulder position versus a cross-arm position (palm on contralateral shoulder) with a difference greater than 1 mm considered abnormal.[71]

Ultrasound can also be used for injection or aspiration, with data suggesting ultrasound guidance is more successful than the landmark-based approach (93.6% vs 68.2%).[72] AC joint septic arthritis is uncommon, but can be seen in those with IVDUs and immunocompromised patients.[73] The AC joint should be evaluated if there is initial

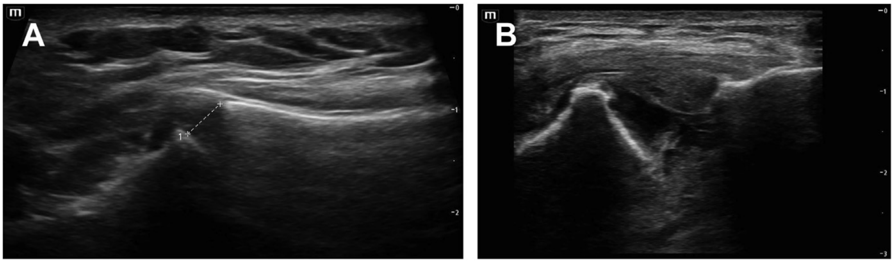

Fig. 7. (*A*) The acromioclavicular joint consists of the distal clavicle and the acromion process of the scapula. (*B*) Separation of the acromioclavicular joint appears on ultrasound as widening of the joint space more than 2 to 3 mm when compared to the unaffected side.

suspicion for glenohumeral joint pathology without evidence of glenohumeral joint effusion.[74] A distended AC joint capsule greater than 3 mm represents an effusion (**Fig. 8**). In-plane arthrocentesis with sterile technique is preferred, but the out-of-plane technique may be necessary if there is not sufficient overlying soft tissue to accommodate needle visualization. If injecting anesthetic, the joint can typically accommodate 0.5 to 2 mL of anesthetic.[67]

Shoulder joint

Shoulder dislocations are a common ED presentation. Reduction attempts are less successful the longer the joint is dislocated; therefore, rapid diagnosis and reduction is important.[75] POCUS can decrease time to diagnosis and reduction, radiation exposure, and health care costs and is 100% sensitive and specific for shoulder dislocation.[76,77] Septic arthritis occurs 3% to 12% of the time in the shoulder joint.[78] Ultrasound guidance increases the accuracy of arthrocentesis compared with a landmark approach (100% vs 82%).[72,79,80]

A linear or curvilinear probe may be used to visualize the glenohumeral joint (**Fig. 9**). One approach to locate the glenohumeral articulation is to place the probe on the posterior humerus in a probe plane and slide superiorly.[81] An alternative approach is to place the probe on the scapular spine and trace it laterally to the glenoid.[77] Anterior dislocations are diagnosed by anterior displacement of the humeral head away from the probe and glenoid rim (**Fig. 10**), with the humeral head seen deeper in the figure. Conversely, posterior dislocations are diagnosed by posterior displacement of the

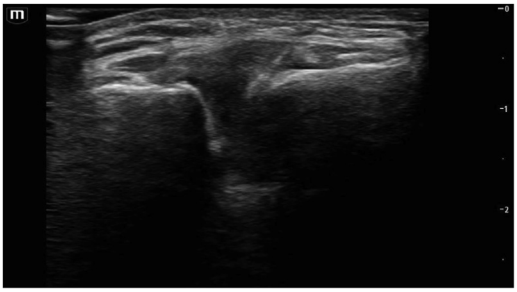

Fig. 8. Acromioclavicular joint effusion appears as distention of the joint capsule filled with hypoechoic fluid.

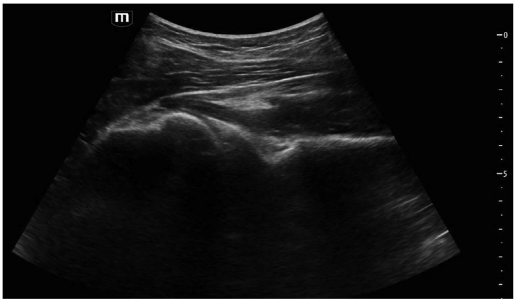

Fig. 9. The posterior shoulder joint is visualized with the humeral head articulating with the glenoid process of the scapula.

humeral head toward the probe with the humeral head seen more proximally on the screen.

The synovial space is easily accessed in a posterior approach using the same view described earlier. As the posterior shoulder joint capsule is thin, the posterior recess is a common place for effusion to collect.[82] With ultrasound, an effusion appears as a hypoechoic or anechoic material that is compressible/displaceable and does not have Doppler signal (**Fig. 11**).[83] Elevation of the infraspinatus tendon greater than 2 mm from the posterior glenoid labrum and a fluid stripe greater than 3 mm is suggestive of a large effusion, though effusions as small as 4 mL are detectable by ultrasound.[78,84] Once space is identified, insert the needle in-plane toward the glenohumeral joint. Anesthetic (about 10 mL) may be injected into the joint space under ultrasound guidance with a sterile procedure to enhance pain management during shoulder reduction.[67]

Elbow joint

Between 3% and 9% of all cases of septic arthritis occur in the elbow joint.[85] Ultrasound decreases aspiration attempts and increases successful aspiration.[86,87] To perform arthrocentesis, the patient's elbow should be placed in 90° of flexion with the arm resting on a table or across the torso. Place a linear probe on the posterior humerus in a longitudinal axis and slide inferiorly. In this view, the triceps tendon, distal humerus, and posterior fat pad should be visible (**Fig. 12**).[88] The olecranon fossa appears V shaped. If an effusion is present, it will appear hypoechoic at the base of the

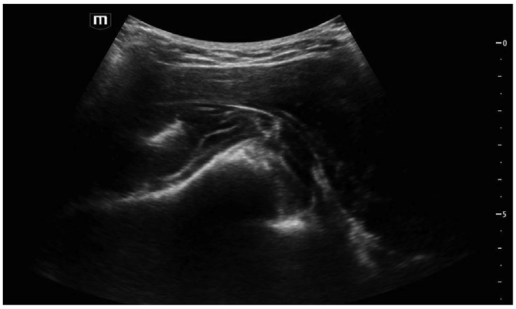

Fig. 10. An anterior shoulder dislocation is demonstrated by anterior displacement of the humeral head from the glenoid rim.

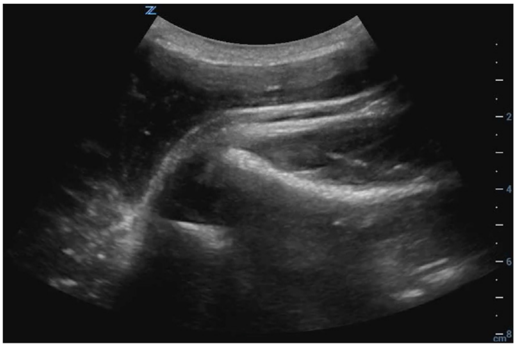

Fig. 11. A shoulder effusion is evidenced by compressible hypoechoic fluid with absence of Doppler signal within the joint space.

fossa and will displace the fat pad out of the fossa (**Fig. 13**).[89] Rotate 90° to visualize the joint in short axis. A needle can be inserted into the effusion using the in-plane technique from the lateral side of the elbow avoiding the triceps tendon by diving beneath it.

Wrist joint

Ultrasound improves arthrocentesis success in medium-sized joints like the wrist (94% vs 60%).[90] To assess the wrist with ultrasound, the patient's hand should be positioned in protonation with slight wrist flexion and ulnar deviation by placing a towel roll under the distal forearm. The linear probe should be placed on the dorsal distal forearm with the radius in a longitudinal view (**Fig. 14**). Copious gel may be needed to facilitate visualization of the angular surface.[91] Slide the probe distally to visualize the articulation of the radius and scaphoid. The extensor pollicis longus tendon should be located directly below the probe as this serves as a guard to prevent tendon injury during needle insertion. For arthrocentesis, insert the needle at a steep angle under the

Fig. 12. The elbow joint can be visualized at the distal humerus as it articulates with the olecranon and radial head.

Fig. 13. An effusion of the elbow joint appears as hypoechoic fluid lifting the fat pad up and out of the V-shaped olecranon fossa.

middle of the probe on the ulnar side. With the out-of-plane technique, only the needle tip or shaft may be visible in the effusion (**Fig. 15**). It is also possible to insert the needle in-plane in a distal to proximal direction if there is sufficient soft tissue.[67]

Hip joint

The incidence of septic arthritis is between 2 and 6 cases per 100,000 in the general population.[92] The hip joint is the most common site of septic arthritis in children,[92] and represents approximately 15% of all cases of septic arthritis in adults.[73] Ultrasound-guided hip injections are more accurate than the landmark technique, with 1 meta-analysis showing ultrasound was 100% successful versus 72% with the landmark technique.[93] Ultrasound has also been shown to decrease time to diagnosis and definitive management of septic arthritis.[94]

Place the patient in a supine position. A linear or curvilinear probe may be used, depending upon body habitus. The femoral head and neck should be visualized in

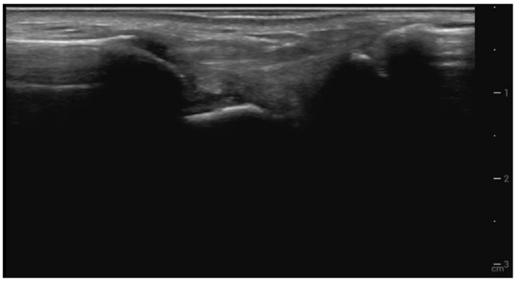

Fig. 14. The wrist joint can be visualized at the distal radius as it articulates with the carpal bones.

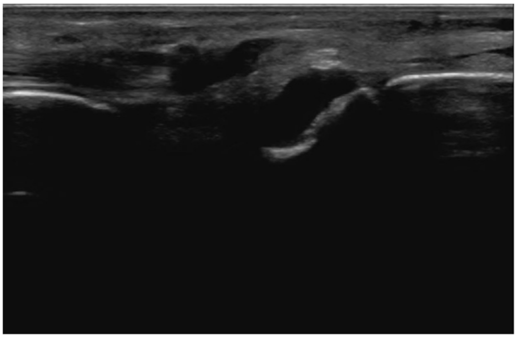

Fig. 15. An effusion of the wrist joint may be accessed out-of-plane with the probe over the extensor pollicis longus tendon to protect it from needle injury.

the short axis. Rotate to the long axis and slide superiorly. The joint space should come into view between the femoral head and acetabulum, with the probe in the same axis as the femoral neck (**Fig. 16**).[95] A hip effusion appears as a hypoechoic or anechoic fluid elevating the joint capsule and collecting in the potential space anterior to the femoral neck and immediately below the articular capsule, called the anterior synovial recess (**Fig. 17**).[96] An abnormal hip effusion refers to an anterior synovial fluid stripe greater than 5 mm in diameter or greater than 2 mm of asymmetry compared to the contralateral hip.[97] The operator must take care to position the affected and unaffected hips in the same position for ultrasound, as the anterior synovial recess width varies with hip positioning (ie, larger with hip inversion and smaller with frog-leg position).[98] Before needle insertion, assess for the location of the lateral circumflex artery with color Doppler. During arthrocentesis, the needle should be advanced in-plane in an inferior to superior direction, targeting the anterior synovial recess at the intersection between the femoral head and neck.

Knee joint

Among adults, 45% to 50% of all septic arthritis cases involve the knee.[99,100] One systematic review found ultrasound-guided knee arthrocentesis had better accuracy and less patient discomfort when compared to the landmark technique.[101] Ultrasound-guided arthrocentesis also results in a larger volume aspiration with no difference in

Fig. 16. The hip joint is visualized in the long axis of the femoral neck as the femoral head articulates with the acetabulum.

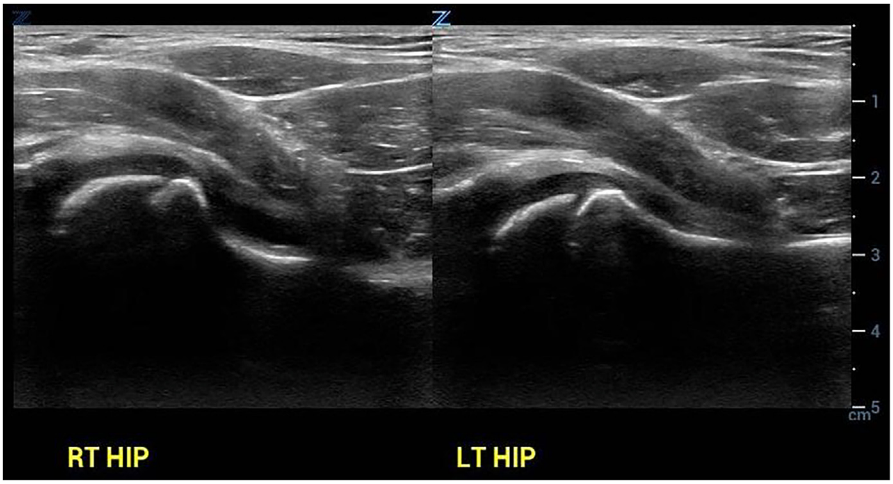

Fig. 17. A hip effusion can be seen as a collection of hypoechoic fluid in the anterior synovial recess just above the femoral neck. In this image, growth plates are apparent in this pediatric patient in addition to an asymmetric right-sided hip effusion.

procedural time compared with the landmark approach.[79,102] Moreover, ultrasound can minimize the number of attempts and improve procedural confidence when performed by novice physicians in the ED.[102]

For arthrocentesis, the patient should be seated or supine with the affected knee in slight flexion with a towel roll support behind the knee to increase the intercondylar space. Visualize the long axis on the femur and slide distally until the patella becomes visible (**Fig. 18**). The joint space should be evaluated in both long and short axes to

Fig. 18. The knee joint is evaluated in a long axis at the interface of distal femur and patella.

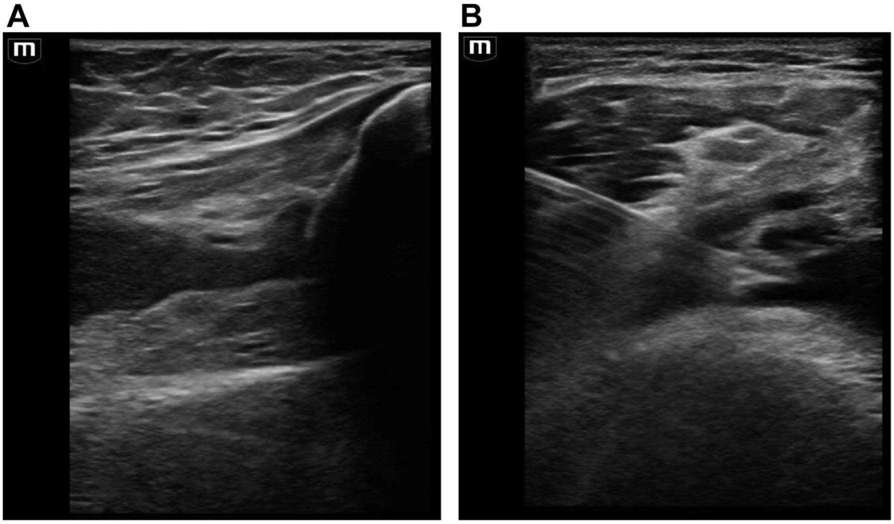

Fig. 19. (*A*) A knee joint effusion displaces the suprapatellar fat pad anteriorly above the femur and below the quadriceps tendon. (*B*) A needle is visualized tracking in-plane into a knee effusion.

locate the largest area of effusion. In the suprapatellar space, the suprapatellar fat pad lies between the femur and quadriceps tendon, while the prefemoral fat pad is immediately anterior to the femur. A joint effusion displaces the suprapatellar fat pad anteriorly (**Fig. 19**A). Once identified, the probe should be rotated to the short axis and a needle advanced in-plane from the lateral or medial direction, avoiding the midline quadriceps tendon (**Fig. 19**B).[95]

Baker's cyst

Baker's cysts are a fluid collection in the gastrocnemio-semimembranosus bursa, which communicates with the knee joint. These cysts often arise from degenerative diseases of the knee. One meta-analysis reported ultrasound has 94% sensitivity and 100% specificity when compared to MRI.[103] To evaluate for a Baker's cyst, place a linear probe on the posterior-medial knee in the short axis. If present, it appears as an anechoic fluid collection between the semimembranosus and medial gastrocnemius tendons. A tapering connection to the knee joint capsule is often visible beneath the cyst. Color Doppler should also be used to avoid misidentifying a vascular lesion.[104] The cyst should also be imaged in the long axis to avoid mistaking tendon anisotropy for a fluid collection.[105]

Ankle joint

The ankle joint represents 9% of all septic arthritis cases.[99] Several case reports have described the use of ultrasound-guided arthrocentesis in the ED setting.[106–110] One randomized trial reported a higher success rate with ultrasound guidance compared with the landmark approach (100% vs 85%).[111]

The affected ankle should be positioned in slight plantar flexion. Visualize the anterior tibia in the short axis using the linear probe. Rotate to the long axis and slide distally to the tibiotalar joint space. The distal tibia and talus should be in view with potential fluid collecting in the V-shaped joint recess (**Fig. 20**). Slide the probe medially to locate the dorsalis pedis artery and tibialis anterior tendon. During needle

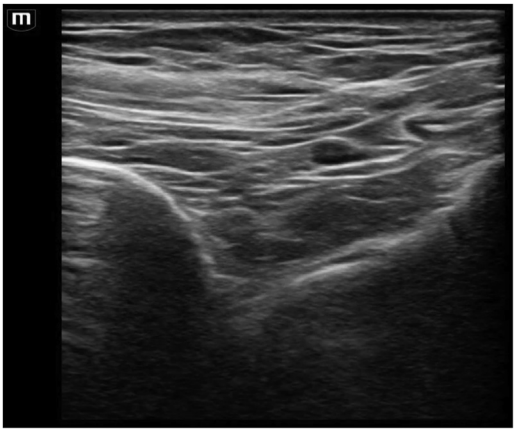

Fig. 20. The tibiotalar joint space of the anterior ankle is found at the distal tibia in a long axis.

advancement, the artery and tendon should be visualized directly below the probe to protect these structures from accidental damage. The needle may be introduced out-of-plane with a steep angle under the medial side of the probe into the effusion (**Fig. 21**).[112] Alternatively, the subtalar space may be evaluated for lateral ankle effusion. For this approach, the linear probe should be placed anterior to the distal tip of the lateral malleolus in a short axis to the foot. The view should include the talus and calcaneus with the sinus tarsi, or joint space, in-between. The needle can be advanced out-of-plane aiming anterior to posterior into the sinus tarsi.[108,112] It is recommended to target the needle toward the calcaneal portion of the sinus tarsi to avoid the intermediate band of the frondiform ligament (inferior extensor retinaculum roots).[113]

Bursitis

Bursitis is an inflammation of an extra-articular fluid-filled bursa sac (**Fig. 22**). One-third of bursitis cases are bacterial, or septic.[114] Septic bursitis occurs most often

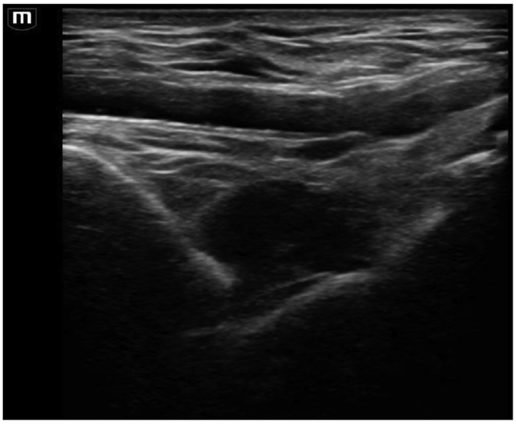

Fig. 21. An effusion of the ankle joint may be accessed by tracking a needle out-of-plane at a steep angle from the medial side of the linear probe into the hypoechoic fluid collection, avoiding the tibialis anterior tendon and dorsalis pedis artery.

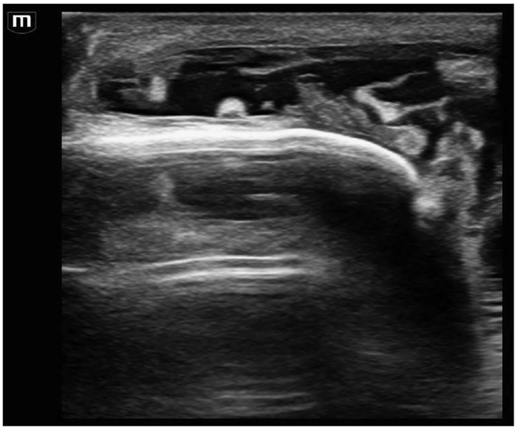

Fig. 22. Bursas often appear as fluid-filled structures superficial to a joint or bony protuberance.

at the olecranon or prepatellar bursae given their superficial locations.[114] The bursa and overlying soft tissue should be evaluated in 2 directional planes with a linear probe. Color Doppler allows the evaluation of overlying vascular structures. A needle may be advanced in-plane aiming for the bursa fluid while avoiding surrounding structures.[113–115]

Tendons

Tendon rupture

Tendon ruptures typically occur due to a sudden force applied while tension is applied to a muscle. Partial tendon ruptures (which can progress to complete ruptures if missed) or complete tendon ruptures without loss of extension/flexion may be challenging to diagnose on history and physical examination alone. Moreover, examination can be challenging when there is significant pain or edema limiting the assessment of the tendon. Data suggest that 10% to 50% of tendon ruptures are initially misdiagnosed.[115,116] While MRI has excellent accuracy for diagnosing tendon injuries, it is expensive, time consuming, and not universally available. POCUS provides an alternate modality that can be easily used at the bedside to assess for tendon injury.

POCUS has been described for a variety of tendon injuries, including the quadriceps,[117–119] patellar,[120–123] Achilles,[124–126] biceps,[127–129] triceps,[130] and extensor pollicis brevis tendons.[131–133] One study of 34 ED patients with suspected upper or lower extremity tendon injuries found that POCUS was 100% sensitive and 97% specific, while physical examination was 100% sensitive and 76% specific.[134] They also found that POCUS was performed much sooner than MRI or surgical consultation (46 minutes vs 139 minutes). A 2021 meta-analysis of 15 studies of suspected Achilles tendon injury reported POCUS was 95% sensitive and 99% specific.[135]

To perform this technique, place a linear probe over the corresponding tendon and visualize the entire length in the short and long axes. A normal tendon has a long, fibrillar, bandlike appearance in long axis and circular shape with black and white dots in short axis. A partial tendon injury will appear as disruption of the normal tendon architecture, giving it an irregular or wavy appearance with hypoechoic fluid present in the tendon path. A complete tendon rupture will have loss of the tendon fiber continuity; a retracted, curled tendon stump may also be visible (**Fig. 23**). POCUS can distinguish partial versus full tendon injury with 95% to 100% sensitivity and 71% to 83% specificity.[115,136] When compared with partial tendon injuries, full tendon injuries will have a thinner tendon diameter, posterior acoustic shadowing, and retraction of the tendon sides.[115,136] If the tendon injury is in close proximity to a joint space, an associated effusion might also be present. When the case is unclear, compare it with the contralateral side. Dynamic POCUS can also help identify more subtle cases, by demonstrating separation of the proximal and distal aspects of the tendon when moving the joint or applying compression with the ultrasound probe to stretch the tendon in real-time.[122,128,132]

Tenosynovitis

Tenosynovitis is a severe bacterial infection occurring within the closed space of the digital flexor tendon sheaths. Physical examination can be unreliable, and all 4 of Kanavel's signs are present in only 22% to 54% of cases.[137,138] POCUS can be performed rapidly at the bedside, is noninvasive, and the images can be shared with specialists who may not be available on-site. Multiple case reports and case series comprising over 50 cases have demonstrated the role of POCUS for diagnosing tenosynovitis.[139–147] More recently, a prospective study of 57 patients with suspected flexor tenosynovitis reported that POCUS was 94% sensitive and 65% specific.[138]

Similar to assessing for tendon ruptures, the tendon should be visualized with a linear probe in both planes. When assessing for tenosynovitis, color Doppler is also recommended to assess for hyperemia. Sonographic findings of tenosynovitis include edema of the tendon ($\geq$20% increase in diameter compared with the contralateral tendon), a hyperechoic peritendinous effusion, and a thickened synovial sheath that is hypoechoic with hyperemia on color Doppler assessment.[146,147]

Muscles

Rhabdomyolysis/myositis

In the United States, approximately 26,000 cases of rhabdomyolysis are reported annually.[148] Rhabdomyolysis and myositis are 2 conditions that are commonly diagnosed by history, physical examination, and creatine kinase level. Ultrasound may be used as a diagnostic adjunct as it can be performed rapidly at the bedside before laboratory values return and has been found to be specifically useful in the early diagnosis of exercise-induced rhabdomyolysis.[149]

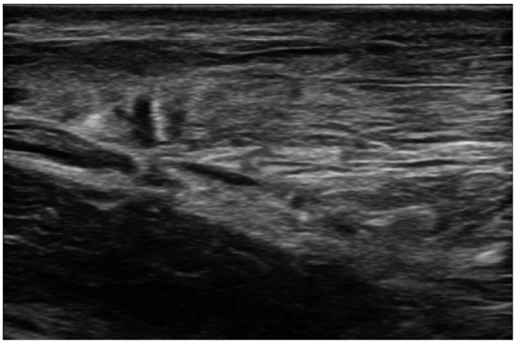

Fig. 23. Tendon rupture with loss of the tendon fiber continuity.

To perform this examination, use a linear or curvilinear probe to visualize the affected muscle groups beginning in areas with the greatest amount of discomfort. The area of interest should then be compared to an unaffected area of muscle (preferably on the contralateral side if asymptomatic). Normal muscle on ultrasound appears as hypoechoic with linear hyperechoic strands of fibroadipose septae.[150] Rhabdomyolysis and myositis appear on ultrasound as hypoechoic musculature with increased layer thickness and disruption of the normal tissue architecture.[151] (**Fig. 24**) Other ultrasound findings in rhabdomyolysis include hyperechoic areas of muscle due to hypercontractile muscle fibers, hypoechoic areas of muscle due to edema and inflammation, increased muscle thickness, and fluid within the surrounding muscles.[150] Loss of the muscle texture is the most characteristic finding and is thought to be due to muscle necrosis.[152]

Hematoma

Ultrasound can be a useful tool when used in combination with the history and physical examination to diagnose hematoma and help differentiate it from other musculoskeletal pathologies. It may also be used to evaluate the location and extent of the hematoma, as well as if active bleeding is occurring. Ultrasound can also be used for serial assessments to evaluate changes in size or superimposed infections.

Fig. 24. Rhabdomyolysis with hypoechoic musculature with increased layer thickness and disruption of the normal tissue architecture.

Using a linear or curvilinear probe, begin at the area of swelling or discomfort. Hematomas are typically rounded collections that appear hypoechoic in the acute phase and more hyperechoic with increased chronicity. They can be smooth or irregularly shaped and have been described on ultrasound as hypoechoic, heterogeneous (ie, having hypoechoic and echogenic components), complex (ie, having internal septations), or uniformly echogenic.[153] Color Doppler may be used to assess for active bleeding within the hematoma.[154] Additional sonographic signs associated with hematomas include the “plankton sign” and the “hematocrit sign.” The “plankton sign” is a dynamic movement of protein or cellular debris within the hematoma due to respiratory or cardiac movements. The “hematocrit sign” is the layering of cellular debris and is visualized as a gradient of echogenicity.[155]

SUMMARY

POCUS is a useful tool for evaluating skin, soft tissue, and musculoskeletal concerns in the ED. It can lead to prompt diagnosis and can be used to assist in common ED evaluations. POCUS can be used to help differentiate cellulitis from abscess, as well as identify NF. It is also helpful to diagnose common musculoskeletal conditions, such as effusions, fractures, and tendon pathology, and assist in procedures such as arthrocentesis and hematoma blocks. Finally, it can be used to assist in the diagnosis of rhabdomyolysis and myositis.

CLINICS CARE POINTS

- POCUS is commonly performed with a linear array probe in the long and short axes over the area of interest.
- POCUS findings to differentiate cellulitis from abscess include a hypoechoic fluid collection at the area of concern often with surrounding hyperemia.
- POCUS is used commonly in musculoskeletal concerns to evaluate for fractures, tendon ruptures, or joint effusions.
- POCUS may be used as an adjunct for procedures such as arthrocentesis or hematoma blocks allowing for real-time needle tracking and visualization.
- POCUS can be used in the early diagnosis of rhabdomyolysis by noting loss of muscle texture.

DISCLOSURE

The authors have no relevant conflicts of interest to disclose.

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