Advanced Diagnostic Topic for Austere Providers: Skin and Soft Tissue

Justin Grisham and Michael D. Perreault

Introduction

Soft tissue injuries and infections account for 80% of injuries sustained in a wilderness or austere setting [1]. Ultrasonography provides an excellent means to evaluate for and identify many of these soft tissue injuries including cellulitis, abscesses, and foreign bodies. The skilled practitioner can also use ultrasound to provide procedural guidance for abscess drainage and the removal of foreign bodies.

Equipment Considerations

A high frequency linear array probe of 7.5 MHz or higher is ideal for the evaluation of the soft tissue (*see* Fig. 1). Deep penetration of the tissue is usually not required, and the higher frequency probe offers the resolution required to identify minimal areas of fluid and small foreign bodies. In general, most high frequency linear arrays will penetrate to a depth of up to 6 cm or so. There are rare cases in which a low frequency curvilinear (1–5 MHz) or phased array (2–5 MHz) probe may be required to achieve the adequate penetration to clearly identify the back wall of an abscess (see Figs. 2 and 3). This is particularly important when scanning thoracic or abdominal abscesses that may communicate with the thoracic or peritoneal cavities respectively. The lower frequency probes may also be necessary to adequately evaluate obese patients.

Probe size and thus footprint varies, but a larger probe is generally utilized in order to facilitate the evaluation of a greater amount of soft tissue. Smaller probes may be useful in procedural guidance or when evaluating smaller anatomical structures such as digits.

J. Grisham (✉) · M. D. Perreault
Department of Emergency Medicine, Madigan Army Medical Center, Tacoma, WA, USA
e-mail: Justin.d.grisham.mil@mail.mil; michael.d.perreault.mil@mail.mil

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Fig. 1 Linear transducer: Linear transducers produce rectangular images using high frequency

Fig. 2 Curvilinear transducer: Curvilinear transducers exhibit low frequency and a wide field of view

Ultrasound resolution (and corresponding image quality) is normally greatest at a point where the ultrasound beam narrows to its minimum size. This is known as the focal zone. For any given probe, there is a minimum distance from the surface of the probe to the focal zone. For this reason, the resolution of superficial structures closest to the ultrasound probe (before the focal zone is reached) can be limited. Utilizing a water bath to increase the standoff distance between the probe and the anatomical structure in question can improve visualization by placing the area of interest within the focal zone of the probe [2] (*see* Fig. 4). This technique can also aid in the evaluation of small structures such as fingers or toes that may be difficult to maintain probe contact with due to their small and spherical nature (*see* Fig. 5).

Technique

Soft tissue structures of interest should be evaluated in the transverse and longitudinal axis. Traditionally the probe marker is placed towards the patient's head or to the patient's right. However, if the ultrasound images will be used for procedural guidance, the probe should be oriented so that the directionality of the images seen matches the surface alignment of the patient. Scanning with the ultrasound probe in a dedicated fashion such as from distal to proximal or lateral to medial and labeling images as such will prevent confusion during future review.

Cellulitis

Cellulitis accounts for 25% of all soft tissue injuries in the austere environment [3]. It may accompany abscesses and in rare cases lead to necrotizing soft tissue infections. Ultrasound identification of cellulitis is nonspecific and requires the correct clinical picture of erythematous, warm, and painful skin, usually in a limited and unilateral distribution.

Soft tissue is expected to have well-delineated tissue planes. Cellulitis can be identified as anechoic layering of fluids between and among soft tissue planes. This is often described as a "cobblestone" like appearance (*see* Figs. 6 and 7). A "cobblestone" appearance is not specific for cellulitis, as many other conditions may lead to

Fig. 3 Phased array transducer: Phased array transducers have smaller flat footprints and exhibit a pie-shaped field of view

Fig. 4 Water bath positioning. To facilitate visualization of small parts, have the patient place the affected area in a container of water, and hover the probe over the area of interest

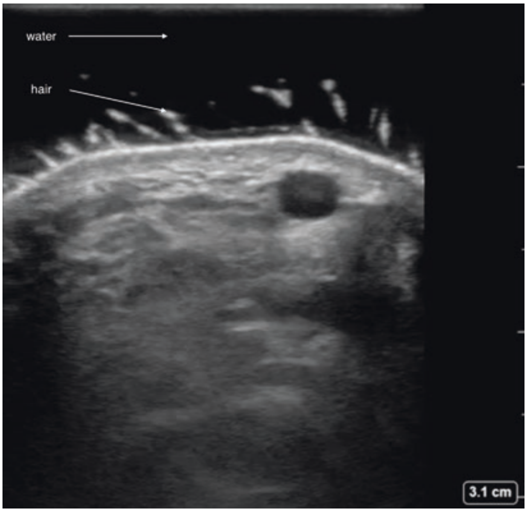

Fig. 5 Water bath ultrasound. Dorsal hand ultrasound using a water bath showing separation of transducer from the tissue of interest

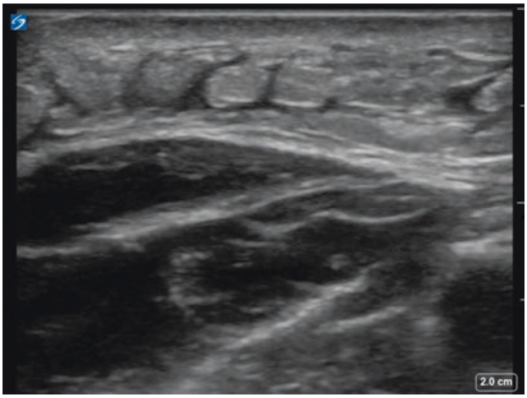

Fig. 6 Cellulitis. Cellulitis typically appears as cobblestoning of the subcutaneous tissue with associated thickening of the dermal layers

fluid accumulation in soft tissue (any cause of peripheral edema or localized inflammation). Cellulitis may also be identified by a loss of the usually well-delineated tissue planes which is thought to occur due to tissue thickening and inflammation. Air that is identified within soft tissue planes or obstructs images should raise the clinical suspicion for a necrotizing soft tissue infection in the correct clinical

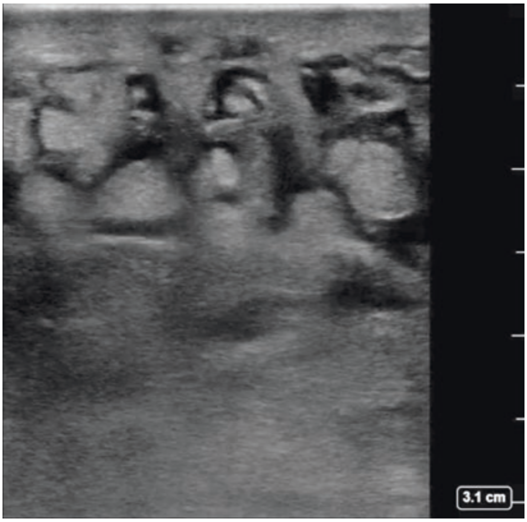

Fig. 7 Cellulitis with increased soft tissue edema. As cellulitis becomes more severe or with concomitant edema, there will be increased fluid within the subcutaneous tissue visualized by thicker anechoic pockets

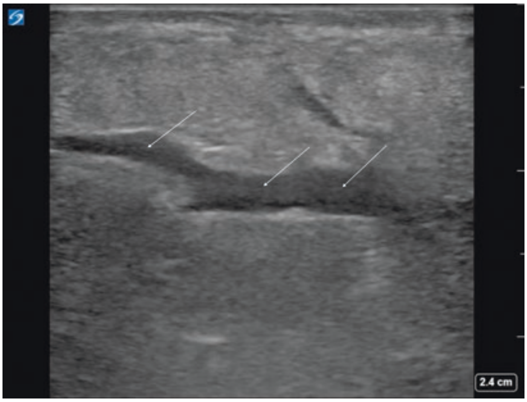

Fig. 8 Necrotizing fasciitis with perifascial fluid. Fluid tracking along the fascial plane with thickened subcutaneous tissue and a loss of normal architecture. Perifascial fluid greater than 4 mm likely indicates a diagnosis of necrotizing fasciitis

context (*see* Fig. 8). Sonographic findings of necrotizing soft tissue infection include distorted and thickened fascial planes with turbid fluid accumulation in both the fascial layers and subcutaneous edema [4].

The soft tissue in question should be systematically scanned in both transverse and longitudinal axis while looking for the nonspecific signs of cellulitis and examining for such complicating features as abscesses or foreign bodies. Examine the affected tissue completely to the margins to visualize the return of normal well-delineated tissue planes. If there is doubt about the diagnosis, compare the affected tissue to the tissue on the contralateral side or tissue elsewhere on the body that is thought to be normal.

Abscess

Ultrasound greatly improves the identification of abscess when compared to palpation. Physical exam has an accuracy of 86% while utilization of ultrasound improves that accuracy to 98% [5]. Further, ultrasound can be used to measure the size of the abscess to evaluate if drainage is required, as abscesses under 1 cm are unlikely to require drainage [6]. Color Doppler (if available) may also be used to better identify vascular structures and ensure no vascular flow exists within a suspected abscess cavity. Prior to drainage, the tissue around the abscess can be examined for communication to deeper structures that may require more advanced intervention, neurovascular structures and tendons that should be avoided during incision, and foreign bodies that may injure the provider and cause recurrent infection in the patient [7].

An abscess can be identified by an irregularly shaped to round anechoic or hypoechoic structure that may contain echogenic material. The soft tissue in question should be systemically scanned in both transverse and longitudinal axis while looking for the suspected abscess. Light pressure applied from the probe to the abscess may result in movement of the echogenic purulent material within the abscess and aid in identification. Once the abscess has been identified, measure its dimensions in short and long axis to determine the need for drainage. Visualize the complete margins of the abscess and look specifically for any deeper tracts or connections to deep structures. Consider more advanced surgical management if either is found. If point of care drainage is appropriate, the depth of the abscess should be measured from the skin surface and the surrounding tissue examined for neurovascular structures and tendons that should be avoided during drainage. Find the most superficial portion of the abscess and mark the corresponding skin (Fig. 9).

Abscess drainage is rarely performed with live ultrasound guidance. As previously mentioned, utilize the ultrasound to mark the most superficial portion of the abscess, clean and anesthetize the skin around this mark, and perform an incision

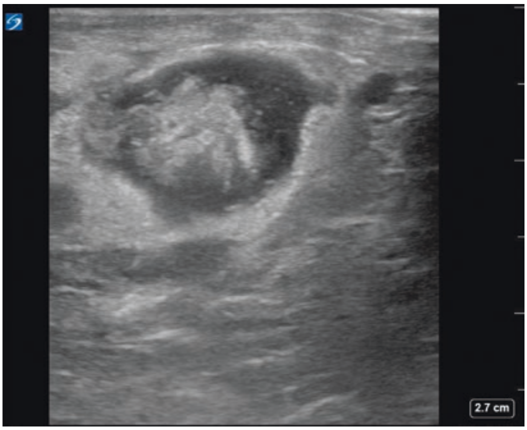

Fig. 9 Abscess. Hypoechoic fluid collection with thick echogenic material representing a small abscess

and drainage of the abscess. Examine the area of the abscess after incision and drainage with the ultrasound to ensure there are no missed pockets of purulent material or loculations.

Foreign Body

Foreign bodies such as wood, glass, metal, plastic, and organic material in soft tissue account for about 2% of soft tissue injuries in the austere environment [8]. Given the potential for delayed treatment in these environments, early identification of foreign bodies is important to reduce infection, pain, and inflammation. Patients with foreign bodies in their feet or hands may not be able to ambulate or perform work duties. Ultrasonography has been proven in the identification of foreign bodies as well as in procedural guidance for their removal [9, 10]. Ultrasonography is more sensitive than plain film radiography and can identify between 94% to 98% of foreign bodies [11, 12]. In addition, ultrasound can be used to identify injuries to neurovascular structures while evaluating for foreign bodies or after their identification.

Identification of a foreign body is made through direct visualization of an echogenic structure in the area of suspicion or by identification of secondary signs such as reverberation artifact, shadowing, or fluid collection (Figs. 10 and 11).

Reverberation artifact occurs when an ultrasound beam encounters two strong parallel reflectors. It is often seen with metallic or glass objects such as a needle or shrapnel when viewed in a long axis or short axis. If these objects are small or in the superficial skin, the artifact may aid in their identification [13]. A foreign body that has been retained for greater than 24 hours may have a surrounding hypoechoic rim of fluid. Such a finding increases the sensitivity and specificity of foreign body identification [14]. Foreign bodies with smooth and flat surfaces tend to produce

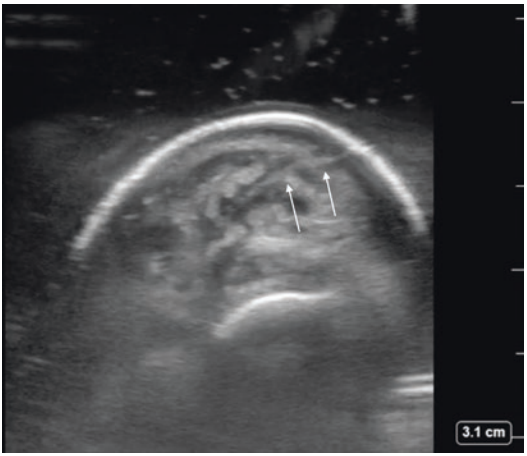

Fig. 10 Foreign body. Finger ultrasound in water bath with embedded foreign body (arrows)

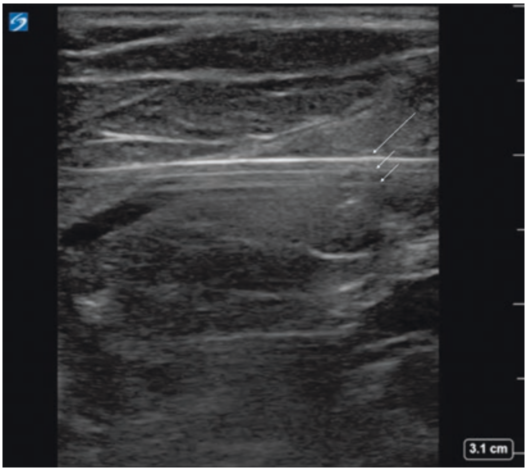

Fig. 11 Metal foreign body. Brightly echogenic foreign body represents a broken needle within the neck of a patient from intravenous drug abuse

clean shadowing deep to the foreign body while objects with irregular surfaces usually demonstrate dirty shadowing [15].

Before using ultrasound to scan for foreign bodies, evaluate the patient for entrance wounds and estimate the trajectory and path of any foreign bodies. Palpation may be useful. Then place the probe over the entrance wound and evaluate a wide margin of tissue in the suspected trajectory of the foreign body. Evaluate the tissue in both transverse and longitudinal axis while looking for the hyperechoic foreign body or secondary signs such as fluid collection, artifact, or shadowing. Once the foreign body has been identified, examine the surrounding tissue for damage to other structures such as nerves, vasculature, or tendons. Measure the size of the foreign body in both the short and long axis as well as its depth. Mark the location of the foreign body on the skin.

Once a foreign body has been recognized, ultrasound is a useful modality to guide its removal. Using ultrasound in this fashion decreases complications [12]. The size and position of a foreign body can be accurately identified with ultrasonography, and the surgical incision required to remove the foreign body can be smaller and more accurate [16].

Ultrasound can be used to guide foreign body removal in a similar fashion to ultrasound guidance for vascular access or a peripheral nerve blocks (see chapters "Initial Training, Credentialing, and Quality Assurance/Quality Improvement Processes", "Care of Equipment", 30 and 31). Estimate the surgical path by evaluating the skin around the foreign body. Identify any nerves, tendons, or vascular structures that should be avoided. Clean the skin at the planned incision site and anesthetize the superficial skin and deeper structures along the surgical path while using the ultrasound for direct visualization. Make a small incision in the skin and perform a blunt dissection with forceps while maintaining visualization of the foreign body and any structures along the dissection path that should be avoided. Capture and remove the foreign body, irrigate the site, and then close or allow the wound to heal by secondary intention.

Limitations of Current Knowledge and Opportunities for Future Research

Ultrasound examination of soft tissue has been used successfully for decades to identify cellulitis, abscesses, and foreign bodies. Nevertheless, there are plenty of opportunities for research in this application of ultrasound. As small, portable ultrasound devices become more readily available, there will likely be questions raised regarding validation of image quality in relation to more standardly used cart-based systems. This is certainly relevant in the austere environment. Additionally, as the "democratization" of ultrasound continues, ultrasound capabilities will be increasingly available to medical providers at diverse levels of experience and expertise, and will likely include advanced practice practitioners, nurses, paramedics, and other paraprofessionals. Research into the optimal model for initial training and skills sustainment for these varied groups will be needed. Some of this is already being done, particularly in the military.

Pearls

Use a linear high frequency array for most soft tissue scanning.

Be thorough and systematic when scanning soft tissue to avoid missing subtle findings.

Orient the screen image to the surface features of your patient.

Whenever possible, scan in two planes.

Use water baths or other methods to achieve stand-off from the surface of the probe in order to better image superficial structures.

Use color Doppler when available to delineate vascular structures.

Use ultrasound in conjunction with physical exam to improve the sensitivity of your clinical assessments.

If you are uncertain about what you are seeing, compare it to an unaffected side or region.

Pitfalls

You may need to use a lower frequency probe in order to adequately image deeper structures.

Not all that "cobblestones" is cellulitis – use clinical judgement and be alert for other causes of soft tissue edema.

If you can't clearly see the back wall of an abscess, beware extension or tracking into deeper tissue or cavities.

Failure to recognize subtle artifacts may lead to missed recognition of more serious soft tissue infections or foreign bodies.

Failure to completely scan through the entire area of interest into normal appearing surrounding tissue may lead to misdiagnosis.

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