Review paper

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High-resolution ultrasound in the evaluation of musculoskeletal infections

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Abstract

Soft tissue and osseous musculoskeletal infections are common but can be difficult to diagnose clinically. Signs, symptoms, and physical examination findings may be nonspecific, and laboratory values can be inconclusive. The extent of disease may also be underestimated on physical examination. Soft tissue infections most commonly occur secondary to direct inoculation from broken skin and less frequently due to the seeding of the soft tissues from hematogenous spread, while osseous infections are more commonly due to hematogenous seeding. Infections may also be iatrogenic, following surgery or other procedural interventions. High-resolution ultrasound is an extremely useful imaging modality in the evaluation of musculoskeletal soft tissue and joint infections, and can occasionally be used to evaluate osseous infections as well. Ultrasound can aid in the early diagnosis of musculoskeletal infections, allowing for prompt treatment, decreased risk of complications, and treatment optimization. Ultrasound is sensitive and specific in evaluating soft tissue edema and hyperemia; soft tissue abscesses; joint, bursal and tendon sheath effusions/synovitis; and subperiosteal abscesses. This article describes the typical high-resolution grayscale as well as color and power Doppler ultrasound imaging findings of soft tissue infections including cellulitis, fasciitis, necrotizing deep soft tissue infection, pyomyositis, soft tissue abscess, infectious bursitis, and infectious tenosynovitis. Ultrasound findings of septic arthritis as well as osteomyelitis, such as subperiosteal spread of infection (subperiosteal abscess). are also reviewed. In addition, the use of ultrasound to guide fluid and tissue sampling is discussed.

Introduction

Soft tissue and osseous musculoskeletal (MSK) infections are common but can be difficult to diagnose clinically. Signs, symptoms, and physical examination findings may be nonspecific, and laboratory values can be inconclusive[1,2]. The extent of disease may also be underestimated on physical examination. Early diagnosis and treatment are essential to prevent complications, decrease morbidity and mortality, and optimize long-term clinical outcomes in these patients.

Immunosuppressed patients, those at the extremes of age, and patients with systemic illnesses are at increased risk of MSK infection[1,2]. Other risk factors include trauma, recent surgery, burns, substance abuse, malnutrition, and obesity[1,2]. Soft tissue infections most commonly occur secondary to direct inoculation from broken skin and less frequently due to the seeding of the soft tissues from hematogenous spread, while osseous infections are more commonly due to hematogenous seeding[1,3]. Infections may also be iatrogenic, following surgery or other procedural interventions.

Pain, swelling/edema, erythema, and fever are typical presenting signs and symptoms of MSK infections[1–3]. Crepitus can occur in the setting of soft tissue gas. Laboratory analysis often includes white blood cell (WBC) count, C-reactive protein level (CRP), and

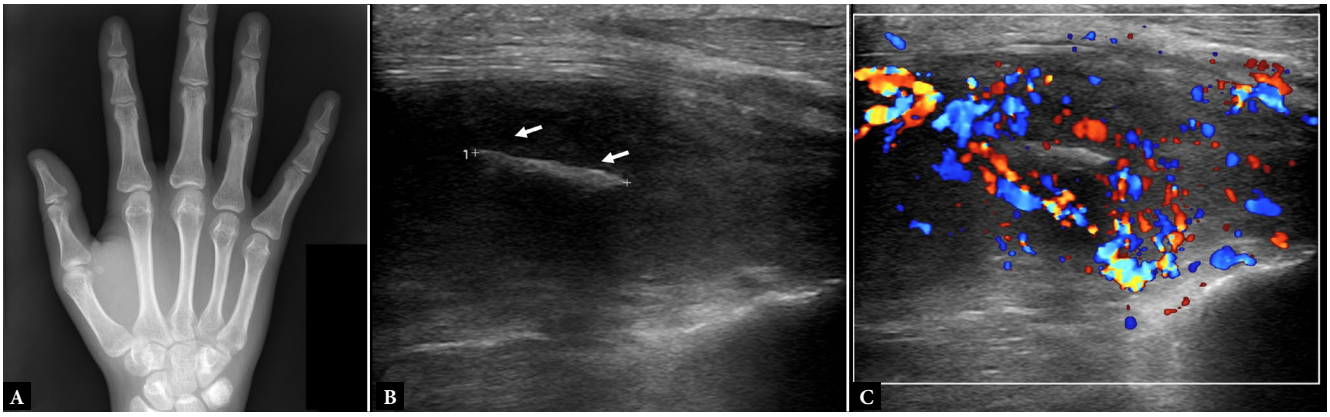

Fig. 1. *Retained foreign body and cellulitis. 13-year-old female with right hand injury after falling onto a tree stump.* **A.** *Initial radiographs were normal, without radiopaque foreign body or acute abnormality identified. Subsequent focused ultrasound was performed 4 days later when patient returned with increased swelling, erythema, and pain.* **B.** *Grayscale ultrasound (US) at area of concern between the thumb and index finger demonstrates linear echogenic foreign body with posterior acoustic shadowing (arrows).* **C.** *Color Doppler imaging shows hyperemia in the soft tissues surrounding the foreign body, consistent with cellulitis. No fluid collection was present*

erythrocyte sedimentation rate (ESR)[1,2]. Blood and infected tissue cultures can identify the causative micro-organisms responsible for infection.

High-resolution ultrasound (US) is often used to diagnose soft tissue and joint infections, and occasionally, osseous infections. US can aid in the early diagnosis of MSK infections, allowing for prompt and optimal treatment, and decreasing the risk of complications. US is sensitive and specific in evaluating soft tissue edema and hyperemia, lymphadenopathy, thrombophlebitis, joint effusion /synovitis, bursal distention and inflammation, tenosynovitis, soft tissue abscesses, and periosteal abscesses. This article describes US techniques and guidelines for their application. The pathophysiology and typical US imaging findings of soft tissue infections including cellulitis (Fig. 1, Fig. 2, Fig. 3, Fig. 4, Fig. 5, Fig. 6, Fig. 8), soft tissue abscesses (Fig. 2, Fig. 3), superficial thrombophlebitis (Fig. 2), pyomyositis (Fig. 3), fasciitis (Fig. 4), necrotizing deep soft tissue infection (Fig. 4), infectious bursitis (Fig. 5), and infectious tenosynovitis (Fig. 6) are reviewed. US findings of septic arthritis (Fig. 7, Fig. 8) and osteomyelitis (Fig. 9, Fig. 10, Fig. 11, Fig. 12), including subperiosteal spread of infection (subperiosteal abscess), are also discussed. US-guided fluid and soft tissue sampling (Fig. 5) and drain placement are also reviewed.

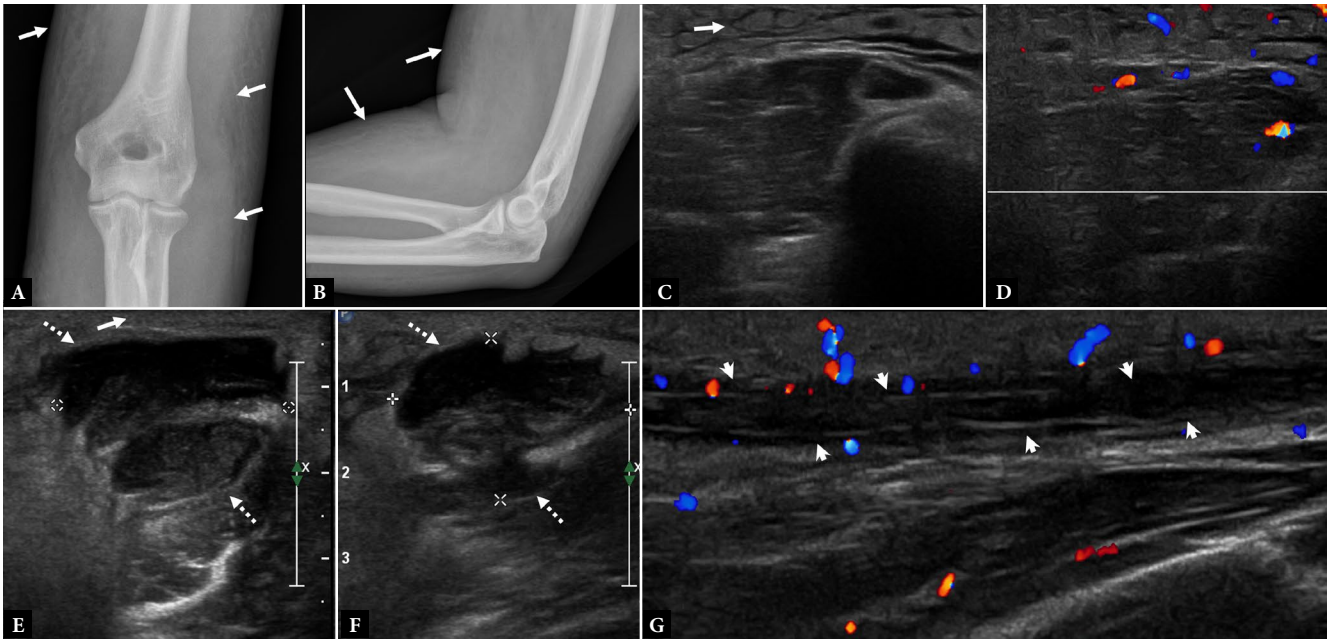

Fig. 2. *Cellulitis, abscess, and superficial thrombophlebitis. 45-year-old male with history of intravenous drug use and hepatitis C, now with severe elbow pain and swelling, fever, and elevated white blood cell (WBC) count.* **A.** *Frontal and* **B.** *lateral radiographs show stranding (arrows) in the subcutaneous fat, consistent with edema.* **C.** *Transverse grayscale ultrasound (US) image in the region of the antecubital fossa shows a cobblestoned, echogenic appearance of the subcutaneous fat (arrow), consistent with edema, suggesting cellulitis.* **D.** *Color Doppler US image shows hyperemia in the region of cellulitis.* **E.** *Transverse and* **F.** *long-axis grayscale US images in this region show a heterogeneous, mixed echogenicity collection (dashed arrows), measured by calipers, consistent with an abscess.* **G.** *Color Doppler image shows a longitudinal filling defect in a vein (short arrows), with loss of flow, consistent with superficial thrombophlebitis*

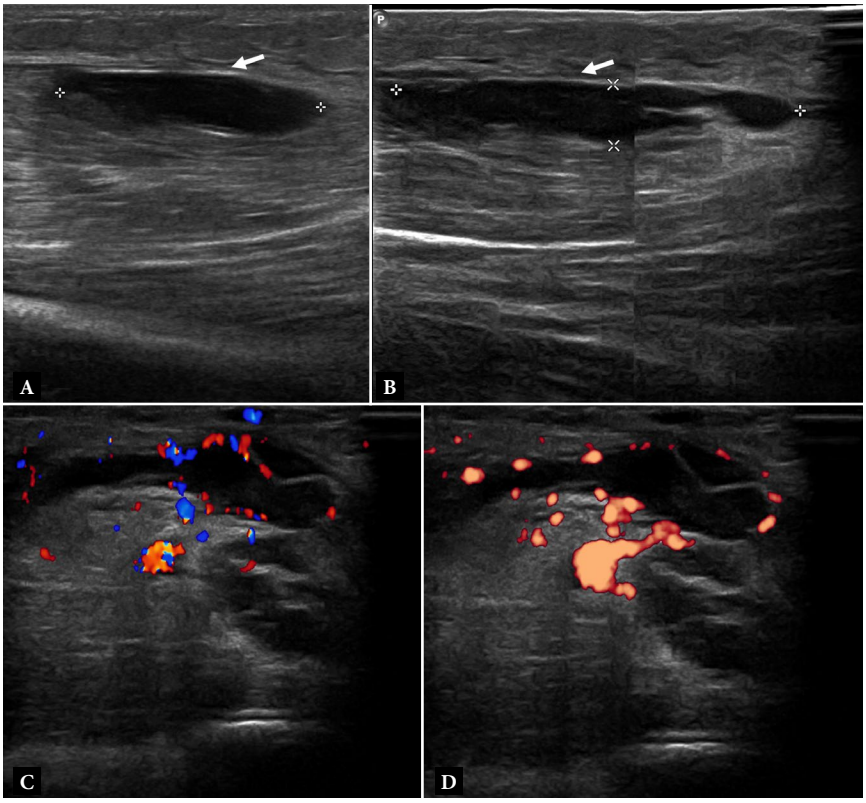

Fig. 3. *Cellulitis and pyomyositis. 23-year-old female with history of intravenous drug use, presenting with a swollen, painful arm and fever.* **A.** *Transverse and* **B.** *long-axis grayscale US images of the upper arm show a cobblestoned, echogenic appearance of the subcutaneous fat, consistent with edema, which can be seen with cellulitis. Within the adjacent biceps brachii muscle, there is an anechoic lobulated collection (arrows), measured by calipers, consistent with abscess.* **C.** *Color and* **D.** *power Doppler US images show hyperemia of the wall of the abscess*

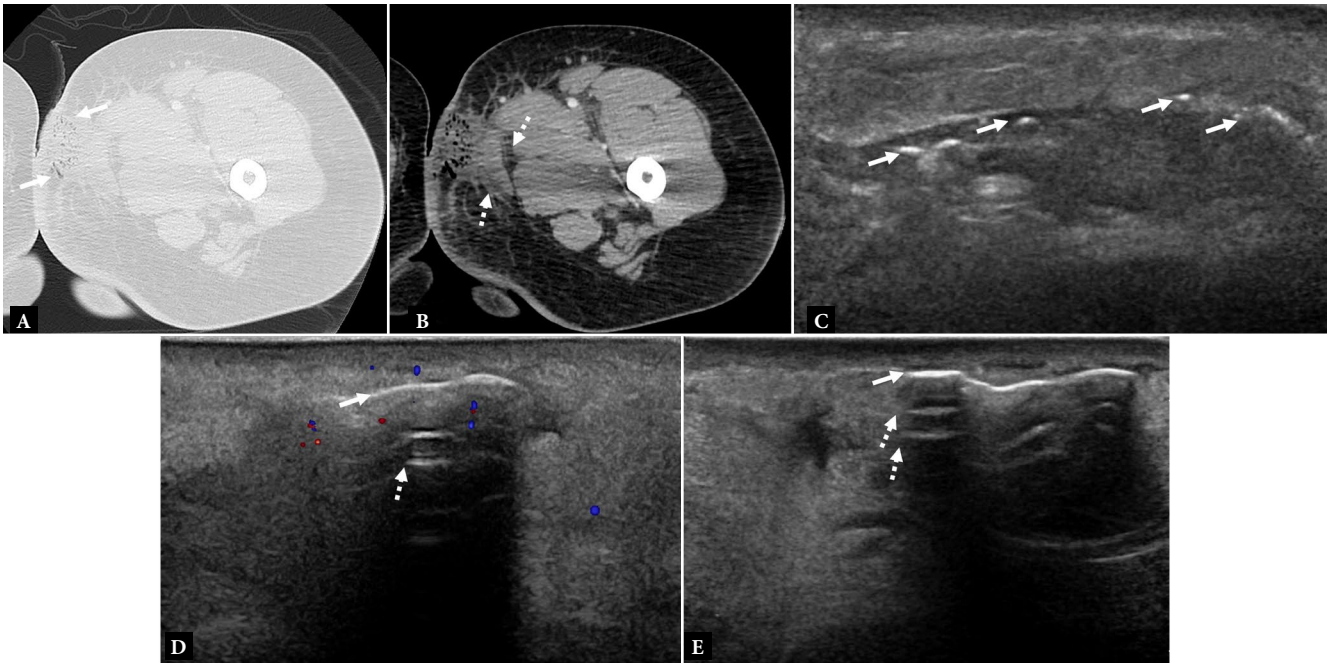

Fig. 4. *Cellulitis, fasciitis, and soft tissue gas in necrotizing deep soft tissue infection. 30-year-old female with leg pain.* **A.** *Axial contrast-enhanced computed tomography (CT) image in lung window shows multiple foci of gas (arrows) in the medial soft tissues of the thigh.* **B.** *Same image, in soft tissue window, shows thickening of the skin, edema in the subcutaneous fat, and edema along the adjacent fascial planes (dashed arrows).* **C–E.** *Transverse grayscale US images in this region show a cobblestoned, echogenic appearance of the subcutaneous fat, consistent with edema, suggesting cellulitis. Multiple echogenic foci of gas are present (arrows), with ring down artifact (dashed arrows)*

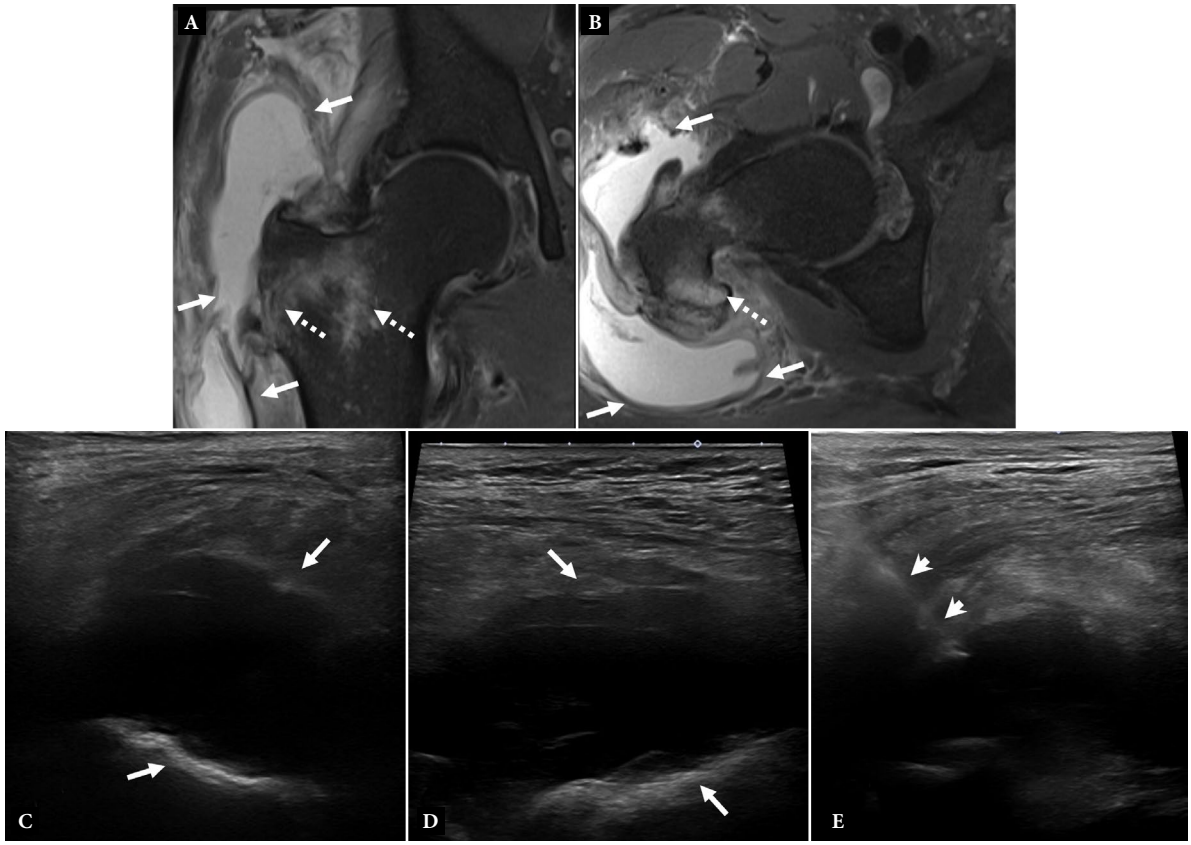

Fig. 5. *Cellulitis, bursitis, and diagnostic aspiration. 56-year-old male with severe hip pain and fever.* **A.** *Coronal and* **B.** *axial T2-weighted fat-saturated magnetic resonance (MR) images of the hip show a large, complex fluid collection (arrows) in the trochanteric bursa. Bone marrow edema is present in the adjacent femur (dashed arrows).* **C.** *Transverse and* **D.** *long-axis grayscale US images show a cobblestoned, echogenic appearance of the subcutaneous fat, consistent with edema, suggesting cellulitis. Fluid collection (arrows) is seen adjacent to the greater trochanter femoral cortex.* **E.** *US-guided aspiration was performed to confirm septic bursitis. Note needle (short arrows)*

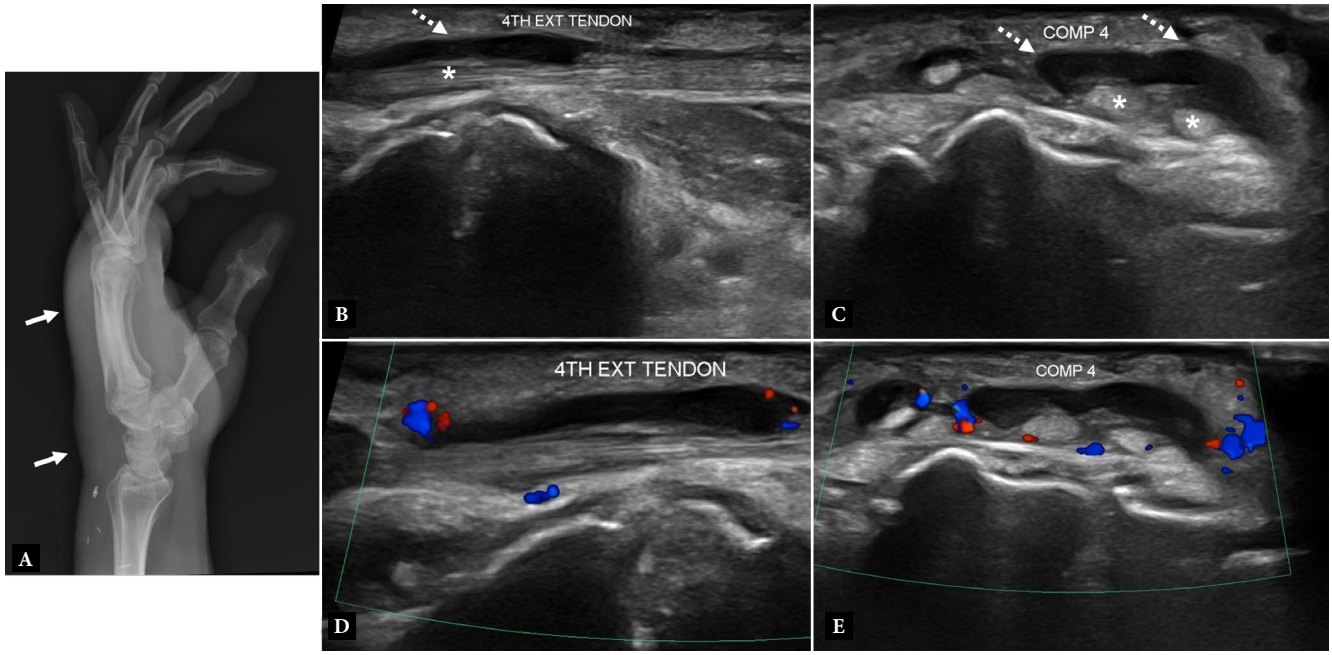

Fig. 6. *Cellulitis and infectious tenosynovitis. 70-year-old male with pain and swelling of the dorsal hand following a cat bite.* **A.** *Lateral radiograph of the hand shows dorsal soft tissue edema (arrows), which can be seen with cellulitis. Metallic clips are present from a prior unrelated surgery.* **B.** *Long-axis and* **C.** *transverse grayscale US images in the region of the fourth extensor compartment show fluid (dashed arrows) along the extensor tendons (*), consistent with tenosynovitis.* **C**. *Long-axis and* **D.** *transverse color Doppler US images in this region show hyperemia*

High-resolution US

High-resolution US utilizes high-frequency linear transducers (10 MHz and higher) with high contrast and spatial resolution, and can be used to evaluate soft tissue edema and fluid collections, joint and bursal effusions, tendon sheath effusions, and subperiosteal fluid collections, to document the extent of disease, and to monitor therapeutic response. US is helpful in detecting foreign bodies such as wood, glass, metal, and plastic (Fig. 1)[4]. Color and power Doppler imaging allows evaluation for the presence and degree of vascularity within the area of concern. Increased Doppler signal in joints, bursae, and tendon sheaths indicates active synovitis (Fig. 5, Fig. 6, Fig. 7, Fig. 8)[5].

US is also an excellent modality to guide fluid aspiration from joints, tendon sheaths, bursae, and soft tissue collections (Fig. 5), and to perform synovial and soft tissue biopsies, as well as bone biopsies, in select cases. Furthermore, US can be used to guide drain placement. In particular, US helps the proceduralist avoid passing through infected soft tissues or fluid collections, and reduces the risk of iatrogenic seeding when attempting aspiration of deeper structures such as joints[6,7]. US guidance also prevents inadvertent injury to surrounding structures.

In the case of suspected periprosthetic joint infection (PJI), US is helpful to evaluate periprosthetic fluid collections, synovitis, joint effusions, and sinus tracts, and can guide the aspiration of fluid collections surrounding and within the joint[8,9].

US has both advantages and disadvantages when used to evaluate MSK infections. When compared to magnetic resonance (MR) imaging and computed tomography (CT) examinations, US offers the advantages of higher resolution, fewer contraindications, wider availability, and lower cost. In addition, sonographic evaluation of soft tissue structures is less affected by metallic artifact compared to CT and MRI. US can also detect soft tissue gas. On US, gas manifests as small echogenic lines of parallel echogenic bands extending posteriorly to the air, known as ring down artifact, caused by fluid trapped between air bubbles creating resonant vibration (Fig. 4)[10]. US is inferior in evaluating the osseous structures when compared to CT, MRI, and nuclear imaging (technetium-99m methylene diphosphate (MDP) bone scintigraphy, gallium-67-labelled leukocyte imaging, indium-111-labelled leukocyte scan combined with technetium-99m sulfur colloid bone marrow imaging, and fluorodeoxyglucose (FDG) positron emission tomography (PET) CT)[2].

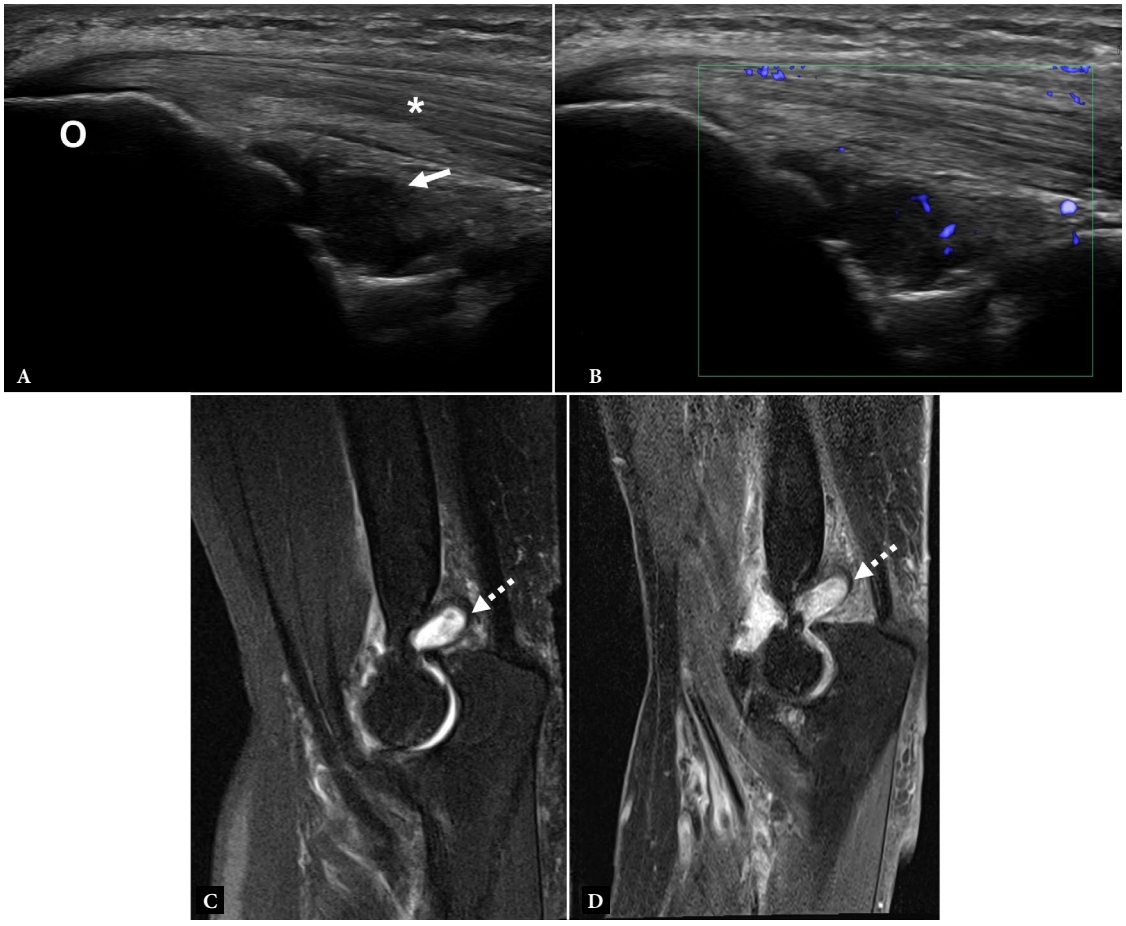

Fig. 7. *Joint effusion and synovitis. 75-year-old male with fever, elbow pain and swelling.* **A.** *Long-axis grayscale US image through the posterior elbow shows mixed echogenicity joint effusion (arrow), deep to the triceps tendon (*), adjacent to the olecranon (O).* **B.** *Microvascular flow imaging (MVFI) in the same areas shows mild hyperemia suggesting synovitis.* **C.** *Sagittal T2-weighted MR image shows increased synovial-fluid complex signal (dashed arrow) distending the joint.* **D.** *Contrast-enhanced sagittal T1-weighted MR image with fat saturation shows diffuse, heterogeneous enhancement of the joint contents (dashed arrow), consistent with effusion and synovitis*

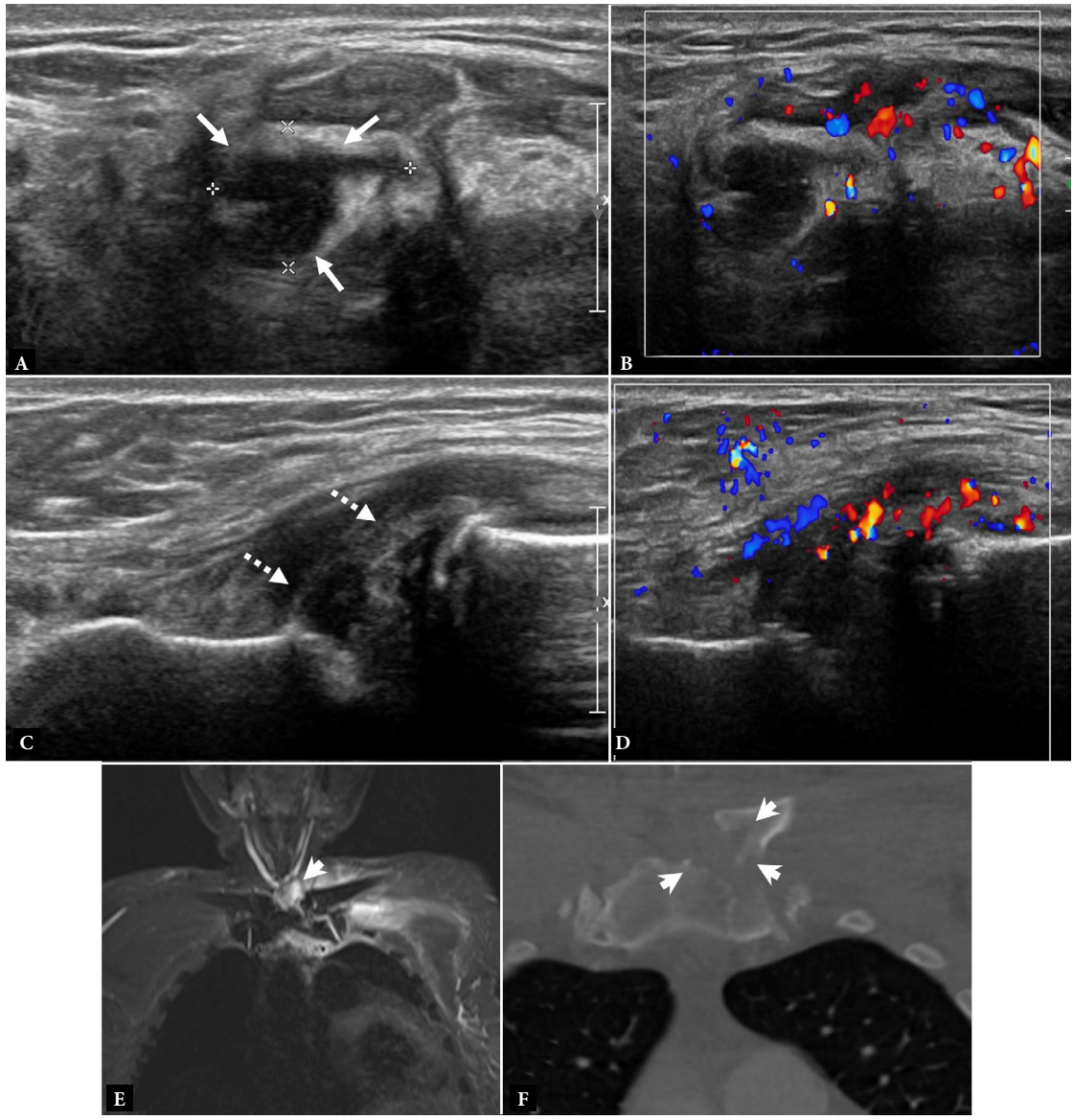

Fig. 8. *Cellulitis, joint effusion, synovitis, abscess, and septic arthritis. 58-year-old male with end-stage renal disease, left-sided chest pain, fever, and elevated WBC count.* **A.** *Transverse grayscale US image just superior to the sternoclavicular joint (SCJ) shows a lobulated, heterogeneously hypoechoic fluid collection in the anterior soft tissues (arrows, measured with calipers), consistent with a complex joint effusion.* **B.** *Color Doppler US image shows hyperemia in the surrounding soft tissues, consistent with cellulitis.* **C.** *Long-axis grayscale US image at the level of the SCJ shows a heterogeneous, complex joint effusion (dashed arrows).* **D.** *Color Doppler US image in the same region shows peripheral hyperemia, consistent with synovitis.* **E.** *Coronal short tau inversion recovery (STIR) MR image shows edema in the soft tissues around the SCJ, with superior high signal abscess (short arrow).* **F**. *Coronal reformatted CT image with algorithm shows widening of the SCJ with erosions (short arrows)*

As both infection and inflammatory arthritis demonstrate joint effusion and synovitis, it may be difficult to differentiate between the two conditions on US alone. However, the distribution and characteristics of US findings, patient history, and laboratory results can be helpful. For example, synovitis, tenosynovitis, and bursitis are common in rheumatoid arthritis, while inflammatory changes of the distal interphalangeal joints, with enthesopathy and erosive changes, suggest psoriatic arthritis[11,12]. Infectious arthritis is typically a monarticular process, while the findings in inflammatory arthritides are usually multifocal and bilateral. Crystal deposition diseases, including gout and pyrophosphate arthropathy, can also mimic infection. In gout, monosodium urate (MSU) crystal aggregates can be seen in the joints as echogenic foci[12,13]. MSU deposition within the synovium can result in heterogeneously hyperechoic synovium with hyperemia[12,13]. Deposition of MSU crystals along the superficial layer of hyaline cartilage produces an irregular hyperechoic line along the anechoic cartilage, which parallels the hyperechoic line of the subchondral bone, producing the double contour sign[12,13]. In calcium pyrophosphate dihydrate deposition disease (CPPD), calcification can be identified in the hyaline cartilage, within tendons and ligaments, and within the triangular fibrocartilage of the wrist as well as the meniscus of the knee on a variety of imaging modalities, including radiography, US, CT, and MR[12,13]. On US, CPPD will appear as hyperechoic foci within the cartilage[13].

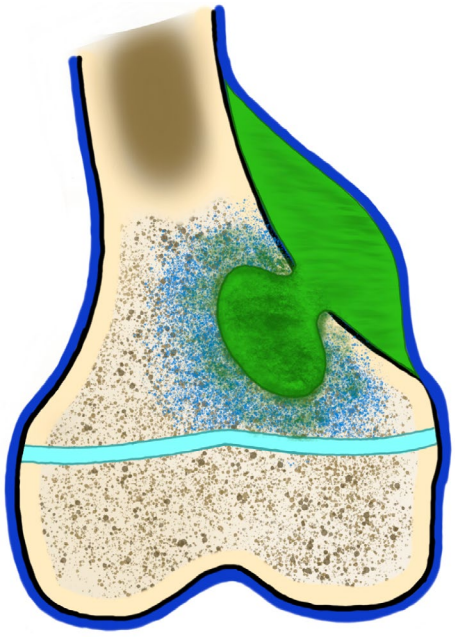

Fig. 9. *Osteomyelitis with subperiosteal abscess. Artist's graphic of osteomyelitis and its associated findings. Osteomyelitis involving the cortex and medullary cavity of the long bone of a skeletally immature patient. Extracortical extension of infection into the subperiosteal space creating a subperiosteal abscess (green)*

Pathophysiology of MSK infections

Soft tissue infections often result from either direct inoculation through broken skin or contiguous spread from an adjacent infection, either from trauma, prior surgery, or a diabetic ulcer, with hematogenous seeding less common. Postoperatively, MSK infections may occur due to direct intraoperative inoculation or from contiguous spread from a postoperative wound[2]. Septic arthritis and osteomyelitis are most commonly caused by hematogenous seeding. Young children are more susceptible to septic arthritis due to direct vascular communication between the epiphysis and the metaphysis under one year of age, and the intraarticular location of the metaphyses of several long bones[2,7,14–21]. MSK infection following therapeutic or diagnostic joint procedures is rare. A study by Keating *et al*., showed no iatrogenic infections following 133 aspirates in 115 patients with suspected PJI following knee arthroplasty[22].

Staphylococcus aureus is the most common causative bacterial organism. However, the majority of MSK infections are polymicrobial, and the most common causative species vary by age[1,2] (Tab. 1). Patients with sickle cell disease are prone to *Salmonella*-related infections, while *Pseudomonas* and *Klebsiella* are commonly encountered infectious organisms in patients who use intravenous drugs. Fungal infections are more widespread in immunocompromised individuals. The knee and the hip are the most commonly affected appendicular joints in tuberculosis-related septic arthritis[23,24].

Cellulitis

Cellulitis (Fig. 1, Fig. 2, Fig. 3, Fig. 4, Fig. 5, Fig. 6, Fig. 8) refers to infection of the epidermis, dermis, hypodermis, and occasionally the superficial fascia, often with broken skin and skin ulceration[1,2,25–27]. Usually occurring due to direct inoculation, *Staphylococcus aureus* and *Streptococcus pyogenes* are the most common causative organisms[2,9,28,29]. Clinically, patients present with soft tissue swelling, pain, and erythema.

Phlegmon/Abscess

A phlegmon is infected granulation tissue, while an abscess (Fig. 2, Fig. 3) is an infected organized focal fluid collection of debris and inflammatory cells surrounded by hyperemic connective tissue[1,2,27,29]. These may result from direct inoculation, contiguous spread from an adjacent infection, or hematogenous spread[1,3,30]. A retained foreign body (Fig. 1) predisposes to phlegmon/abscess formation. Over time, a phlegmon may organize into a defined abscess collection, which may be amenable to imageguided aspiration or drain placement.

Myositis

Myositis is nonspecific muscular inflammation, which may be infectious, inflammatory, or traumatic in nature. Pyomyositis (Fig. 3) is a bacterial, mycobacterial or fungal infection of skeletal muscle, usually caused by *Staphylococcus aureus,* resulting in muscular edema and often phlegmon and abscess formation[1,2,26,28,31]. Patients with underlying muscle injury are at an increased risk of developing pyomyositis[20,28,31,32]. Underlying systemic illnesses, such as human immunodeficiency virus infection, diabetes mellitus, malnutrition, hematologic malignancy, and organ transplantation, also increase the risk of pyomyositis[18,28,29,33]. Although any skeletal muscle may be involved, the quadriceps, gluteal, and iliopsoas musculature are most commonly affected[20,27,28,32,33].

Fasciitis

Infectious fasciitis (Fig. 4) is usually secondary to direct inoculation and can involve both the superficial and deep fascial layers.

Necrotizing deep soft tissue infection/fasciitis (Fig. 4) is a rapidly progressive, often fatal infectious fasciitis, usually polymicrobial, frequently caused by *Clostridium* species and gram-positive cocci[2,28,30,34]. Mortality rates of necrotizing fasciitis range from 15 to 80%, usually due to sepsis or multisystem organ failure[30,35]. Clinically, patients present with fever, erythematous skin, and pain. Pain is often reported to be out of proportion to the physical examination findings. Crepitus, as well as eventual skin bullae and necrosis, may

Tab. 1. Most common bacterial species causing musculoskeletal infections by age and conditions

Age/condition	Most common bacterial species
Neonate	*Staphylococcus aureus, Streptococcus,* and *Escherichia coli*
Children aged 1–4 years	*Staphylococcus aureus, Streptococcus pyogenes,* and *Haemophilus influenzae*
Children aged >4 years	*Staphylococcus aureus*
Adults	*Staphylococcus aureus* and *Enteric species*
Prosthetic joints	*Propionibacterium acnes*

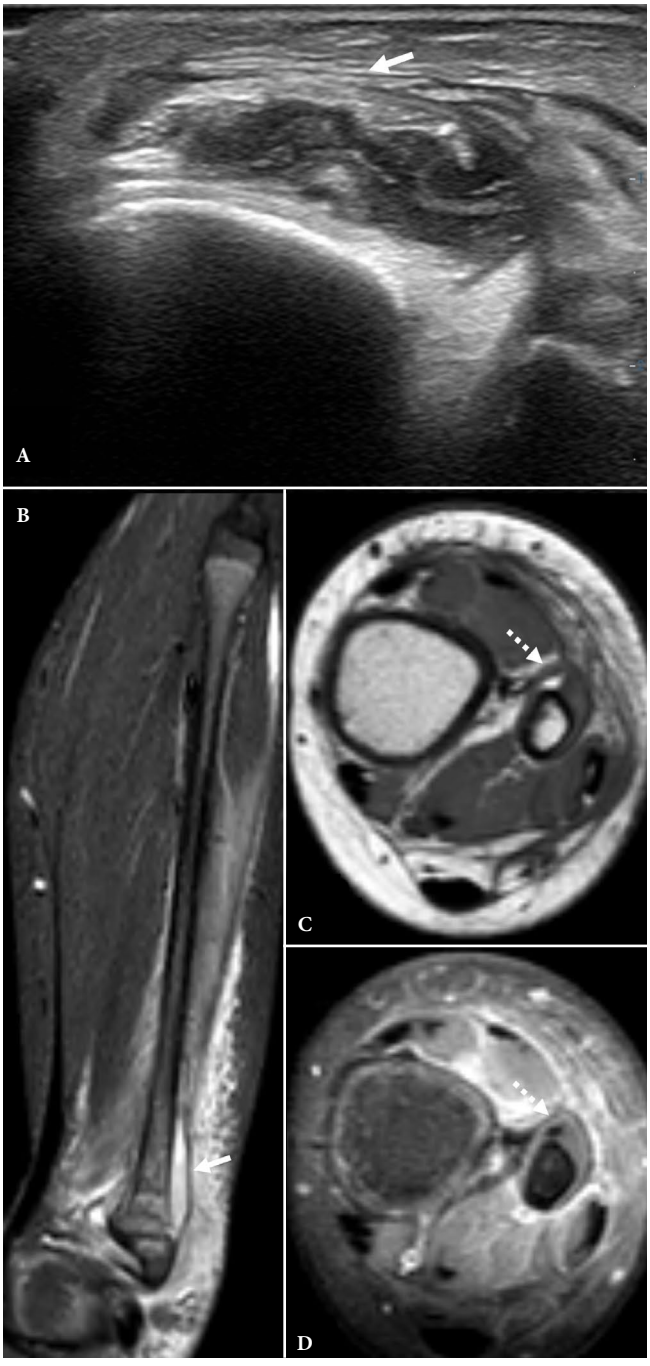

Fig. 10. *Subperiosteal abscess and osteomyelitis. 2-year-old male with 2-day history of ankle pain and inability to bear weight.* **A.** *Transverse gray-scale US image at the distal fibula near the ankle joint demonstrates a heterogeneous complex subperiosteal fluid collection (arrow) adjacent to the distal fibular cortex at the level of the metaphysis.* **B.** *Coronal STIR,* **C.** *axial T1-weighted, and* **D.** *post-contrast axial T1-weighted fat-saturated MR images of the left leg demonstrate a heterogeneous hyperintense subperiosteal collection (arrow) with an internal locule of fat, which is hypointense on post-contrast images (dashed arrow) centered at the distal fibular metaphysis. Edema signal within the distal fibular metaphysis and epiphysis is noted, with corresponding T1 marrow replacement. Findings are consistent with distal fibula osteomyelitis. Note the enhancing edema in the adjacent subcutaneous fat along the adjacent superficial and deep fascial planes and involving the distal leg musculature, consistent with associated soft tissue infection*

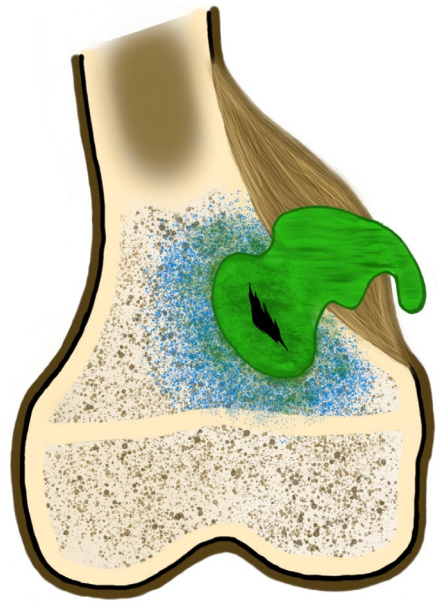

Fig. 11. *Chronic osteomyelitis. Artist's graphic of chronic osteomyelitis and its associated findings. Chronic osteomyelitis with a defect in the cortex (cloaca, with escaping pus, green), with surrounding new bone formation (involucrum, striped light brown), and a fragment of necrotic bone (sequestrum, black fragment) within the medullary cavity*

be present[28,36]. The lower extremities are most commonly affected, representing approximately 50% of cases[28,37].

Bursitis

Bursitis is most often non-infectious, secondary to repetitive trauma, crystal deposition, and inflammatory arthropathies[2,28,38,39]. Infectious bursitis (Fig. 5) is most commonly due to bacterial organisms, usually from either direct inoculation or spread from an adjacent infection[2,28,38,40,41]. Superficial bursae, such as the olecranon and prepatellar bursae, are more likely to become infected than are deep bursae, as they are more susceptible to direct inoculation from minor trauma[1,2,9,28,38–41].

Tenosynovitis

Infectious tenosynovitis (Fig. 6) is typically bacterial in etiology, but may also be secondary to atypical mycobacterial, fungal, or tuberculous etiologies. Infectious tenosynovitis usually occurs as a result of either penetrating trauma, often a puncture wound or human, insect, or animal bite, or extension of adjacent infection, and most commonly involves the hands[1,2,9,28,,29,42]. Prompt diagnosis is essential to prevent complications such as tendon necrosis and rapid spread of infection[9,42]. This is particularly true in the flexor tendons of the hand and wrist, where pyogenic tenosynovitis can spread rapidly due to variability in bursal and tendon sheath interconnections in the hand and communication of the space of Parona (a potential space along the volar aspect of the forearm and wrist between the flexor digitorum profundus and flexor pollicis longus tendons, and the pronator quadratus muscle) with the carpal tunnel[42]. Distinguishing infectious from inflammatory tenosynovitis can be difficult, however, typically, internal debris occurs with infectious tenosynovitis.

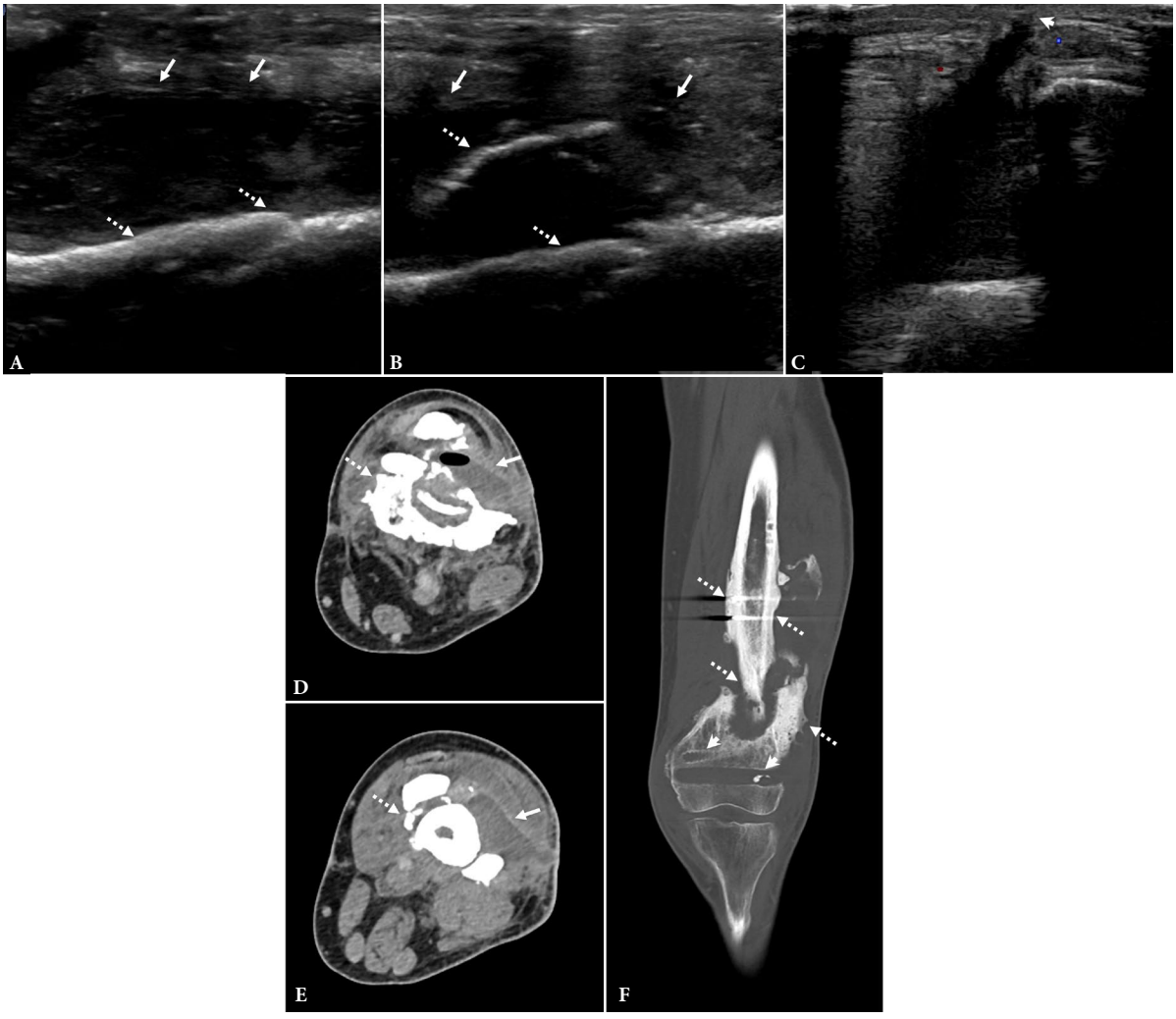

Fig. 12. *Chronic osteomyelitis. 30-year-old male previously treated for osteomyelitis involving ununited left femur fracture with multiple prior debridements and hardware removal. The patient did not complete full course of antibiotic therapy. He presented with new pain following trauma and was found to have acute on chronic osteomyelitis.* **A.** *and* **B.** *Long-axis grayscale US images show a heterogeneous hypoechoic fluid collection (arrows) adjacent to the irregular cortex (dashed arrows) from the ununited fracture.* **C.** *Transverse grayscale US image shows communication of the fluid collection to the skin surface (short arrow).* **D.** *and* **E.** *Axial contrast-enhanced CT images in soft tissue windows in the same region show chronic ununited fracture fragments (dashed arrows) as well as the peripherally enhancing fluid collection (arrows), extending from the skin surface into the fracture cavity. Note the gas in the abscess.* **F.** *Coronal reformatted CT image with bone algorithm shows sclerotic bone (dashed arrows) in the region of the fracture, consistent with chronic osteomyelitis. Note the tracts from prior hardware (short arrows)*

Septic arthritis

Septic arthritis (Fig. 7, Fig. 8), or infection of the joint, may occur secondary to direct trauma, hematogenous spread, or may result from indwelling hardware or surgical procedures. Predisposing factors include prosthetic joints as well as underlying medical conditions, such as immunosuppression, diabetes mellitus, cirrhosis, and inflammatory arthropathy[2,7,25]. Septic arthritis occurs most frequently in patients under the age of three and over the age of 55 years[43], and most commonly affects the large joints such as the hip, shoulder, and knee, due to their robust vascularity[25,27]. Bacterial arthritis may result in rapid bone and cartilage destruction, with eventual osteonecrosis, secondary osteoarthritis, and osseous ankylosis[7,9,25].

Septic arthritis should be suspected in patients presenting with an acute monoarticular involvement. Patients typically report a painful joint with associated erythema, swelling, fever, and elevated WBC count and inflammatory markers. Arthrocentesis with culture is needed for definitive diagnosis of septic arthritis.

In the pediatric population, septic arthritis often occurs with osteomyelitis, commonly in joints where the metaphysis is intraarticular, such as the hip and shoulder[7,18,44–46]. The differential diagnosis in children with an acutely painful hip with limp includes trauma, transient synovitis, neoplasm, inflammatory arthritis, osteonecrosis, and septic arthritis[47]. The Kocher criteria are helpful in differentiating septic arthritis from transient synovitis[7,19,21,46–48]. They include non-weight bearing, temperature greater than 38.5 degrees C, WBC count greater than 12,000 cells/mm^3, and ESR greater than 40 mm/hour. The presence of one criterion has a 3% probability, two criteria have a 40% probability, three criteria have a 93% probability, and four criteria have a 99% probability of septic hip.

Osteomyelitis/Subperiosteal abscess

Osteomyelitis (Fig. 9, Fig. 10, Fig. 11, Fig. 12) is infection of the bone marrow, and may be acute, subacute, or chronic in nature. US has limited utility in the diagnosis of osteomyelitis but may be helpful in detecting subperiosteal spread of infection (subperiosteal abscess). Subperiosteal abscess formation (Fig. 9, Fig. 10) is more common in children due to the less adherent periosteum and is thought to be secondary to either extension of infection from the medullary cavity through the cortex or from direct inoculation[2,19,49,50]. In chronic osteomyelitis (Fig. 11, Fig. 12), US may be helpful in identifying cortical defects and sequestrations, as well as sinus tracts extending from the skin surface to the underlying infected bone[50].

Ultrasound examination technique and guidelines for use

Technique

When evaluating for soft tissue infections, high-frequency linear array transducers are typically used (10 MHz and greater), although lower frequency transducers may be needed for the evaluation of deeper soft tissues. In patients with large body habitus, a curvilinear transducer of less than 10 MHz is often needed to evaluate deep structures such as the hip[51]. A large amount of US gel, acoustic standoff pad, or water bath may be useful for visualizing superficial structures. Transducer pressure can be utilized to assess the compressibility of fluid. Imaging of the contralateral body part for comparison is often helpful. Color and/or power Doppler interrogation should be utilized to evaluate for increased vascularity when infection is suspected. Care should be taken to avoid excessive transducer pressure, as it can obscure subtle increase in color and power Doppler signal.

Microvascular flow imaging (MVFI) (Fig. 7 B) is a newer technique that uses filters to reduce artifacts from random motion, creating greater sensitivity to low-velocity flow in small vessels[52]. As a result, MVFI is more sensitive in detecting small vessels compared to the color, power, and spectral Doppler modalities[52].

American College of Radiology (ACR) Appropriateness Criteria Guidelines

The American College of Radiology (ACR) Appropriateness Criteria endorse radiographs as the initial imaging modality in the setting of "suspected osteomyelitis or septic arthritis or soft tissue infection (excluding spine and diabetic foot)"[53]. US of the area of interest is considered "usually appropriate" as the next imaging evaluation with normal radiographs or with radiographic findings "suggestive of joint effusion or soft tissue swelling"[53]. US is considered "usually appropriate" when there is suspected soft tissue infection with a puncture wound and possible retained foreign body and normal radiographs[53].

ACR Appropriateness Criteria state that US of the area of interest "may be appropriate" as the next imaging examination for "suspected osteomyelitis or soft tissue infection with implanted extraarticular surgical hardware" with normal radiographs or with radiographic findings "suggestive of osteomyelitis or soft tissue infection with implanted extraarticular surgical hardware"[53]. US of the area of interest "may be appropriate" as the next imaging examination for "suspected septic arthritis with arthroplasty or other implanted intraarticular surgical hardware" in the setting of normal radiographs or radiographic findings "suggestive of septic arthritis with arthroplasty or other implanted intraarticular surgical hardware"[53]. US "may be appropriate" when radiographs show soft tissue gas, without a history of puncture wound, when there is clinical suspicion of necrotizing deep soft tissue infection, although these patients often undergo surgical exploration rather than additional imaging[53].

In the pediatric population, the ACR Appropriateness Criteria consider US of the area of interest as "usually appropriate" in children younger than five years of age with concern for osteomyelitis or septic arthritis of the extremity as the initial imaging, as well as the next imaging study following radiographs[19]. US of the area of interest is also considered "usually appropriate" in children 5 years of age or older with concern for osteomyelitis or septic arthritis involving an extremity[19]. US-guided aspiration is also considered "usually appropriate" in children with one or more clinical signs concerning for septic arthritis[19].

MSK soft tissue infections: us findings

Cellulitis

On US, cellulitis (Fig. 1, Fig. 2, Fig. 3, Fig. 4, Fig. 5, Fig. 6, Fig. 8) typically manifests as dermal thickening and subcutaneous edema which shows streaks of hypoechoic or anechoic fluid, with indistinct tissue planes[1,27,54]. Color and power Doppler interrogation shows hypervascularity in the affected region. Thin, linear fluid deposits are frequently present along interlobular septa and along hyperechoic fat lobules, creating a "cobblestone" appearance[1,9,27–29,54–56]. US is helpful to evaluate for associated deep venous thrombosis or superficial thrombophlebitis (Fig. 2), as well as underlying abscess formation (Fig. 2, Fig. 3)[25,27,28]. Thrombosed vessels (Fig. 2) are not compressible with transducer pressure. In acute thrombosis, the vessel is often distended by hypoechoic thrombus, and collateral vasculature is not present. In chronic thrombus, the vessel often exhibits an irregular, narrowed lumen containing echogenic thrombus, with surrounding collaterals frequently present.

Abscess/phlegmon

On US, a phlegmon is a heterogeneous, ill-defined, often hypoechoic region within the soft tissue, typically with hyperemia[54]. In contrast, an abscess (Fig. 2, Fig. 3) appears as a more well-marginated, focal fluid collection of mixed echogenicity depending on contents, with variable septations, and posterior acoustic enhancement. Abscesses are often surrounded by a thickened, hyperechoic wall which is hyperemic with color or power Doppler interrogation[9,20,27,55–57]. There is typically edema and hyperemia in the adjacent soft tissues. If gas is present within the abscess or the adjacent soft tissues, it will appear as small echogenic foci with ring down artifact consistent with reverberation artifact (Fig. 4 C–E)[29,56,57]. Swirling purulent material may be noted with application of transducer pressure to the abscess[9,56].

Myositis/Pyomyositis

On US, intramuscular abscesses (Fig. 3) are focal fluid collections located within a muscle, often of mixed echogenicity with septations, and usually with a thickened hyperechoic and hyperemic margin[1,18,29,33]. The adjacent soft tissues are typically hyperemic and edematous. If gas is found within the abscess, hyperechoic foci with reverberation artifact/dirty shadowing may be present (Fig. 4 C–E)[1,18].

Infectious fasciitis

Due to the high fatality rate without prompt diagnosis and treatment, patients suspected of having necrotizing deep soft tissue infection/fasciitis typically undergo immediate surgical evaluation rather than time-intensive imaging. Radiographs and CT can demonstrate soft tissue gas (Fig. 4 A–B).

With US, the affected fascia will be thickened and distorted, with hypoechoic fluid along the fascial layers (Fig. 4)[34,36,37,55]. Lin *et al.* showed that fluid collections along the deep fascia greater than 2 mm in depth have an accuracy of approximately 73% in the diagnosis of necrotizing fasciitis[36]. If soft tissue gas is present, there will be several hyperechoic foci with reverberation artifact/dirty shadowing (Fig. 4 C–E)[29,37]. Muscle edema may also be visualized.

Infectious bursitis

On US, an infected bursa is surrounded by peribursal edema, and is distended, with mixed echogenicity fluid with possible internal debris and septations (Fig. 5)[9,28]. The bursal wall is typically thickened, with hyperemia noted on color or power Doppler evaluation (Fig. 5)[1,9,29,57].

Infectious tenosynovitis

On US, a thickened tendon sheath distended with abnormal anechoic or hypoechoic collection indicates tenosynovitis (Fig. 6). The tendon may appear enlarged and hyperemic[9,18,29]. Simple fluid can be differentiated from synovitis using color and power Doppler interrogation, with associated hyperemia consistent with active tenosynovitis (Fig. 7)[5,55]. There is often thickening, edema, and hyperemia of the adjacent subcutaneous tissues[18].

MSK joint infections: US findings

Septic arthritis

On US, a joint effusion is an abnormal hypoechoic or anechoic intraarticular collection that is compressible without detectable color or power Doppler signal[21]. Infected or inflamed joint effusions often have heterogeneous echogenicity with irregular, hyperechoic synovial thickening (Fig. 8)[21,54]. If active synovitis is present, the joint collection is typically hypoechoic, poorly compressible, with increased color or power Doppler signal, consistent with hyperemia and active inflammation (Fig. 8)[5]. Periarticular hyperemia may also be seen on color and power Doppler imaging.

In children, US can detect hip effusions and joint fluid as small as 1 ml; in patients with septic arthritis of the hip with symptoms of less than one day, the initial US may be falsely negative due to lack of accumulation of detectable fluid[19,21]. In pediatric US examinations, the distance between the anterior femoral neck cortex and the joint capsule should be less than 5 mm, and should not be more than 2 mm thicker than the contralateral side[21]. In pediatric patients, the unossified hypoechoic epiphysis should not be mistaken for joint fluid; comparison with the contralateral unaffected joint is helpful in avoiding this error[18,21]. In addition, cartilage is noncompressible and without Doppler signal[21]. In adults, if the iliofemoral ligament and joint capsule are not imaged perpendicular, this typical hyperechoic tissue may appear hypoechoic due to anisotropy and be mistaken for a joint effusion[51]. Post hip arthroplasty, joint effusions may be loculated more posteriorly and laterally[51]. Additionally, in the adult population, US can be potentially falsely negative in the diagnosis of small joint effusions, and a thorough evaluation of the posterior and lateral aspects of the joint, with a lower frequency transducer, may be helpful[51,58].

MSK osseous infections: US findings

Osteomyelitis and subperiosteal abscess

US of osteomyelitis may demonstrate thickening and elevation of the periosteum with associated hyperemia on color/power Doppler evaluation[59]. When present, a subperiosteal abscess typically appears as a spindle-shaped fluid collection along the osseous surface, displacing the periosteum outward (Fig. 9, Fig. 10)[9,14,18,50,59–61]. There is often inflammation and hyperemia in the adjacent soft tissues (Fig. 10). In children, incompletely fused physes should not be mistaken as cortical irregularity from underlying osteomyelitis[21]. In chronic osteomyelitis, the periosteal reaction is typically thicker, with lack of hyperemia compared to periostitis occurring in acute osteomyelitis. A cloaca, an opening of the bone cortex that occurs in chronic osteomyelitis to allow the escape of pus, may be seen on US as a defect in the bone (Fig. 11). A sequestrum, a devitalized, sequestered bone fragment, can also be present in chronic osteomyelitis, and can be identified on US as an echogenic fragment of bone near the cloaca. Periosteal thickening may also be evident. Intraosseous and extraosseous abscesses may have fistulous communications with the skin surface (Fig. 12).

Summary

US is a helpful imaging modality in the evaluation of various MSK, soft tissue and joint infections, and can be useful in assessing some osseous infections. US can provide prompt diagnosis, evaluate the extent of disease, and monitor response to therapy, thus helping to optimize treatment, decreasing the risks of complications, and improving long-term clinical outcomes.

Conflict of interest

The authors do not report any financial or personal connections with other persons or organizations which might negatively affect the contents of this publication and/or claim authorship rights to this publication.

Author contributions

Original concept of study: JSW, IO, KE, AB, NC, MST. Writing of manuscript: JSW, IO, KE, AB, NC, MST. Analysis and interpretation of data: JSW, IO, KE, AB, NC, MST. Final approval of manuscript: JSW, IO, KE, AB, NC, MST. Collection, recording and/or compilation of data: JSW, IO, KE, AB, NC, MST. Critical review of manuscript: JSW, IO, KE, AB, NC, MST.

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