Musculoskeletal Ultrasound Intervention: Principles and Advances

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KEYWORDS

- Ultrasound
- Musculoskeletal intervention
- Prolotherapy
- Barbotage
- Ganglion cysts
- Ganglia

The use of ultrasonography in interventional musculoskeletal radiology is well established[1–3] and is used primarily to guide needle placement for injections, aspirations, and biopsies. The chief advantage of ultrasound imaging is its ability to perform real-time, multiplanar imaging without ionizing radiation. It is relatively inexpensive, is widely available, and permits comparison with the asymptomatic side. Conversely, the modality is operator dependent and requires detailed knowledge of the relevant anatomy, often resulting in a long learning curve. As well, physically deep and osseous lesions may not be visualized readily.

An exhaustive review of ultrasound-guided musculoskeletal intervention is beyond the scope of this section. The foremost goals of this chapter, then, are to present core principles and practical information that can be applied to most procedures. This includes a discussion of guidelines and precautions regarding the use of corticosteroids, a medication that is commonly injected under ultrasound guidance into soft tissues and joints. After this, various aspects of intra-articular intervention will be presented, including suggested routes of access for several major joints. Intratendinous calcium aspiration and intratendinous prolotherapy performed under ultrasound guidance are relatively new variations on old concepts. Both have shown great potential in the treatment of refractory chronic tendon disorders and will be described in detail. Finally, intervention of bursae and ganglion cysts will be reviewed.

GENERAL PRINCIPLES

The choice of ultrasound probe is critical. High-frequency (7–12 MHz), linear array transducers should be used routinely. To visualize deep structures such as the hip in larger patients, lower frequency curvilinear probes may be required. However, such probes should be avoided when possible because they are prone to anisotropic artifact. Anisotropy is a phenomenon in which the appearance of a structure varies depending on the angle from which it is being examined. Anisotropic artifact is common when imaging acoustically reflective, highly organized structures such as ligaments, tendons, muscles, and nerves. When the insonating sound beam is not perpendicular to the structure of interest, the sound reflects off of the structure and away from the transducer, resulting in a hypoechoic "drop off" (**Fig. 1**).

Regardless of the transducer selected, a complete sonographic examination (including color Doppler) of the area to be punctured is required to define the relationship of adjacent critical structures to be avoided such as nerves and vessels. Only then can a needle trajectory be planned safely. Areas of superficial infection should also be avoided when selecting a needle path to prevent deeper spread. These include areas of cellulitis, septic bursitis, and abscess. In cases of aspiration or biopsy of suspected malignancy, magnetic resonance (MR) imaging should be performed before the procedure, and the proposed needle route should be discussed with an orthopedic oncologic surgeon to avert unnecessary

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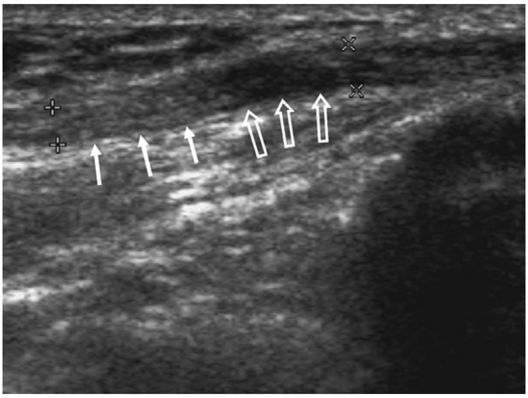

Fig. 1. Anisotropic artifact. Longitudinal sonogram of the ulnar nerve (*solid arrows*) at the level of the wrist using a linear, high-frequency transducer. As the nerve curves toward the transducer face, the insonating sound beams are no longer perpendicular to the nerve. As a result, the nerve appears hypoechoic (*open arrows*), simulating disease. Curvilinear transducers often exacerbate anisotropy because the insonating beams from the ends of the transducer face tend not to be perpendicular to the structure being examined.

transgression of anatomic compartments that may complicate surgical management.[4]

One common localization technique is to perform the puncture without direct ultrasound guidance.[5] In this "safe injection" technique, the lesion is first scanned transversely, and its maximum width is determined. Two dots are marked on the skin surface to either end of the transducer (Fig. 2A). The probe is then turned 90°, and the maximum length of the lesion is ascertained. Marks are placed again to either end of the transducer, the depth of the lesion is noted, and the four dots are connected to form a cross hair. The patient's skin is then sterilized, and a needle is inserted through the center of the cross hair at right angles to the original scan planes and passed to the predetermined depth (Fig. 2B). The advantage of this technique is that it is less time consuming because the probe requires no special sterile preparation.

Most musculoskeletal procedures, however, can be performed with a free-hand technique, which allows direct, dynamic visualization of the needle tip. The following is the author's method of choice. After planning a safe route of access, a line parallel to the long axis of the transducer face can be drawn on the skin adjacent to the end of the transducer where the needle will be introduced (Fig. 3). Once the patient's skin and transducer are sterilized and draped, the probe can be returned quickly to the same location and orientation by aligning the probe to the skin mark. A 1.5-in (3.8 cm) 25-G needle is then used to infiltrate the subcutaneous tissues with local anesthetic such as lidocaine 1% or 2%. The needle is directed toward the intended target under constant observation with the long axis of the needle parallel and in line with the long axis of the transducer face. The angle at which the freezing needle is advanced should be noted mentally because any other needles introduced afterward will follow an identical path. In many cases, it will be possible to advance the freezing needle into the target directly and use the same needle to perform aspiration or injection. This avoids puncturing the patient multiple times and helps to expedite the case. Glenohumeral joints can be accessed routinely with this single-puncture method as can hip joints and hamstring origins in thinner patients. If one intends to perform a procedure with only one needle, it is prudent to securely screw the needle onto the syringe and then unscrew the needle by an eighth turn. This ensures that the syringe can be removed easily from the needle without disturbing the needle's position once at the target site.

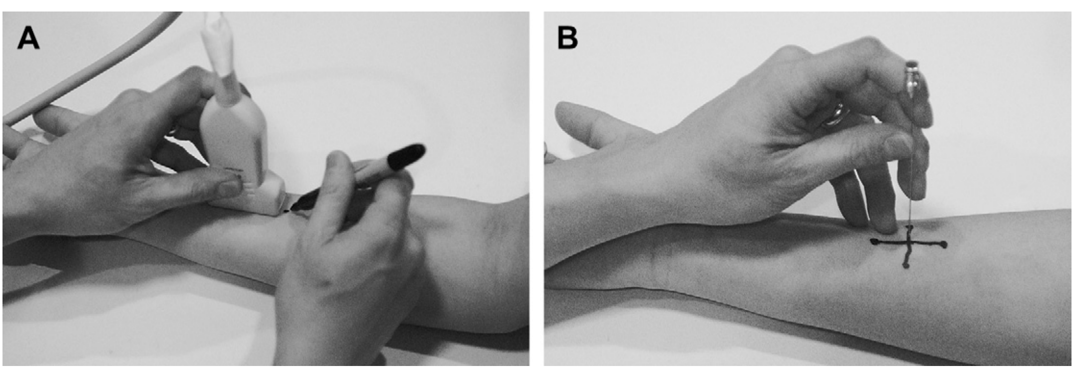

Fig. 2. Safe injection technique. (*A*) Dots are placed on the skin surface to either end of the transducer after determining the maximal length and width of the lesion. (*B*) A cross hair is drawn by connecting the four dots. A needle is then passed through the center of the cross hair to the predetermined depth. (Sterile technique not depicted above.)

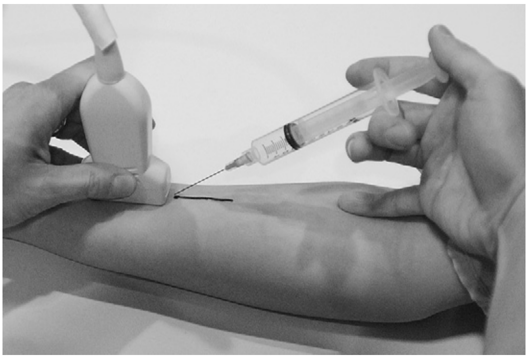

Fig. 3. Freehand technique. Once a safe needle trajectory has been chosen, a line parallel to the transducer face is drawn on the skin at the proposed needle entry site. The needle is introduced to the target along this line under constant ultrasound guidance. (Sterile technique not depicted above.)

It is sometimes difficult to visualize smaller caliber needles, and several strategies are effective in discriminating the needle tip. First, the transducer face should remain as perpendicular to the needle as possible by heel–toe angling and rocking of the probe. When ideally oriented in such a manner, reverberation artifact posterior to the needle is commonly seen, which aids in highlighting the needle (**Fig. 4**). Another approach is to sweep the transducer from side to side while repeatedly moving the needle in and out, which aids in identifying the tip in real time. Injecting a small amount of local anesthetic will disrupt the adjacent soft tissues and also helps to localize the needle tip. At other times, rotating the transducer 90° to examine the needle in short axis may be useful in determining whether the needle has veered off to one side of the intended course.

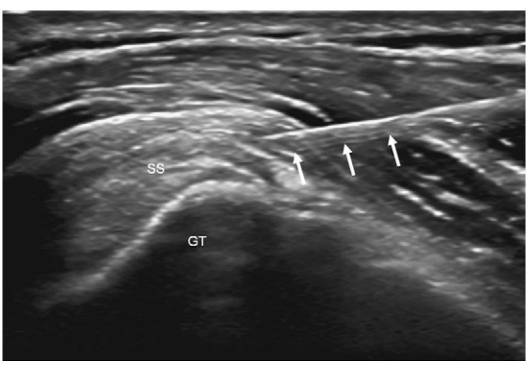

Fig. 4. Reverberation artifact. Coronal sonogram of the distal supraspinatus tendon (SS) upon its insertion onto the greater tuberosity (GT). A 25-G needle introduced for a diagnostic block of the subacromial bursa shows reverberation artifacts (*solid arrows*), which appear as multiple, parallel lines deep to the needle. This artifact, when present, is useful in helping to identify the needle position. Smaller caliber needles tend to produce less, if any, reverberation.

Sterile skin preparation and aseptic technique vary tremendously between institutions and radiologists. In our department, sterile coupling gel and disposable sterile drapes are always used. Extra-articular structures are routinely punctured after thorough cleansing of the skin and probe only. Disposable plastic probe covers are used, however, for intra-articular work to minimize the risk of septic arthritis. Standoff pads are prone to physically interfere with procedures and are, therefore, never used.

The needle size, length, and type should be selected based on the task at hand. Larger needles (18–20 G) are generally required for aspiration of suspected thick material such as pus, ganglia, or organized hematoma. Smaller needles (22–27 G) suffice for most injections but are inappropriate for aspirations unless the aspirate is thin. Specialized needles with cutting tips such as the Westcott biopsy needle (Becton, Dickinson and Company, Franklin Lakes, New Jersey) or core-biopsy needle sets are often required for soft tissue biopsies.

MEDICATIONS

The most common medications used in musculoskeletal intervention are for local anesthesia. Lidocaine 2% (Xylocaine) is the author's drug of choice and has rapid onset with a duration of action of up to 5 hours.[6] Bupivacaine (Sensorcaine, Marcaine) is an alternate slower-onset anesthetic but one which can last up to 12 hours and is available in 0.25%, 0.5%, and 0.75% concentrations. The duration of action of both drugs is shorter with lower concentration formulations.[6]

Corticosteroids have potent anti-inflammatory properties and are commonly prescribed for injection into soft tissues, bursae, tendon sheaths, and joints. At the author's institution, the two corticosteroids used most routinely are triamcinolone acetonide and methylprednisolone acetate (Depo-Medrol). These are generally mixed 1 part lidocaine 2%, 1 part bupivacaine 0.25%, and 2 parts 40 mg/mL corticosteroid before injection.

Several potential side effects of corticosteroids are relevant to musculoskeletal intervention, which practitioners need to be aware of. First, skin atrophy, fat necrosis, and skin depigmentation may develop from corticosteroids applied topically or injected intralesionally, intradermally, or subcutaneously. Methylprednisolone is less prone to causing skin atrophy than triamcinolone[7–11] and, therefore, is preferred when injecting lesions near the skin surface.

Secondly, animal models have shown that the biomechanical properties of tendons are adversely affected by intratendinous corticosteroid administration.[12,13] Corticosteroids may limit formation of granulation and connective tissue, reduce tendon mass, and decrease the amount of load that a tendon can withstand before mechanical failure. Case reports of tendon rupture after intratendinous corticosteroid injection are common in the literature.[14–16] Although corticosteroids have been used to treat tendon degeneration, or tendinosis, inflammation is not a predominant feature of this condition and, when present, may be important in the healing process.[17] Currently, there is no good evidence to substantiate the use of corticosteroids in treatment of chronic tendon lesions.[18] Even peritendinous injections may predispose to tendon rupture[15,19–21] and, therefore, should be performed with caution.

Corticosteroids have also been implicated in cartilage breakdown when injected into synovial joints, particularly weight-bearing articulations.[22–24] Articular surfaces develop multiple cystic defects, which become filled with necrotic debris. Such lesions appear not to develop in similarly injected non–weight-bearing joints. Reduction in cartilage elasticity has also been shown, which may further accelerate cartilage breakdown as the cushioning effect of cartilage is lost. There has been at least one case report of a Charcot-like arthropathy after intra-articular corticosteroid use.[25]

Currently, there is no consensus and no evidence-based guidelines for the number of safe injections at one site or the appropriate interval between injections.[18] As such, many recommendations for the use of locally injected corticosteroids are anecdotal. **Box 1** summarizes some suggestions for corticosteroid use in soft tissues and joints.

Box 1
Suggestions for corticosteroid injection into soft tissues and joints

- Use methylprednisolone when injecting superficial lesions or superficial joints.
- Mix the corticosteroid with local anesthetic solution to provide immediate but short-term pain relief.
- Avoid intratendinous injections.
- Use caution with peritendinous injections, especially when the adjacent tendon is heavily loaded (such as the patellar and Achilles' tendons) or is torn.
- Avoid intra-articular injections unless there is a specific indication, such as end-stage osteoarthritis.
- Be mindful of injection into structures that communicate with a joint. Examples include the long head of biceps tendon sheath, flexor hallucis longus tendon sheath, and Baker's cysts.
- Advise at least 2 weeks of rest and avoid heavy loading for 6 weeks after peritendinous and intra-articular injections.
- Be careful not to damage the articular cartilage with the needle during injection.
- Allow adequate time between injections to assess its effects, generally a minimum of 6 weeks.
- Be cautious in using more than 3 injections at any one site.
- Do not repeat an injection if at least 4 weeks of symptomatic relief was not achieved after 2 injections.

Data from Speed CA. Fortnightly review: Corticosteroid injections in tendon lesions. BMJ 2001; 323(7309):382–6; and Tehranzadeh J, Booya F, Root J. Cartilage metabolism in osteoarthritis and the influence of viscosupplementation and steroid: a review. Acta Radiol 2005;46(3):288–96.

INTRA-ARTICULAR INTERVENTION

Eustace and colleagues[27] found that blind injections for shoulder pain, even in the hands of musculoskeletal specialists, are successful only in the minority of cases. In their series, only 29% of subacromial injections and 42% of glenohumeral joint injections were performed accurately without image guidance. In another recent study that compared ultrasound-guided and blind aspirations of suspected joint effusions, only 32% of cases returned fluid when performed blindly. In contrast, fluid was aspirated in 97% using ultrasound scan.[28] Indeed, ultrasonography has been shown to be effective in guiding difficult joint aspirations throughout the body.[29,30]

Ultrasound-guided joint aspirations may be performed for diagnosis of conditions such as crystal arthropathy and septic arthritis. In the case of an infected joint, aspiration may be therapeutic as well. Septic joint effusions are commonly hypoechoic with low-amplitude internal echoes but fluid may also be hyperechoic or rarely anechoic (**Fig. 5**B).[31,32] In approximately 0.5% of septic joints, the initial ultrasound examination will find no joint effusion.[33] A repeat ultrasound study should be considered if fever and joint pain persist in these cases. Although septic arthritis may be associated with hyperemia, Doppler ultrasound scan is unreliable in differentiating septic from aseptic joints.[34] Finally, intra-articular injection of local anesthetic should be avoided because

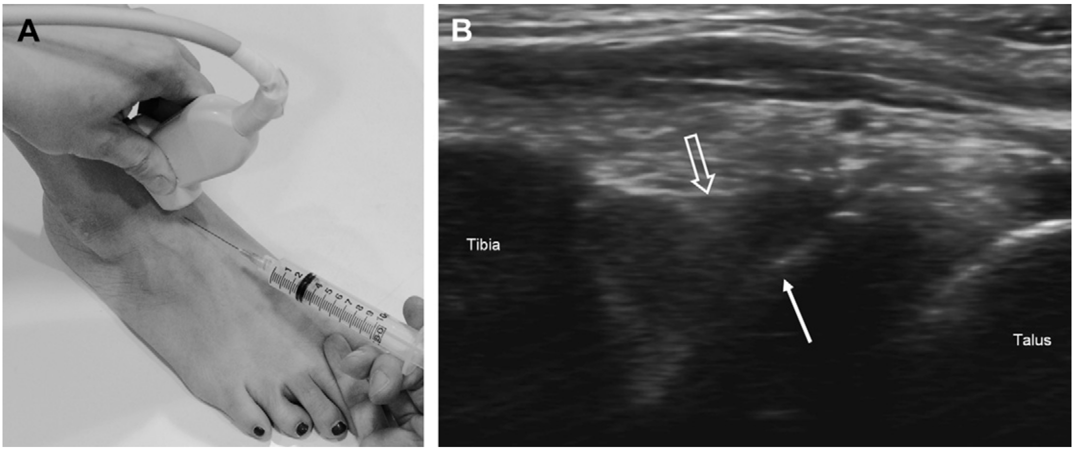

Fig. 5. Ankle joint access from an anterior approach. (*A*) The transducer is aligned in a sagittal plane at the tibiotalar articulation, and the needle is introduced from an anteroinferior approach. Care should be exercised to avoid puncturing the dorsalis pedis artery and extensor tendons. (*B*) Sagittal sonogram of the anterior ankle joint in an intravenous drug abuser. A hypoechoic joint effusion containing low-amplitude internal echoes is interposed between the distal tibia and talar dome and displaces the ankle joint capsule anteriorly (*open arrow*). The needle tip is seen within the joint space (*solid arrow*). (*Sterile technique not depicted above.*)

lidocaine is bacteriostatic and may contribute to false-negative results.

Ultrasound-guided joint injections are also commonly performed for diagnosis and therapy. Diagnostic blocks are performed by injecting a small amount of anesthetic into a joint and then clinically assessing whether the procedure has improved the patient's symptoms. Several in vitro and animal-based studies have shown chondrotoxic effects resulting from intraarticular exposure to anesthetic solutions, including lidocaine and bupivicaine.[35–41] Although data are preliminary, these results stress the need to perform all intraarticular interventions with caution and only when there is a reasonable clinical indication. The author uses an equal volume mixture of lidocaine and bupivicaine for this purpose, but the total volume of injected solution will depend on the size of the joint. Most hip and shoulder joints easily receive 10 mL, whereas the small joints of the hands and feet may take less than 1 mL. In all cases, injection should be terminated if the patient complains of excessive discomfort. The procedure is useful in confirming or ruling out the source of pain and, in cases of subsequent surgery, helps to predict postsurgical pain relief. Pain response is graded subjectively on a 10-point scale, and the patient is asked to keep a diary of blockade efficacy over the next 24 hours. Patients should be instructed not to overuse the joint because pain relief, although potentially dramatic, will be short-lived.

Therapeutic intra-articular injection of corticosteroid and viscosupplement are useful in treating osteoarthritis[26] and can be performed under ultrasound guidance. Viscosupplementation is a procedure in which hyaluronic acid, or a derivative, is injected directly into afflicted joints and aims to replace what is believed to be an important factor of joint lubrication. Several formulations are commercially available that vary in their duration of effect and treatment schedules. Although the precise mechanism of action is not entirely understood, numerous clinical trials have shown some improvement in pain and joint function.[42,43]

The following section describes potential routes of access to the most commonly injected joints. As already discussed, every precaution should be taken to prevent septic arthritis. Proper sterile preparation and draping of the patient and of the equipment are essential.

Shoulder Joint

The majority of shoulder joints can be injected while the patient is seated. However, if the patient is known to become faint or is overly anxious, a lateral decubitus position works equally well. Although the glenohumeral joint may be accessed from anteriorly or posteriorly, the preferred approach is the latter. This route is particularly advantageous when performing gadolinium injections before MR imaging because there is less chance of causing interstitial injection of the rotator cuff interval or anterior labrum where misplaced contrast material could simulate disease.

With the patient's hand gently resting on the opposite shoulder, the posterior joint is examined in an axial plane, and the key landmarks of the triangular-shaped posterior labrum, humeral head, and joint capsule are identified (**Fig. 6**).

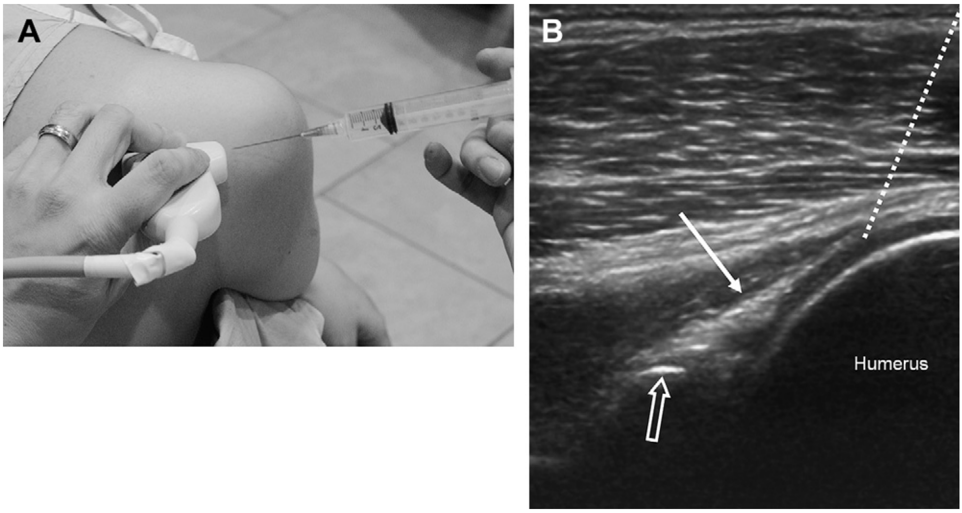

Fig. 6. Shoulder joint access from a posterior approach. (*A*) With the patient seated, the posterior glenohumeral joint is examined in a transverse plane. (*B*) The needle is introduced from a lateral and posterior approach (*dotted line*). Important landmarks include (**1**) the humeral head (Humerus) which is lined by a thin, hypoechoic layer of articular cartilage, (**2**) the bony glenoid rim (*open arrow*), and (**3**) the echogenic, triangular-shaped posterior labrum (*solid arrow*) which arises from the glenoid. (Sterile technique not depicted above.)

The needle is introduced laterally in an axial plane and is advanced medially. The needle target is between the posterior-most aspect of the humeral head and the posterior labrum. Particular care should be taken to not puncture the labrum or articular cartilage, however. Once the needle tip is felt against the humeral head, a small test injection of anesthetic is performed. With correct intra-articular placement, anesthetic will flow easily into the joint. If there is resistance to injection, gently twirling the syringe or withdrawing the needle by 1 to 2 mm while continuing to inject a small amount of anesthetic will often resolve the problem.

In almost all cases, the 1.5-inch 25-G needle used for local anesthesia will suffice in accessing this joint with a single puncture. In larger patients, the use of a longer 22-G spinal needle may be required.

Elbow Joint

The patient is seated or laid supine with the elbow flexed and the arm placed comfortably across the chest (Fig. 7A). The ultrasound probe is then positioned along the posterior elbow and is oriented sagittally such that the triceps tendon is visualized

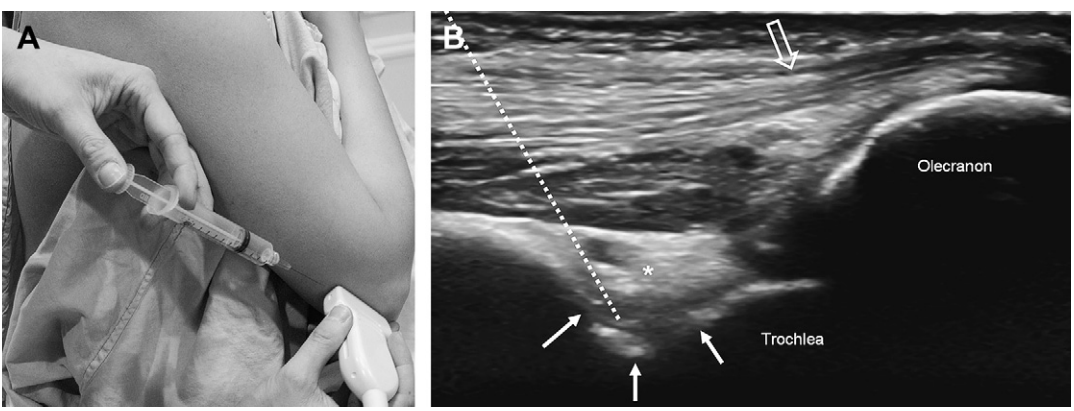

Fig. 7. Elbow joint access from a posterior approach. (*A*) With the patient seated and the affected arm placed across the chest, the posterior joint is examined in a sagittal plane. (*B*) The needle is introduced from a postero-superior approach (*dotted line*), passing adjacent to the triceps tendon (*open arrow*), through the posterior fat pad (*asterisk*) and into the joint. The concave olecranon fossa of the humerus (*solid arrows*) provides a useful landmark. (Sterile technique not depicted above.)

longitudinally. The probe, which remains parallel to the triceps fibers, is then slid laterally until just out of view of the triceps tendon. Key landmarks are the olecranon fossa of the humerus, the posterior fat pad, and the olecranon (**Fig. 7**B). The needle is introduced from a superior approach, passing beside the triceps tendon and through the posterior fat pad to enter the joint space. This joint is easily accessible with a 1.5-inch long needle.

Hip Joint

There are two common approaches to accessing the hip joint and the choice between the two depends on operator preference, the presence of a joint effusion, and body habitus. In both cases, the patient is laid supine and the joint is punctured anteriorly.

When a joint effusion is present or in larger patients, the best approach is often with the probe aligned along the long axis of the femoral neck. The concave transition between the anterior aspect of the femoral head and neck can be visualized clearly, and the joint capsule is seen immediately superficial (**Fig. 8**). The needle is introduced from an inferior approach and passes through the joint capsule to rest on the subcapital femur. Septic hip arthritis is a frequent clinical concern, particularly in patients with hip arthroplasties. Although a fine needle is useful for joint injections, aspiration for suspected septic arthritis should be performed with an 18-G spinal needle. Not only will purulent material be easier to aspirate, but a 22-G Westcott biopsy needle can be introduced through the larger needle to obtain synovial biopsies, if required.

In thinner patients, it is often easiest to access the hip joint with the ultrasound probe oriented axially. When positioned correctly, the femoral head and acetabular rim will be in view (**Fig. 9**). The needle is introduced from an anterolateral approach, remaining lateral to the femoral neurovascular bundle. The needle tip is advanced until it rests on the femoral head, adjacent to its most anterior aspect. The hip labrum, which arises from the acetabulum, should be avoided.

Knee Joint

A knee joint distended with effusion is most easily injected or aspirated through the suprapatellar bursa with the patient supine and the knee flexed slightly. A small pillow or sponge placed behind the knee is helpful. The probe is placed in a sagittal plane superior to the patella, whereby the fibers of the distal quadriceps tendon are seen in long axis (**Fig. 10**). The probe is kept parallel to the quadriceps tendon but is slid medially or laterally until the quadriceps fibers disappear from view. A needle is then passed directly into the bursa.

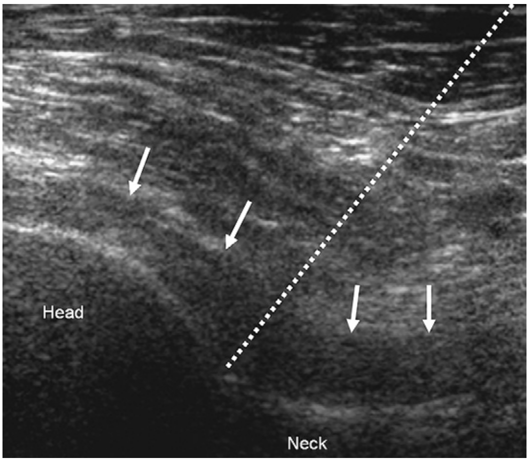

Fig. 8. Hip joint access—long axis technique. With the ultrasound probe aligned along the long axis of the femoral neck, the distinctive concave transition between the femoral head and neck is visualized. In this case, the anterior hip joint capsule (*solid arrows*) is displaced anteriorly by a large joint effusion. The needle is introduced from an inferior and anterior approach (*dotted line*), lateral to the femoral neurovascular bundle (not shown).

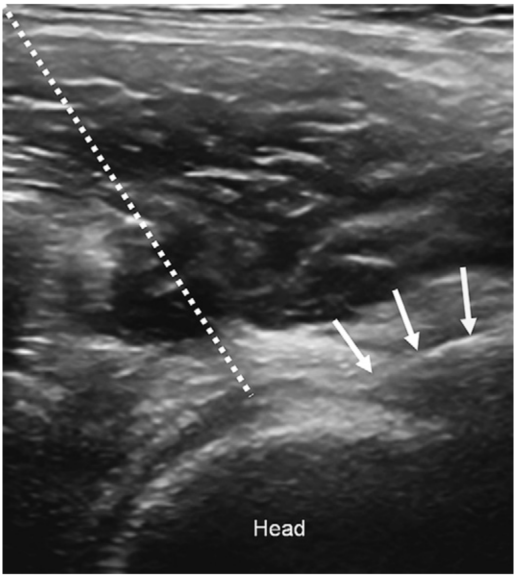

Fig. 9. Hip joint access—short axis technique. With the transducer oriented in a transverse plane, the key landmarks of the femoral head and anterior acetabulum (*solid arrows*) are visualized. The needle is introduced from an anterior and lateral approach (*dotted line*), piercing the anterior joint capsule to rest upon the femoral head. The femoral neurovascular bundle (not shown) is medial to and remote from the needle path.

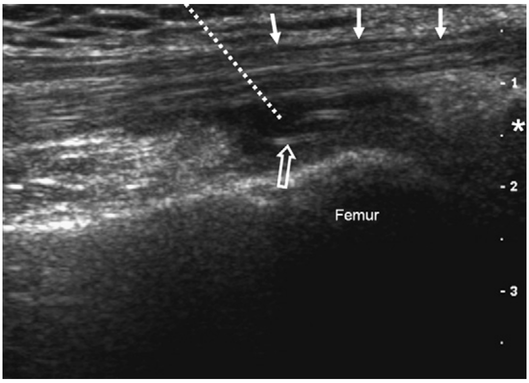

Fig. 10. Knee joint access from anterior approach. Sagittal sonogram of the suprapatellar knee shows the distal quadriceps tendon (*solid arrows*), the distal femur, and the superior patellar pole (*asterisk*). The needle is introduced from an anterior and superior approach (*dotted line*) and is preferably passed to one side of the quadriceps tendon without puncturing it. In this case, synovial plicae (*open arrow*) are present in a mildly distended suprapatellar bursa.

For knee joints with no joint effusion, the medial patellofemoral facet affords an excellent target. After palpating the patella and medial patellofemoral joint line, the probe is placed in an axial plane so that the patella and medial femoral condyle are visible. The probe is then turned 90° and oriented along the joint line. The needle is introduced either from an inferior or superior approach directly into the joint.

Ankle Joint

With the patient supine, the anterior tibiotalar joint is examined in a sagittal plane (see Fig. 5A). If there is any doubt of correct probe placement, performing plantar flexion and dorsiflexion maneuvers will readily identify the talus moving across the tibia. The position of the dorsalis pedis artery and extensor tendons should be noted and kept away from during needle placement. A needle then is introduced into the joint in a sagittal plane using an inferior approach (see Fig. 5B).

INTRATENDINOUS INTERVENTION

Calcific and noncalcific tendinosis are two potentially symptomatic diseases that are often refractory to conservative management. The ability of ultrasound scan to accurately depict and localize tendon abnormalities makes ultrasound-guided calcium aspiration and prolotherapy invaluable in treating these conditions.

Treatment of Calcific Tendinosis

Rotator cuff **calcific tendinosis** (also commonly referred to as **calcifying tendinitis**), is caused by the deposition of carbonate apatite crystals,[44] most commonly in the critical zone of the supraspinatus tendon roughly 1 cm proximal to its insertion.[45–47] Uhthoff and Loehr[46] described three distinct stages in the disease process, namely the precalcific, calcific, and postcalcific stages. Depending on the phase of disease, the imaging appearance and physical consistency of the calcification differ significantly as do patient symptoms.

The calcific stage consists of three phases. The **formative** and **resting phases** are chronic and may be associated with varying degrees of pain at rest or with movement. Many patients, however, are asymptomatic.[48] These calcifications tend to be well circumscribed and discrete when examined radiographically[49] and often produce significant acoustic shadowing by ultrasound scan (Fig. 11).[50] Attempts at aspirating calcifications in these two phases tend to be difficult because the calcifications are quite hard and chalklike.

The **resorptive phase** is the last phase in the calcific stage and is the most symptomatic. Shedding of calcium crystals into the adjacent subacromial bursa may result in severe pain and restricted range of motion.[51] This phase typically lasts for 2 weeks or longer. These calcifications appear ill-defined on radiographs and produce little or no acoustic shadowing by ultrasonography (Fig. 12).[50] When aspirated, these calcified deposits typically are soft with a slurrylike consistency.

Calcific tendinosis is usually a self-limiting condition in which the calcification resorbs after a period of worsening pain.[48] However, in some patients, the condition can lead to chronic pain and functional impairment. The resolution of calcification correlates well with clinical improvement of symptoms[52–57] and, therefore, various treatments have been devised to promote their removal. There is no conclusive evidence that intralesional steroid injection,[58] acetic acid iontophoresis,[59,60] or pulsed ultrasound therapy are effective.[48] Extracorporeal shockwave lithotripsy uses acoustic waves to fragment calcium deposits, and substantial or complete clinical improvement has been reported in 66% to 91% of patients.[52,54,61,62] However, access to lithotripter equipment is limited and is less available than ultrasound imaging.

Open or arthroscopic surgery currently provides the greatest long-term relief in terms of substantial or complete clinical improvement with numerous studies reporting between 76.9% and 100% good or excellent results.[49,63–73] However, surgery may be complicated by prolonged postsurgical disability and reflex sympathetic

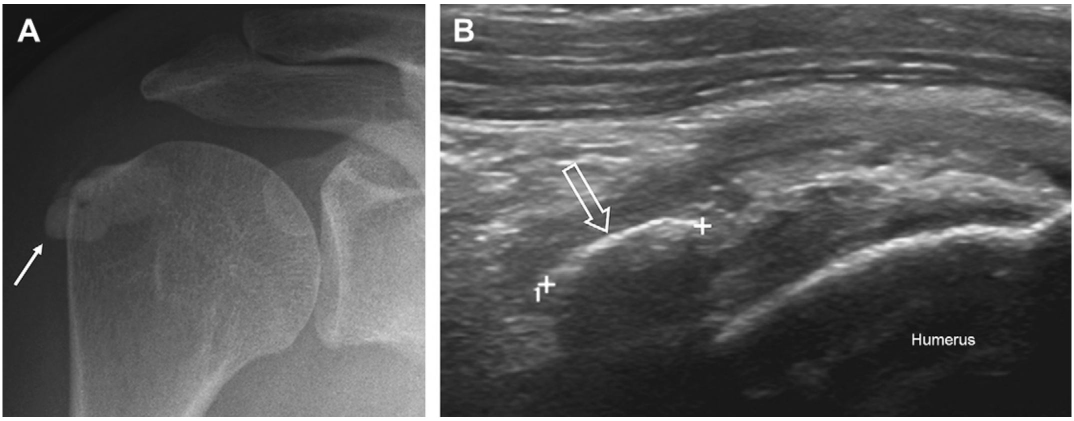

Fig. 11. Hard calcifications in calcific tendinosis. Examples of "hard calcification" that typify the formative phase of calcific tendinosis. (*A*) The anteroposterior radiograph of patient A shows a large, sharply circumscribed calcification within the infraspinatus tendon (*solid arrow*). (*B*) In patient B, the supraspinatus tendon is imaged longitudinally. A large intratendinous calcification (*open arrow*) produces significant posterior acoustic shadowing artifact.

dystrophy.[52,63,74–76] Because conservative measures are successful in up to 90% of patients,[71] surgery is generally indicated only in those who have progressive symptoms, whose symptoms interfere with activities of daily living, and who have not responded to conservative therapy.[77]

Image-guided needle irrigation and aspiration (**barbotage**) of rotator cuff calcifications has been shown to be an effective minimally invasive technique and was first described three decades ago.[78] In a recent study, del Cura and colleagues[56] reported that 91% of patients experienced significant or complete improvement in range of motion, pain, and disability when aspiration was performed under ultrasound guidance. Given the potential risks of surgery, percutaneous calcium aspiration should be considered after failure of medical therapy.[56,79] Successful aspiration may not be possible in cases in which the calcification appears striated because this is thought to represent calcification of the tendon fibers themselves. Also, clinical outcomes when attempting to remove numerous, diffuse, small (<5 mm) calcifications are only fair to poor, even when treated surgically.[80]

Image-guided barbotage techniques vary greatly, and there is no accepted standardized methodology. Needle sizes have ranged from 15 G[81] to 25 G,[58] and some investigators have advocated a two-needle irrigation system,[76,82,83] whereas others have used only one.[56,57,76] In some published results, as many as 15 passes were made through the same calcification,[78,83,84] whereas other researchers opted to limit potential

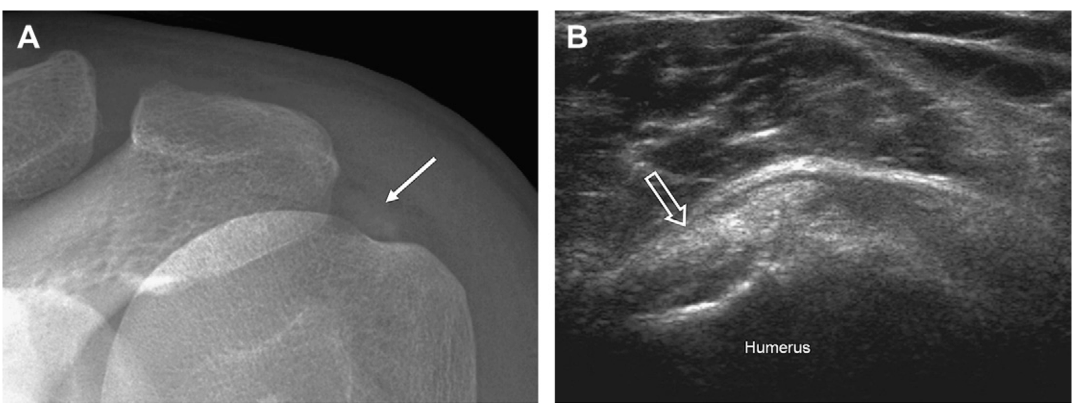

Fig. 12. Soft calcification in calcific tendinosis. Examples of "soft calcification" that characterize the resorptive phase of calcific tendinosis. (*A*) Faint, ill-defined calcification (*solid arrow*) is seen on the anteroposterior radiograph of patient A who suffers from excruciating shoulder pain. (*B*) In patient B, a vague, hyperechoic area is seen anteriorly within the supraspinatus tendon, which is scanned in short axis (*open arrow*).

iatrogenic cuff damage by performing a single lesional puncture only.[56,57]

At our institution, we routinely perform a full-shoulder ultrasound examination before any intervention. This is done to ensure that there are no co-existing disorders such as rotator cuff tears. We also ensure a recent set of radiographs has been performed to characterize the calcifications more fully and to act as a baseline for follow-up. The patient is placed into the lateral decubitus position opposite the affected side. Although the procedure can be done sitting, patients have been documented to become syncopal during aspiration.[56] Depending on the location of the calcification in the cuff, the arm is positioned appropriately. In the case of the supraspinatus tendon, a "hand in back pocket" position is used. The calcification is then targeted under ultrasound scan before sterile preparation of the skin and equipment. A 20-G needle connected to a syringe filled with 2% lidocaine is advanced into the subacromial bursa where a small amount of anesthetic is injected before the needle continues into the calcification. Importantly, lidocaine is injected into the calcification without first aspirating to prevent the needle tip from becoming obstructed. Several short injections, each followed by release of pressure on the plunger, are performed. If successful, lidocaine and calcium fragments will evacuate into the syringe. The syringe should be held below horizontal to prevent re-injection of aspirated material. Also, new lidocaine-filled syringes can be exchanged for when required. Barbotage should be continued until no more calcification can be aspirated. However, it may not be possible to aspirate very hard calcifications, in which case the calcification can be ground gently with the needle tip by rotating the syringe (**Fig. 13**). This mechanical perturbation of the deposit is hypothesized to stimulate cell-mediated resorption.[57,76,78,85] There is collaborative evidence in the surgical literature that suggests that calcific deposits need not be removed completely to achieve successful outcomes.[72,78] The needle is then withdrawn into the subacromial bursa where a combination of 1 mL 2% lidocaine and 1 mL of 40 mg/mL triamcinolone is injected to mitigate the risk of post-procedural bursitis (**Fig. 14**).

Patients are instructed to rest the shoulder for up to a week and are advised to take nonsteroidal anti-inflammatory medication, as needed, to manage discomfort. A follow-up appointment is made for 6 weeks after barbotage and includes repeat ultrasound and plain film studies.

Treatment of Noncalcific Tendinosis

Tendon degeneration, often referred to as "tendinopathy" or "tendinosis," is not characterized by an inflammatory response but rather infiltration of fibroblasts and vessels.[86] Tendinosis is generally considered to be caused by repetitive microtrauma with an ensuing chronic cycle of tendon degeneration and repair resulting in a weakened tendon. These changes have been shown to appear as hypoechoic areas on sonography (**Fig. 15**).[87] Several techniques have been described to treat tendinosis. Autologous blood, which contains fibroblast growth factors, has been used successfully in treatment of refractory medial and lateral epicondylitis of the

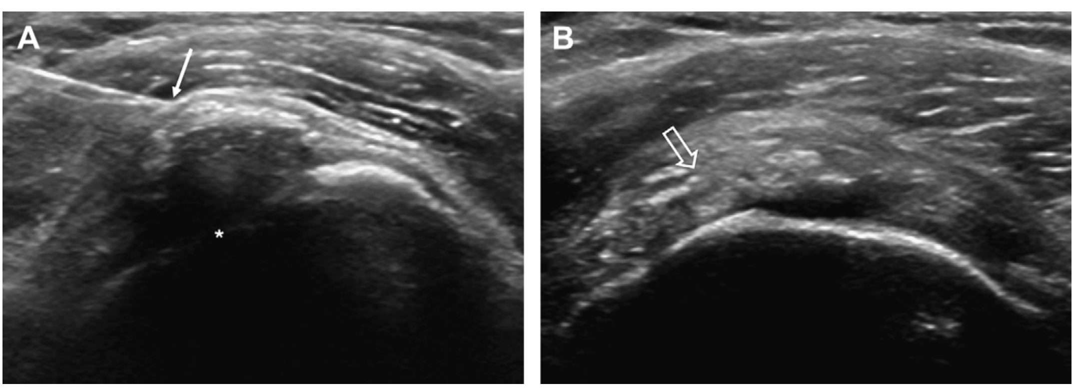

Fig. 13. Incomplete aspiration of supraspinatus calcification. (*A*) Sonogram of the supraspinatus tendon in short axis shows placement of a needle (*solid arrow*) at the edge of a "hard" calcified deposit. There is marked posterior acoustic shadowing that obscures the humeral cortical surface (*asterisk*). Only a small amount of calcification could be aspirated. The calcification instead was gently ground with the needle tip. (*B*) Follow-up sonogram 6 weeks later shows marked change in the appearance of the calcification with loss of the acoustic shadowing seen previously (*open arrow*). The patient's symptoms improved significantly between the two examinations.

Fig. 14. Subacromial bursal injection. An oblique short-axis sonogram of the supraspinatus tendon shows placement of a needle (*open arrow*) within the subacromial bursa (*solid arrow*). The bursa has been distended partially with injected lidocaine and corticosteroid at the end of a barbotage procedure.

elbow.[86,88–90] Ohberg and Alfredson reported significant improvement in chronic achillodynia after obliteration of neovessels using polidocanol as a sclerosing agent.[91]

Prolotherapy is another treatment option that has shown promising results. It is a technique in which injection of an irritant solution (the proliferant) into a ligament or tendon incites a local inflammatory response, which, in turn, induces fibroblast proliferation and collagen synthesis.[92–94] One popular proliferant solution that has been studied is hyperosmolar dextrose, which has an excellent safety profile and is inexpensive.[95] As little as 0.6% extracellular D-glucose (dextrose) has been shown experimentally to stimulate human cells in producing growth factors within minutes to hours[96] and dextrose concentrations greater than 10% result in a brief inflammatory reaction.[93] In a recent review of the prolotherapy literature, Rabago and colleagues[97] reported positive results compared with controls in both nonrandomized and randomized, controlled studies. Good results have been reported previously after treatment of tendons such as the thigh adductor origins and suprapubic abdominal insertions without image guidance.[98] Intra-articular dextrose administration has also been experimentally used in treatment of osteoarthritis and ACL laxity.[99–101]

Maxwell and colleagues[95] significantly advanced this technique by using ultrasonography to treat chronic Achilles tendinosis. Focal areas of tendinosis and partial tearing were precisely targeted and then injected with 25% dextrose monohydrate solution (**Fig. 16**). In their study, patients showed a significant reduction in tendon pain at rest (88%), with normal activity (84%), and after exercise (78%). The number of intrasubstance tears decreased by 78% and areas of neovascularity diminished by up to 55%. At 1-year follow-up, 67% of patients continued to be asymptomatic, 30% had mild symptoms, and only 3% had moderate symptoms.

As with all interventional procedures, a formal ultrasound examination of the entire area is performed first to characterize the extent and nature of the disease and to exclude other pathology. A 25% dextrose solution is produced by mixing 1 mL of 50% dextrose monohydrate and 1 mL of 2% lidocaine. Once the needle route is planned, and sterile preparation has been performed, a 25-G needle and lidocaine solution are used for local anesthesia. The needle then is advanced directly into the tendon at the site of tendinosis or tearing (**Fig. 17**). Areas of neovascularity are not targeted specifically, but neovessels frequently will coexist in areas of tendinosis and often will decrease with treatment (**Fig. 18**). As advocated by Maxwell and colleagues[95] usually 0.5 mL or less solution is injected into any one lesion. However, several lesions may be injected during a single treatment session.

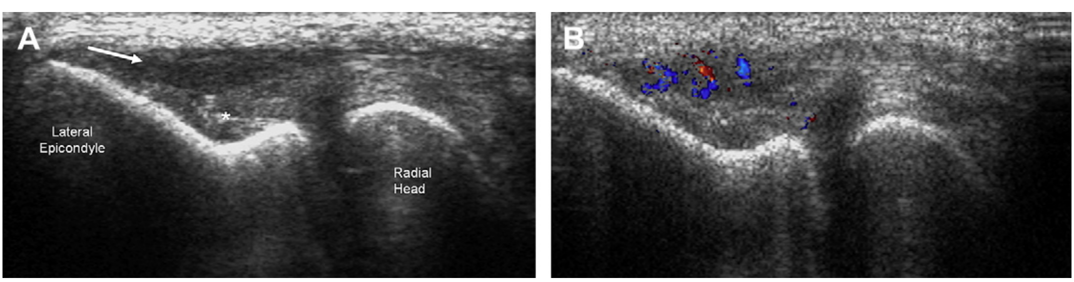

Fig. 15. Common extensor tendinosis. Coronal sonograms of the common extensor tendon origin of the elbow in a patient with lateral epicondylitis clinically. (*A*) A large, hypoechoic area (*solid arrow*) is seen along the superficial aspect of the tendon, characteristic of tendinosis. Normal tendon is seen immediately deep to the lesion (*asterisk*). (*B*) The corresponding color Doppler examination of the same area shows marked hypervascularity, which is a common, albeit nonspecific, finding in tendinosis.

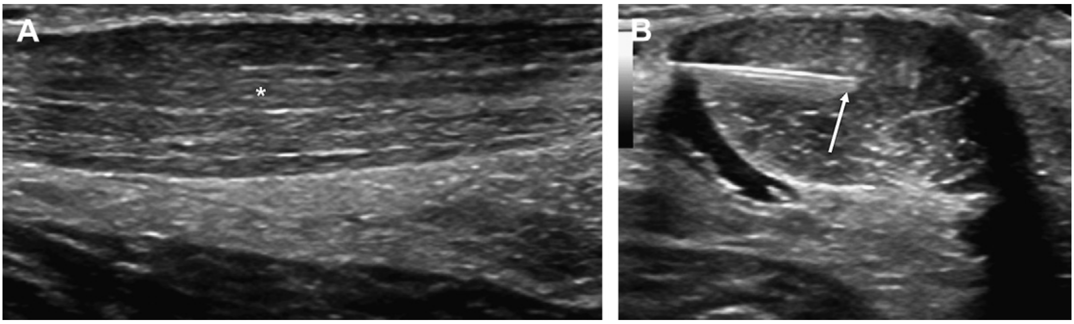

Fig. 16. Achilles tendinosis and prolotherapy. (*A*) On the initial longitudinal sonogram of the Achilles tendon, marked fusiform swelling of the tendon is present (*asterisk*) in its midportion. There are diffuse echopoor areas within the tendon, and the normal fibrillar echotexture is disrupted, particularly along its superficial aspect. (*B*) Short axis sonogram of the tendon at the maximal site of swelling shows needle placement (*solid arrow*) before injection of hyperosmolar dextrose. The patient's symptoms nearly completely resolved after five treatments.

Postprocedure instructions include avoidance of any heavy tendon loading for 2 weeks. Also, nonsteroidal anti-inflammatory medications should not be used for pain relief because they may inhibit the dextrose-stimulated inflammatory reaction. Patients are re-assessed at 6-week intervals, and repeat injections are performed until the patient is asymptomatic or no longer derives any benefit from the treatment. It is worthwhile noting that the tendons in some patients who report

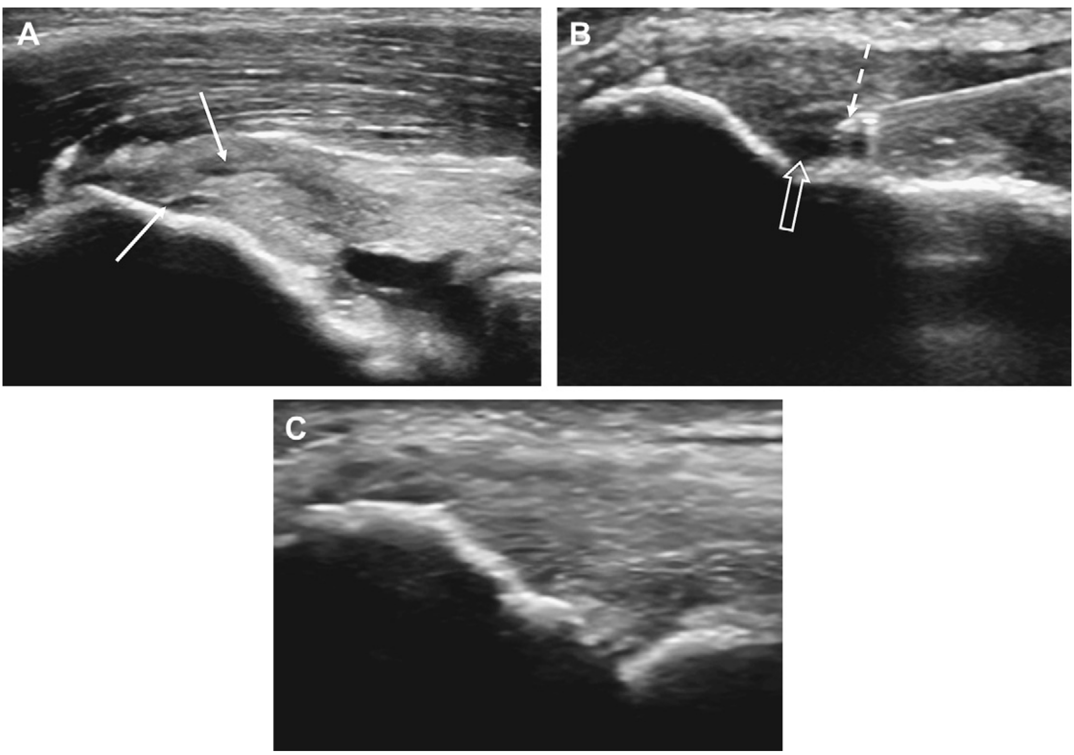

Fig. 17. Common extensor tendon prolotherapy. (*A*) On the preprocedure coronal sonogram of the common extensor tendon of the elbow, two prominent partial tears are present (*solid arrows*). (*B*) A needle is seen within the deeper of the two tears (*dashed arrow*), which has been distended with a small amount of injected dextrose solution (*open arrow*). (*C*) After 10 months (6 injections), the partial tears are no longer seen, and the patient's symptoms had improved subjectively by 90%. However, the tendon continues to be diffusely echopoor and slightly thickened. In the author's experience, even successfully treated tendons often continue to appear quite heterogeneous.

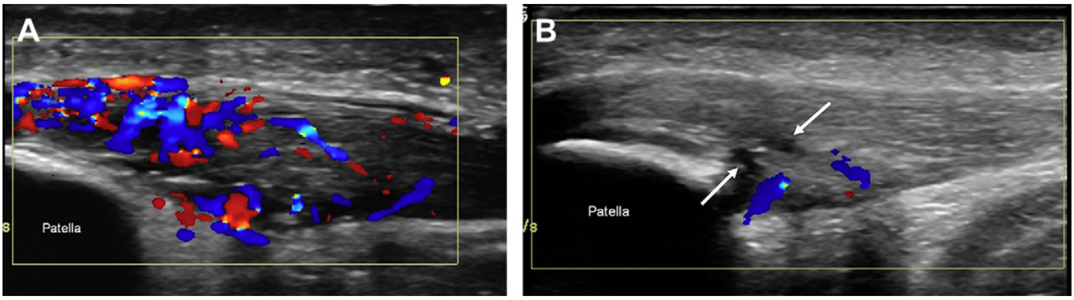

Fig. 18. Jumper's knee and prolotherapy. (*A*) Sagittal sonogram of the patellar tendon origin in a world-class water skier shows a marked amount of hypervascularity and tendon thickening. (*B*) Repeat sonogram after several prolotherapy injections shows significant reduction in the number of vessels present. However, small partial tears are evident along the deep surface of the tendon (*solid arrows*).

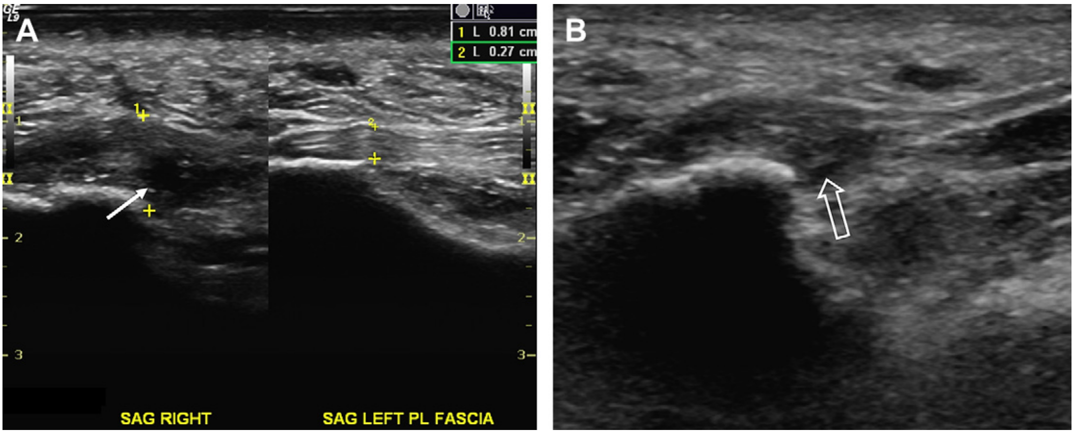

Fig. 19. Plantar fasciitis prolotherapy. (*A*) Sagittal sonogram of the right plantar fascia origin shows marked thickening and a large partial tear (*solid arrow*) when compared with the asymptomatic left side. (*B*) After several dextrose injections, the partial tear had decreased substantially in size (*open arrow*), and the patient's symptoms had completely resolved. Despite this, the tendon remains thickened and heterogeneous.

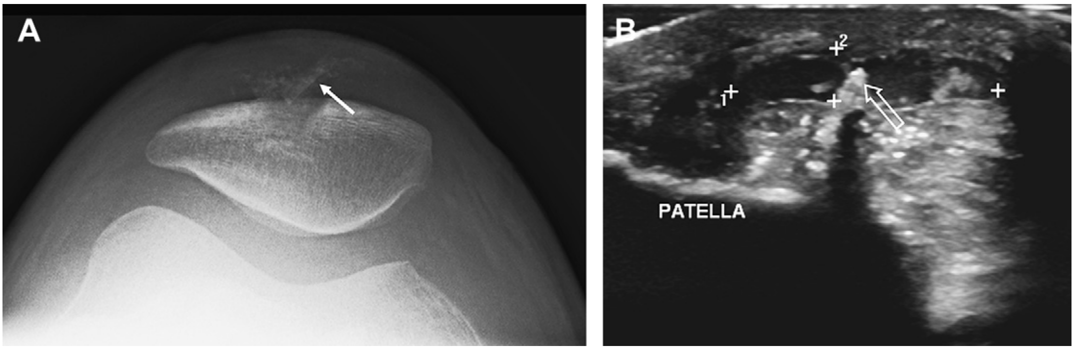

Fig. 20. Frictional bursitis at bone-tendon-bone graft harvest site. (*A*) Skyline view of the patella in a patient who previously underwent ACL repair. The patellar graft harvest site is surrounded by osseous fragments (*solid arrow*). (*B*) Sagittal sonogram of the patella shows a fluid collection (indicated by the calipers) centered over one such fragment (*open arrow*). Progressive swelling and pain with knee flexion and extension had developed over several weeks after surgery.

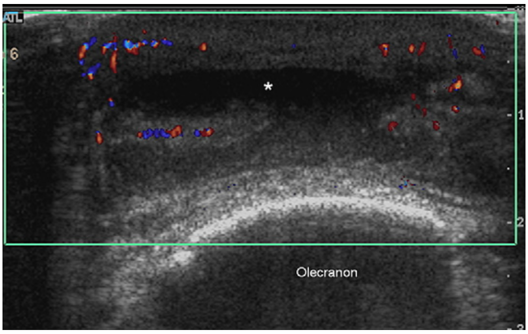

Fig. 21. Septic olecranon bursitis. Short axis sonogram of the olecranon bursa. The synovial-lined bursal walls are markedly thickened and hyperemic, and there is a small amount of anechoic fluid present centrally (*asterisk*). The appearances are nonspecific, and differentiation between septic and aseptic bursitides by ultrasound scan is unreliable.

complete cessation of symptoms continue to appear thickened and hypoechoic and show hypervascularity (**Fig. 19**). In our series of unpublished results, the majority of patients who derive some benefit from prolotherapy only do so after four or five injections. Prospective patients are made aware of this fact before beginning treatment to circumvent any unrealistic expectations.

INTERVENTION OF GANGLION CYSTS AND BURSAE

Ultrasonography is the ideal modality for image-guided aspiration and injection of most cysts and bursae in the musculoskeletal system. The ability of ultrasound imaging to target even very small collections while avoiding adjacent critical structures in real time is essential in treating these lesions successfully.

Treatment of Bursitis

Bursae are fluid-filled sacs that serve to decrease friction between adjacent structures and may or may not be lined with synovium.[102] Inflammation of a bursa may be caused by repetitive use, infection, systemic inflammatory conditions, and trauma. In treating bursitis, it is important to establish the likely cause. Corticosteroids, which are used commonly to treat bursitis resulting from overuse (**Fig. 20**), would be contraindicated in septic bursitis (**Fig. 21**). Caution should also be exercised when injecting corticosteroids into bursae that communicate with a joint to prevent potential steroid-mediated cartilage damage. Therefore, when treating subacromial-subdeltoid bursitis, rotator cuff tearing should be excluded before injection.

In the case of bursae that are distended with a large amount of fluid, immediate and dramatic improvement in symptoms can be achieved by thorough aspiration (**Fig. 22**). However, if performing a corticosteroid injection into a very small collection, incomplete aspiration of the bursa is sometimes advantageous and will help ensure that the potential space is not collapsed entirely before the medication can be injected intrabursally (**Fig. 23**).

Treatment of Ganglion Cysts

Ganglion cysts are the most common cause of a soft tissue mass in the distal upper extremity.[103] The etiology of ganglia is controversial. One widely held view is that cyst formation occurs as a result of trauma or tissue irritation, whereby mucin is produced by modified synovial cells lining the synovial–capsular interface.[104] The mucin eventually pools behind valvelike structures formed by capsular ducts, resulting in ganglion formation.

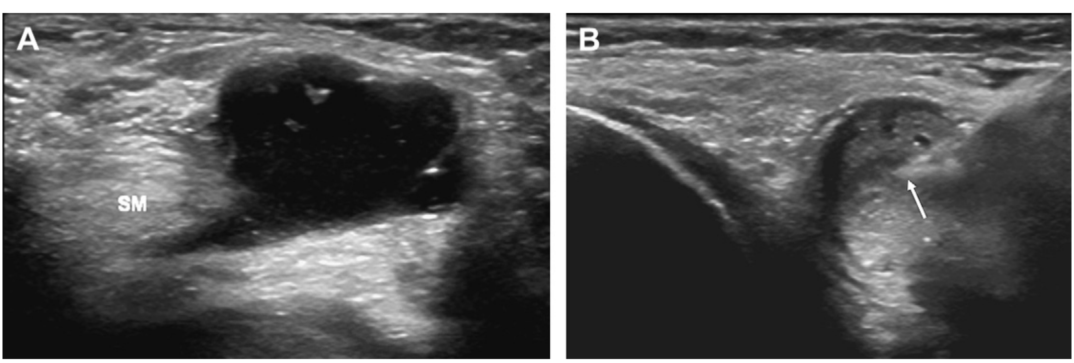

Fig. 22. Semimembranosus bursitis. (*A*) Transverse sonogram of the posteromedial knee. An irregular fluid collection is seen along the medial aspect of the semimembranosus tendon (SM), typical of semimembranosus bursitis. (*B*) A needle (*solid arrow*) has been introduced into the bursa, which has been nearly completely aspirated. The patient experienced immediate relief in his symptoms.

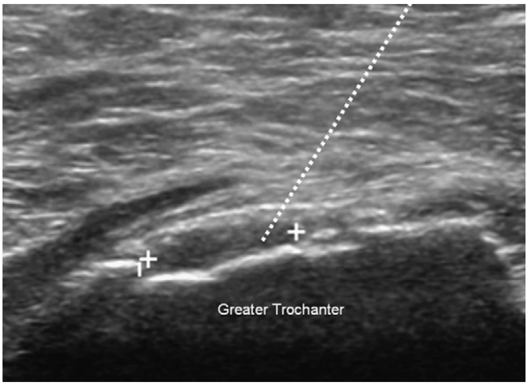

Fig. 23. Greater trochanteric bursitis. Sagittal sonogram of the hip shows a small amount of fluid (indicated by the calipers) adjacent to the greater trochanter. With the patient in a lateral decubitus position, a fine needle can be placed easily into the collection (*dotted line*).

Many lesions are asymptomatic and require no treatment. In fact, 40% to 60% of ganglia have been reported to resolve spontaneously.[105,106] However, in other cases, symptoms related to mass effect may mandate intervention (**Fig. 24**). Patients may complain of restricted range of motion, aching, paresthesias, or weakness. Furthermore, cysts that drain externally are at risk of a deep soft tissue or joint infection.

Although surgery has been stated to have success rates of 99%,[107] complications such as joint instability, postoperative stiffness, decreased range of motion, and neurovascular injury make minimally invasive techniques a viable alternative in symptomatic patients. Success rates for blind, percutaneous aspiration vary tremendously from 33%[108] to 85%.[109] In one of the largest published series of wrist ganglia undergoing nonoperative management, 85 patients were randomly assigned to two groups: aspiration alone or aspiration followed by injection of 40 mg of methylprednisolone.[108] The investigators found no difference in the success rate between these two groups. Interestingly, 96% of those ganglia that did not subsequently recur were treated successfully after only one attempt. Of those lesions requiring a second or third aspiration, only 4% eventually resolved. In this series, multiple aspirations were of little benefit. The major limitation of this study was that all punctures were performed without image guidance.

Breidahl and Adler[110] were the first to describe the use of ultrasound guidance in treatment of ganglia. In their small study population, nine of ten patients derived significant or complete relief after aspiration with a 20-G needle and injection of 40 to 80 mg of triamcinolone. However, the use of corticosteroids in treating ganglia remains controversial.

Ganglia appear as cystic masses by ultrasonography and typically are oval or lobulated in shape (**Fig. 25**).[103,111,112] Internally, a ganglion may be anechoic or contain low-amplitude echoes and septae. An 18-G needle is recommended for

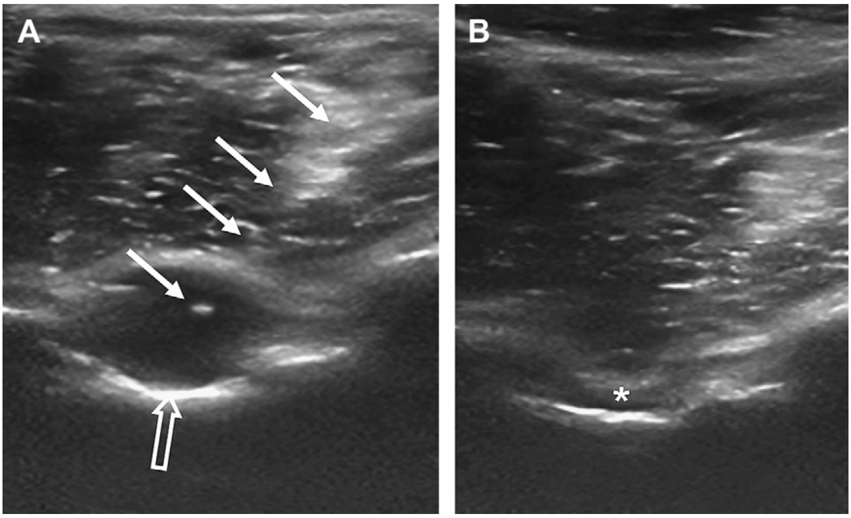

Fig. 24. Spinoglenoid notch ganglion cyst aspiration. (*A*) Transverse sonogram of the spinoglenoid notch (*open arrow*) depicts a small ganglion cyst, presumably impinging upon the suprascapular nerve. An 18-G needle was advanced into the cyst but is only partially visualized along its course (*solid arrows*). (*B*) Transverse sonogram of the spinoglenoid notch after aspirating 2 mL of gelatinous material. The cyst cavity has completely collapsed (*asterisk*). The chronic, dull aching in the posterior shoulder experienced by the patient for months had improved dramatically by the end of the examination.

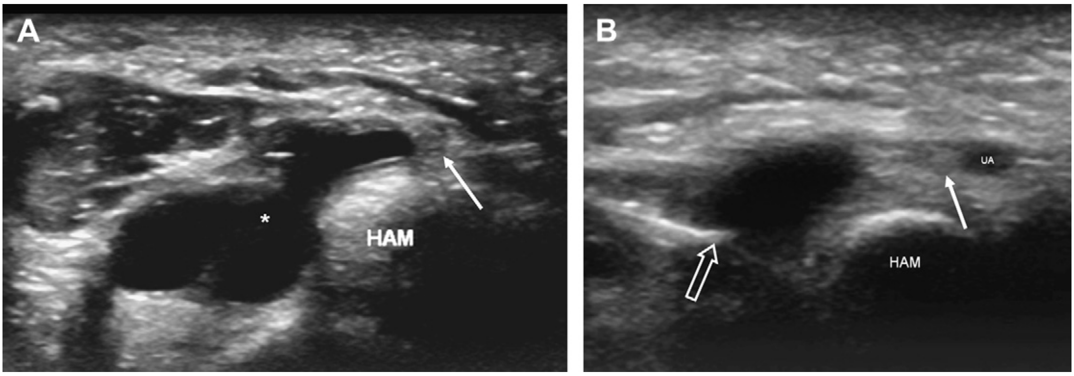

Fig. 25. Aspiration of ganglion cyst causing ulnar nerve palsy. Transverse sonograms of the palmar ulnar wrist. (*A*) A lobulated ganglion cyst (*asterisk*) is seen extending superficial to the hamate (HAM) to abut the ulnar nerve (*solid arrow*). (*B*) A needle (*open arrow*) has partially decompressed the ganglion, which has receded from the ulnar nerve (*solid arrow*) and ulnar artery (UA). The patient's symptoms resolved slowly over the course of several weeks after aspiration.

aspiration of all suspected ganglion cysts because cyst contents are invariably thick and gelatinous.

SUMMARY

Ultrasound-guided intervention is probably underutilized currently in North America. However, the dynamic, multiplanar capability of ultrasonography makes it an attractive alternative to procedures that might otherwise be performed under fluoroscopic or computed tomography guidance. Indeed, the majority of joints, cysts, and bursae can be accessed routinely under sonographic control. In the cases of barbotage and prolotherapy, ultrasonography has given fresh breath to old concepts and has afforded radiologists new options to treat difficult and chronic tendon problems. It is hoped that this review has served as a springboard for the reader to further investigate the important and diverse role ultrasound imaging is able to play in musculoskeletal intervention.

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