

Ultrasound-assisted musculoskeletal procedures: A practical overview of current literature

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ultrasound-based musculoskeletal procedures. In-depth discussion of each ultrasound procedure including pertinent technical details, indications and contraindications is provided. Despite the limited amount of prospective, randomized data in this area, a substantial body of observational and retrospective evidence suggests potential benefits from the use of musculoskeletal bedside sonography.

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Abstract

Traditionally performed by a small group of highly trained specialists, bedside sonographic procedures involving the musculoskeletal system are often delayed despite the critical need for timely diagnosis and treatment. Due to this limitation, a need evolved for more portability and accessibility to allow performance of emergent musculoskeletal procedures by adequately trained non-radiology personnel. The emergence of ultrasound-assisted bedside techniques and increased availability of portable sonography provided such an opportunity in select clinical scenarios. This review summarizes the current literature describing common

INTRODUCTION

Beside procedures involving the musculoskeletal system have traditionally been performed by highly trained specialists. Due to reliance on a select group of practitioners, many procedures may be delayed despite their often urgent nature. As a result, a need arose for more portable and accessible means to allow performance of emergent musculoskeletal procedures by adequately trained emergency surgical and non-surgical personnel. The emergence of ultrasound-assisted bedside techniques and increased availability of portable sonography provided such an opportunity in select clinical scenarios.

The purpose of this review is to summarize the current literature for the most common ultrasound-based musculoskeletal procedures. A thorough discussion of each ultrasound procedure including pertinent technical details and procedural indications/contraindications is included. Although there is a limited number of prospective, randomized studies in this clinical area, there is a significant amount of observational and retrospective evidence that demonstrates potential benefits that stem from ultrasound use in musculoskeletal bedside sonographic applications.

This review will be presented as a series of focused, clinical procedure-oriented sections, each of which is further sub-divided into procedural rationale (including indications and contraindications) and technical overview. Due to the limited scope of this review, the reader is referred to primary literature sources throughout the manuscript for further information pertaining to each topic/procedure.

ARTHROCENTESIS

Rationale

Arthrocentesis involves the aspiration of a synovial joint space, for both therapeutic and diagnostic indications^[1]. It is a commonly performed procedure, with an estimated 50%-62% of general medicine physicians utilizing information from arthrocentesis to guide patient management^[2]. Given the relative simplicity of the procedure and the overall prevalence of joint problems, a general level of comfort with arthrocentesis should be attainable among a variety of medical and surgical specialists. Major clinical indications include: (1) undiagnosed effusion; (2) undiagnosed arthritis; (3) septic arthritis; and (4) symptomatic relief of effusion. Contraindications to arthrocentesis include: (1) active infection overlying the puncture site; (2) tumor/mass overlying the site; and (3) rash overlying the sampling site (relative contraindication).

Adequate anatomic characterization of the intended joint space must be performed prior to arthrocentesis. Physical examination and knowledge of anatomy are crucial to a safe and effective performance of arthrocentesis. With the advent of modern imaging modalities, the practitioner now has multiple methods of anatomic characterization and pre-procedural planning (magnetic resonance imaging, computed tomography, and ultrasound). It is important to note that the physical exam, when compared to ultrasound of the knee, had only a 59% sensitivity and 65% specificity for detection of knee effusions^[3]. This may be due to the finding that the minimal volume of fluid needed for detection on knee ultrasound is approximately 7-10 mL^[4]. Having said that, when compared to other imaging modalities, joint ultrasonography is of uncertain value for purely diagnostic purposes. Thus, the most practical use would be for guidance in diagnostic and therapeutic arthrocentesis^[5].

Current evidence suggests that ultrasound-guided arthrocentesis may be less technically difficult for emer-



Figure 1 Ultrasound-guided arthrocentesis allows confirmation of the needle within the articular space and real-time visualization of fluid withdrawal. Flow can be noted within the articular space by using color or doppler flow while compressing the joint space. This technique prevents inaccurately inserting the needle within solid masses. Note the needle is best visualized when the probe is perpendicular to the needle. Long arrow indicates tibia cortical bone. Short arrow indicates needle tip. Star indicates joint space.

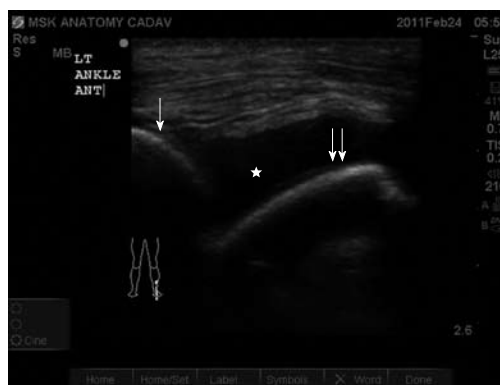


Figure 2 Ultrasound-guided arthrocentesis should be performed by first assessing the joint space for an effusion followed by direct observation of the needle entering the effusion. Use of ultrasound-guided arthrocentesis is highly accurate compared to blind or landmark-techniques for smaller joint spaces such as the tibiotalar joint demonstrated in the image above. Landmarks within the ultrasound image include the bone appearing as a hyperechoic region with superficial tissues including tendons and muscle appearing as heterogenous echoic regions. Fluid within the joint space appears as hypoechoic shapes that conform to the space. Single white arrow indicates the tibia; double white arrow indicates the talus. Star indicates the tibiotalar effusion.

gency physicians, less time consuming, and produce less pain than the traditional “blind” arthrocentesis^[6]. Specifically, cadaver-derived evidence shows that ultrasound-guided arthrocentesis has a higher success rate compared to traditional blind arthrocentesis, particularly in the smaller joints (metatarsophalangeal, metacarpophalangeal, and proximal interphalangeal joints)^[7,8]. This highlights potential advantages of ultrasound-guided arthrocentesis over traditional methods, especially given the ability of sonography to provide direct visualization of pertinent anatomic structures and confirm accurate entrance of the needle into the joint space (Figures 1 and 2).

Technique overview

The ultrasound-guided arthrocentesis is performed under

standard precautions with appropriate draping of the joint and sterile procedure site preparation. Mandatory procedure site and laterality verification is performed. The ultrasound probe of choice will be determined by the joint of interest. In general, an appropriate probe choice is the linear probe (5-10 MHz) which provides good visualization of most superficial joints^[7,8]. If the joint of interest is deep and the linear probe is unable to provide adequate visualization of the space, a curvilinear probe may be necessary. The ultrasound probe is placed in a sterile cover with ultrasound gel within the probe cover or sterile ultrasound gel placed over the joint space in order to obtain adequate quality images. To help determine the intended joint space, the following recommended sonographic criteria may be helpful: (1) anechoic or hypoechoic space; (2) no evidence of flow under color doppler or power doppler; (3) compressible space under direct probe pressure; (4) hyperechoic region deep to the space of interest indicating the cartilage; and (5) hyperechoic region relative to hyaline cartilage, indicating bone^[7]. After verifying the site of interest, the ultrasound probe should be placed such that the aspirating needle will be directly visualized as it enters the intended fluid space. The needle is inserted into the space under direct observation and the fluid is aspirated with or without direct visualization.

TENDON AND ARTICULAR INJECTIONS

Rationale

Muscle and tendon injections are utilized for various musculoskeletal complaints. One common indication for tendon injections is tendinopathy. Tendinopathies affect over 500 000 people in the United States alone^[9]. Efficacy and safety of injections for management of tendinopathies vary based on the affected site^[10], with the most promising results in the treatment of first annular pulley tendinitis^[11]. Conversely, injections at other sites including the Achilles tendon are controversial as some studies have shown potential adverse effects on biomechanical properties and incidences of tendon rupture^[12,13]. Injections of articular surfaces of joints have been used as a therapy for arthritides and other inflammatory joint conditions. A brief summary of the clinical indications and contraindications are listed below in Table 1. The role of medication injections in the symptomatic and therapeutic treatment of musculoskeletal disease is beyond the scope of this review^[14,15].

Injection of tendons and articular surfaces requires a thorough knowledge of the anatomy as well as a detailed physical examination to determine the optimal injection site and placement of the injection agent. Given the great number of anatomic structures surrounding tendons and articular surfaces, as well as the lack of true physical feedback during needle placement, ensuring safe and appropriate placement may be extremely difficult. The use of advanced imaging techniques such as magnetic resonance imaging (MRI), computed tomography (CT),

Table 1 Ultrasound-guided tendon and articular injections: indications and contraindications

Indications	Contraindications
Tendinopathy	Rash over injection site
Achilles tendinitis	
Trigger finger	
Carpal tunnel syndrome	
Lateral epicondylitis	
Rotator cuff tendinopathy	
Dequervain tenosynovitis	
Bursitis	Infection over injection site or obstructing injection path
Trochanteric bursitis	
Olecranon bursitis	Tumor over injection site or obstructing injection path

Table 2 Ultrasound-guided tissue biopsy: indications and contraindications

Indications	Contraindications
Solitary bone lesion with indeterminate imaging characteristics	Infection on overlying site
New bone lesion in patient with known primary tumor	Rash on overlying site (relative)
Determine tumor recurrence	Uncorrected bleeding diathesis (relative)
Evaluate etiology of vertebral body compression fracture	Decreased platelet count (relative)
Determine infectious organism in chronic wound	Inaccessible site (relative)
Determine infectious organism in osteomyelitis	

and ultrasound has allowed more precise visualization of these structures. Due to inherent limitations of real-time MRI and CT scanning for symptomatic injections of the musculoskeletal system, this approach seems to be less useful than sonography.

The use of ultrasound as a real-time imaging modality to directly visualize the needle placement into the tendon or articular surface is practical and safe. Evidence has demonstrated that ultrasound-guided tendon injection reduces pain both during and after the injection, decreases overall patient discomfort, and improves joint or muscle mobility more than traditional blind injections^[16-19]. Furthermore, ultrasound-guided intra-articular injections enable the practitioner to localize fluid collections and perform simultaneous arthrocentesis^[17] (Table 2).

TECHNIQUE OVERVIEW

Ultrasound-guided tendon or articular injection is performed under standard sterile precautions and appropriate preparation/draping of the site. The ultrasound probe of choice will be determined by the intended tendon or articular surface. In general, a good initial probe choice is the linear probe (10-15 MHz) which provides adequate visualization of most superficial structures/spaces. High-



Figure 3 Percutaneous tenotomy or dry-needling can be performed under ultrasound-guidance to provide ideal visualization of the needle. Use of the short-axis plane should be to localize neighboring structures and visualize complete disruption of the tendon fibers. Use of the long-axis plane should be to confirm complete disruption of the tendon from anterior to posterior. However, the actual procedure should be performed within the short-axis plane as maintaining the needle in long-axis is difficult and unreliable to prevent neighboring structure damage. Confirmation of the structure as tendon fibers should rely on noting anisotropy which is characteristic of tendons. Short arrow indicates needle tip. Long arrows indicate Achilles tendon sheath. Stars indicate Achilles tendon fibers in long-axis plane.



Figure 4 Ultrasound-guided injection of the left flexor tendon in transverse plane. Tendon injection under ultrasound (US)-guidance allows improved accuracy in tendon injection. Furthermore, US-guidance allows visualization of the fluid forming a complete peri-tendon fluid collection as noted by the hypoechoic space surrounding the heterogenous tendon appearance. Short arrow indicates the needle in transverse. Long arrow indicates flexor tendon in transverse section.

frequency transducers provide the best resolution for near-field tendons, although a curvilinear probe may be needed to visualize deep joint articular surfaces. The ultrasound probe is placed within a sterile cover with ultrasound gel within the cover or sterile ultrasound gel placed directly over the intended site. After procedure site and laterality are confirmed, the site is scanned in order to inspect regional anatomy and identify any nearby neurovascular structures. In the case of tendon injections, the muscle and tendon should be scanned throughout their course to determine the safest and most optimal injection site. For articular injections, the joint space should be scanned in all dimensions to determine the safest/optimal injection site. Whenever possible, the probe is placed so that the tendon is seen in longitudinal section, as a higher success rate for tendon injections has been noted in this view. Otherwise, a transverse section can be utilized^[18]. The needle is inserted such that it is seen at all times and can be directly visualized entering the tendon or articular space. The authors recommend injection of the agent under direct visualization to prevent inadvertent application into the peri-tendinous or peri-articular structures. Representative ultrasound images can be seen in Figures 3 and 4.

TISSUE BIOPSY

Rationale

In certain clinical situations, a diagnostic biopsy may be necessary before pursuing a more definitive treatment course. The ability to rapidly diagnose and initiate treatment may help improve outcomes. The advent of ultrasound-guided biopsies of the musculoskeletal system allows an appropriately trained clinician to readily obtain

Table 3 Ultrasound-guided drainage and catheter insertion: indications and contraindications

Indications	Contraindications
Undiagnosed soft tissue collection	Infection on overlying site
Cyst	
Abscess	
Hematoma	
Diagnosis of Abscess	Rash on overlying site (relative)
Obtain fluid for determination of causative organism	
Treatment of known abscess	Tumor on overlying site (relative)
Aspiration	
Placement of drainage catheter (if feasible)	
Aspiration of Cyst	
Ganglion cyst	
Synovial cyst	
Determination of causative organism for osteomyelitis	

important diagnostic information in situations where a rapidly progressive disease process is being considered. Furthermore, in situations where trained interventional radiologists are either unavailable or unable to perform timely biopsies, the ability of a general clinician to perform bedside biopsies may be invaluable in conserving medical resources. In the musculoskeletal system the differential diagnosis can include a large number of pathologies (i.e. primary bone tumors, bony tumor metastases, infections, and chronic inflammatory changes). A brief listing of clinical indications and contraindications is listed below in Table 3. More comprehensive discussion of this topic is beyond the scope of this review^[20]. It should be noted that a suspected primary tumor of bone or soft tissue in the musculoskeletal system should only be biopsied by a physician trained in orthopaedic oncology. Also, biopsy performed by general clinicians or at the referring facility (rather than definitive treatment center) may in-

crease both diagnostic errors and complication rates (i.e. need for wider tumor resection at time of surgery, skin complications requiring flap coverage, increased risk of amputation)^[21].

Biopsy of the musculoskeletal system includes a broad grouping of procedures that may be divided into open and percutaneous procedures. While certain clinical scenarios preclude percutaneous biopsy and require an open procedure, percutaneous biopsy should be attempted, if possible and safe, to decrease patient discomfort and diagnostic costs^[22]. Percutaneous biopsies can be further grouped by the type of imaging guidance used to aid the clinician performing the biopsy. Traditional percutaneous biopsy consists of utilizing physical exam findings and knowledge of anatomy to place the needle within the lesion of interest, a method utilized infrequently when the depth of the lesion is beyond a few centimeters of tissue. The availability of CT-guided and fluoroscopically-guided biopsies allows the clinician to perform highly accurate needle placement into lesions that are located near critical/sensitive (i.e. neurovascular) structures or in deeper locations^[20]. Advances in ultrasound technology and clinical implementation have made ultrasound-guided musculoskeletal biopsies both feasible and accurate^[23-28]. Ultrasound-guided needle and core biopsy sensitivities in obtaining the tissue of interest range from 80%-98.4%^[23-28]. Core-needle biopsy has been demonstrated to have a higher sensitivity in obtaining diagnosis with estimated sensitivity of 81%-95% compared to 76%-80% for fine-needle aspiration^[25-27,29]. Additionally, a method of creating a portal to enable forceps to perform a comprehensive biopsy of synovium has been described^[30]. While there may be a perception that ultrasound is less facilitating when performing a diagnostic biopsy of bone lesions, evidence shows sampling accuracy for such lesions of 92%-98% for ultrasound compared to 87% for CT-guided biopsies of similar lesions^[23,25]. Conventional biopsy performed under ultrasound-guidance relies on the echogenicity of the needle to localize it during the procedure - not always an easy task. Recent improvements may further aid the clinician in visualizing the needle. For example, biopsy needles are available that have been coated with echogenic surface markers (Teflon, etched tips, and an echogenic polymer) or feature a vibration system^[29,31]. While there is limited data supporting the use of these types of needles, the use of polymer coated needles may be the most beneficial for technically difficult biopsies^[31]. While further discussion on fine-needle aspiration *vs* core-needle biopsy in musculoskeletal lesions is beyond the scope of this review, it is important to note that the suspected etiology may dictate the type of percutaneous biopsy required Table 2.

Methods

Ultrasound-guided biopsy is performed under standard sterile conditions (i.e. appropriate procedural preparation and draping) over the intended biopsy site. Site and laterality verification is essential. The choice of the ultrasound

probe, as described in previous sections, should be guided by the anatomic location of the tissue to be sampled. The linear probe (10-15 MHz) provides appropriate visualization of most superficial sites including joints, superficial muscles, and superficial bones. For sites located deeper, a curvilinear probe (5-10 MHz) may be required. The ultrasound gel is then utilized as needed throughout the course of the procedure.

The first step in performing an adequate tissue biopsy is to confirm the site of the lesion, bone or soft tissue. If the lesion is located within the bone then a larger (i.e. 14-gauge) cutting needle should be used to allow for bone fragments to be contained within the needle sample. If the lesion is located within the soft tissues then a smaller (18 or 20 gauge) needle is usually sufficient^[22-28,31,32]. Local analgesia should be used generously for all biopsy procedures and should be performed along the entire anticipated biopsy tract (including periosteum and adjacent muscles) prior to initiation of the procedure. Sedation is not universally required, but may be needed for more extensive procedures and may help facilitate more accurate sampling and improve patient comfort. When utilized, sedation requires additional monitoring (i.e. frequent vital sign and pulse oxymetry assessments) and personnel (i.e. sedation nurse and/or anesthesiologist). When possible, the performance of biopsy under local anesthetic is preferred, with sedation used if the patient is unable to tolerate the pain and/or anxiety associated with the procedure.

Prior to the incision for the biopsy, a sonographic scan of the intended biopsy site should be performed to visualize all critical anatomic structures in the area. The optimal biopsy path should be determined based on avoidance of nearby vessels/nerves, and avoidance of muscles if possible. Again, when primary musculoskeletal malignancy is suspected, it is imperative that the biopsy tract be determined by an orthopaedic oncologist, as biopsy obtained *via* an improperly planned tract may be a factor in subsequent inability to perform limb salvage surgery^[21]. Identification of vascular structures in the area of biopsy using color or power Doppler is encouraged^[31]. Detailed recording of the lesion echogenicity, margins, mass size, relation to bone (cortical invasion), and vascularity is an essential part of pre-biopsy evaluation of the intended sampling site because procedural bleeding or even the very presence of a biopsy tract can distort critical sonographic characteristics of the lesion in question^[25]. A small stab incision is then made in pre-marked skin and the biopsy needle is inserted into the lesion under direct sonographic visualization. Longitudinal orientation of the needle in relation to the ultrasound probe is preferred. Once the needle is confirmed to be within the lesion of interest, the biopsy is performed and the needle is removed with or without ultrasound visualization. A post-biopsy ultrasound scan of the region should be performed to confirm hemostasis of the sampled area. The biopsy specimen should then be handled according to established pathology guidelines regarding tissue/sample processing.

FLUID COLLECTION ASPIRATION AND DRAINAGE CATHETER INSERTION

Rationale

Tissue fluid collections are common in all areas of medicine. Therefore, practitioners in a variety of medical fields need to be aware of the relevant diagnostic and therapeutic considerations concerning tissue fluid collections. Within the realm of the musculoskeletal system, some specific subtypes of cysts and abscesses have been studied particularly closely. In general, the diagnosis of a fluid collection can be readily made using ultrasound, CT, or MRI. In many situations, the optimal therapy is either to aspirate the contents of the fluid collection or to place a drainage catheter for continuous drainage, depending on the precise character and/or size of the collection in question. A list of indications and contraindications for percutaneous aspiration or drainage catheter placement in the setting of tissue fluid collections is listed in Table 3. More comprehensive review of this topic is beyond the scope of this manuscript.

Ultrasound has been well described as a tool for diagnosis of tissue fluid collections as well as characterization of soft tissue infections^[33-35]. A brief listing of types of soft tissue infections where ultrasound can be used for diagnosis can be seen in Table 4^[33-35]. Additionally, ultrasound can be used to aid in the diagnosis of osteomyelitis, particularly in pediatric cases^[36]. There is also evidence to support the use of ultrasound in the diagnosis and characterization of soft tissue cysts in the musculoskeletal system^[37-39]. For example, the reported sensitivity and specificity for ultrasound in the diagnosis of meniscal cysts is 97% and 86%, respectively^[37]. However, evidence on the use of ultrasound as a therapeutic aid in aspiration or drainage catheter insertion is still limited. Currently, the most common method to perform fluid collection characterization is by imaging, with aspiration of fluid for analysis in clinically uncertain scenarios.

The use of ultrasound as an image-guidance method in the setting of tissue fluid collections is a relatively new concept. Among musculoskeletal applications, there may be distinct advantages of ultrasound as an image-guidance tool. Firstly, ultrasound-guided aspiration has been identified as an effective method for treating both ganglionic and synovial cysts^[40-43]. Given the evidence to support ultrasound as a diagnostic tool and the ease, cost, and lack of ionizing radiation exposure, the use of ultrasound-guidance in aspiration of these fluid collections should be considered as first-line therapy. Although a discussion of the optimal therapy for various ganglion and synovial cysts is beyond the scope of this review, there is some evidence to support the use of guided aspiration prior to or in lieu of surgical therapy^[44]. For infectious indications, the use of ultrasound for both diagnostic and therapeutic purposes is also well described^[45-52]. Ultrasound-guided aspiration or drainage catheter insertion has been successfully used to obtain fluid samples for microbial cultures as well as therapeutic drainage of

Table 4 Soft tissue infections identifiable on sonography

Cellulitis
Necrotizing fasciitis
Infective bursitis
Infective tenosynovitis
Pyomyositis
Abscess
Hydatid or Tuberculous cysts
Septic arthritis
Post-operative infection
Foreign body

collections^[46-51]. There is also evidence supporting the use of ultrasound-guided techniques in the critically ill where transporting patients between different hospital locations may be either dangerous or not at all feasible^[50]. In the case of multiple abscesses requiring drainage, the use of ultrasound guidance is further supported due to the ability to manipulate the probe rather than the patient, as well as the avoidance of excessive/additional exposure to ionizing radiation seen with CT-guidance^[48]. Another potential application of ultrasound is the performance of tissue aspiration for cultures in the diagnosis of suspected osteomyelitis. While data are still limited, the current literature suggests that ultrasound guidance can be particularly helpful when obtaining tissue samples in suspected pediatric osteomyelitis^[45].

Technique

Ultrasound-guided aspiration or drainage catheter insertion is performed under standard sterile conditions. Procedure site/laterality confirmation is essential. The ultrasound probe of choice is determined by the characteristics of the tissue in question. The linear probe (10-15 MHz) provides appropriate visualization of most soft tissue sites. For deeper lesions, a curvilinear probe (5-10 MHz) may be preferred/necessary. After placing the probe in a sterile cover and applying ultrasound gel, a brief scan through the site of interest should be performed prior to any definitive procedural intervention(s). Critical structures such as vessels and nerves should be identified. The fluid collection in question should be clearly identified and described with regards to the type (i.e. cyst), size, and overall characteristics (i.e. simple *vs* complex).

The ultrasound probe is then placed over the region of interest, with visualization of the needle passage in longitudinal section being preferred. The needle (typically 20- or 22-gauge) is inserted under direct sonographic visualization. Once the needle is within the fluid collection, an aspirate is obtained for analysis. If there is evidence of purulence or other signs of infection, then the placement of a drainage catheter should be considered. This involves the use of a larger needle with a guide-wire being inserted through the needle into the fluid space^[50]. After removing the needle with the guide-wire left in place, a dilator is placed over the guide-wire and the insertion site

Table 5 Percutaneous ultrasound-guided tenotomy: indications and contraindications

Indications	Contraindications
Chronic tendinosis refractory to conservative therapy	Infection on overlying site
Common extensor tendinosis	
Achilles tendinopathy	
Patellar tendinopathy	
Iliotibial tendinopathy	
Trigger finger	
Symptomatic tendon release	Tumor on overlying site
Developmental dysplasia of the hip	
Spastic cerebral palsy	
Deformities of the foot	Rash on overlying site (relative)

is expanded to accommodate an appropriately-sized catheter^[50]. The catheter is then inserted over the guide-wire and placement of the catheter within the fluid collection confirmed by direct visualization. After removing the guide-wire, the catheter is sutured in place and connected to an appropriate drainage system.

PERCUTANEOUS TENOTOMY

Rationale

Tenotomy is the complete or incomplete surgical division of a tendon for therapeutic purposes. The procedure has been described for a myriad of purposes with some of the original descriptions relating to the treatment of foot deformities^[53]. The procedure can be performed using either an open or percutaneous method. The open version of the procedure was the first described and allows direct visualization of all para-tendon structures and the pathologic region of the tendon to confirm the diagnosis^[53]. However, with the advent of percutaneous techniques, shorter procedural times and improved aesthetic outcomes became possible. Furthermore, there is evidence to suggest that percutaneous tenotomy is as safe and effective as the open procedure. It is notable that the extent of the tendinous portion divided in the muscle of interest appears directly correlated with increased postoperative mobility^[54,55]. In animal studies, ultrasound-guided percutaneous tenotomy has been shown to increase complete tendon transection and decrease damage to surrounding structures compared to palpation-guided tenotomy (63). A brief listing of clinical indications and contraindications for percutaneous tenotomy are listed in Table 5. A comprehensive discussion of this topic is beyond the scope of this review^[53-63].

Percutaneous tenotomy is ideally performed at the bedside or in an outpatient setting. The percutaneous approach was first described in the setting of tenotomy of the common extensor tendon for “tennis elbow” with symptomatic improvement equivalent to other surgical procedures^[64,65]. The procedure has since been implemented for a variety of tendinopathies. While the initial descriptions of percutaneous tenotomy involved blind

palpation and determination of the site using anatomic landmarks alone, recent advances in imaging modalities have significantly enhanced the anatomic accuracy of tenotomy procedures. Although CT- and MRI-guided tenotomy is possible, the literature focuses heavily on ultrasound-guidance for percutaneous procedures. Although MRI and other advanced imaging modalities offer an accurate method of diagnosing tendinopathy and/or other tendon abnormalities, the reported sensitivity of ultrasound in tendinopathies of 67%-100% is sufficient to recommend it as a screening exam based, given cost and time requirements compared to the other imaging modalities^[66,67]. There is also evidence from animal models that, compared to surface anatomy/palpation-based techniques, ultrasound-guided tenotomy may be more accurate, faster, and associated with less morbidity^[68].

Technique

Ultrasound-guided percutaneous tenotomy is performed under full sterile precautions and standard draping over the site of interest. Procedural site/laterality confirmation is essential. The ultrasound probe of choice will be determined by anatomic considerations. Most practitioners choose a high frequency (10-15 MHz) linear probe when approaching most superficial structures. If the tendon of interest is located deeper or cannot be visualized anterior to bone or cartilage, then a lower frequency (5-10 MHz) curvilinear probe may be more appropriate. Using a sterile ultrasound cover and gel, a brief scan of the site of interest should be performed prior to any invasive intervention(s). In addition to identifying any important neuro-vascular structures, the preliminary scan may help better characterize the region of interest for the tenotomy. Typical findings of tendinopathy on ultrasound include hypoechoic or anechoic regions within a tendon. Calcifications may appear as hyperechoic regions with clean shadows deep to the region, and tenderness to transducer pressure over the affected area may be present^[66,67]. Most ultrasound machines can also facilitate color or power Doppler imaging to evaluate for vascularity of the region and help guide the procedure to minimize the potential for bleeding.

Although there are different ways to perform a tenotomy, we will focus on techniques that use ultrasound-guidance. Specifically, we will discuss partial tenotomy using a needle (needling) and complete tenotomy using a scalpel^[56-61]. The anatomic region of interest is first injected with local anesthetic. There is currently no evidence to support the routine use of general anesthesia for this procedure^[56-61]. Subsequent to achieving adequate analgesia, the ultrasound probe is positioned parallel to the tendon of interest in order to help guide the procedure, preferably in the longitudinal view.

Needle-based percutaneous tenotomy is performed by using a narrow (20- or 22-gauge) needle, which is inserted under direct ultrasound guidance and penetrates the abnormal tendon region while avoiding neighboring structures. Any calcifications are disrupted during needle



Figure 5 Tendon injection can be performed in either transverse or longitudinal planes. Insertion of the needle in long-axis allows excellent visualization of the tendon sheath and tendon fibers. Prior to injection the needle tip should be well-visualized between the tendon sheath and the tendon fibers. An important method to ensure needle visualization is to angle the probe to make the angle of ultrasound wave as close to perpendicular as possible. Additionally, confirmation of a structure as a tendon involves angling the probe along the tendon to note tendon anisotropy characteristic of a tendon and not noted in nerves or vessels. Short arrow indicates needle tip in long-axis section. Long arrows indicate tendon sheath. Star indicates tendon fibers in long-axis section.

passes through the region. This is repeated under direct ultrasound visualization until the entire tendon has been disrupted by the needle.

Section tenotomy using scalpel is performed using a number 11 blade scalpel. The scalpel is inserted parallel to the tendon fibers under direct ultrasound visualization and penetrates the fibers^[57,58]. The cutting edge of the blade is initially pointed proximally on the tendon^[57,58]. The joint is then passively flexed and extended under visualization. The scalpel is then withdrawn and rotated so that the cutting edge is pointed distally on the tendon. Joint flexion and extension is then repeated^[57,58]. This produces a disruption of a single region within the tendon fibers. The procedure is then repeated by angling the scalpel so that the blade penetrates a series of tendon fibers lateral to the original incision. This is then repeated until the tendon is completely disrupted along the region of interest. The skin incision should be minimized to a single entry point, thus decreasing the chance of any additional tissue injury. A representative sonographic example of tenotomy can be seen in Figure 5.

OTHER POTENTIAL USES

Foreign body removal

Ultrasound has been utilized in diagnosis and treatment of various types of foreign bodies within the soft tissue including wood, plastic, and other radiolucent objects^[69-72]. There is evidence to support the use of ultrasound as a screening tool for foreign bodies and identification of critical neighboring structures that may present difficulty during the removal the object in question. Compared to imaging techniques such as plain radiography or computed tomography, modern ultrasound equipment is capable of rapidly producing a 3-dimensional image of the area in question and allows the physician to quickly and efficiently

plan a surgical or percutaneous removal of the foreign object. In situations where the exact nature of the foreign object is unknown, imaging methods such as MRI may be contraindicated due to the migration risk of metallic objects. Although the evidence is still limited, the use of ultrasound guidance during the removal of foreign bodies should be considered in appropriately selected cases^[69-73].

CONCLUSION

The ultimate goal of all image-guided procedures is to maximize patient safety, improve procedural accuracy, and optimize clinical outcomes. In addition to facilitating these objectives, ultrasound-guidance also offers the benefit of eliminating ionizing radiation exposure during procedures. Ultrasound-guided musculoskeletal procedures described in this review demonstrate the growing trend of using ultrasound as first-line modality in selected bedside musculoskeletal applications, among both specialist and generalist physicians. While additional information is needed to refine the utilization of ultrasound-guided bedside musculoskeletal procedures, there is sufficient evidence to support their increasing use in everyday clinical practice, as outlined in this review. The authors emphasize the need for adequate training, accreditation, and maintenance of skills among those who perform ultrasound-based procedures described herein, regardless of their specialty.

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