Interventional Neuromuscular Ultrasound

The favorable cost profile of ultrasound compared with MRI makes it a valuable tool for obtaining anatomic information in patients with neuromuscular problems.

BY JOHN W. NORBURY, MD; MICHAEL S. CARTWRIGHT, MD, MS; FRANCIS O. WALKER MD; STEVEN MANDEL, MD; DANIEL P. MOORE, MD

The advent of high resolution ultrasound (US) has presented clinicians with a powerful complement to the electrodiagnostic evaluation of conditions affecting the peripheral nervous system. The favorable cost profile of ultrasound compared with magnetic resonance imaging (MRI) makes it a valuable tool for obtaining anatomic information in patients with neuromuscular problems. Additionally, ultrasound presents the neurologist with a useful tool to treat many of the conditions that are seen in neuromuscular clinical practice. In theory, a clinician can offer patients “one-stop shopping” where the patient’s condition is diagnosed and treated in the same visit.

Interventional neuromuscular ultrasound encompasses a range of procedures that are used to diagnose and treat conditions of the peripheral nervous system using ultrasound guidance. Over 1,500 scientific publications support the use of ultrasound for these types of procedures. In practice, most of these procedures consist of US-guided regional anesthesia, US-guided biopsy of nerve lesions, and US-guided therapy with agents such as corticosteroids.

There are several advantages to using ultrasound to guide procedures when compared with either “blind” procedures or other forms of guidance such as fluoroscopy, computed tomography (CT), and electrical stimulation. Unlike CT and fluoroscopic guidance, US-guided interventions do not expose the patient or the provider to ionizing radiation. US-guided procedures are sometimes perceived as less unpleasant than procedures guided by electrical stimulation. Ultrasound also allows the operator to “survey” the soft tissues surrounding the target and identify structures that should be avoided during injections, such as vessels, tendons, and nerves. While scanning nearby structures, ultrasound sometimes reveals musculoskeletal pathology that is also amenable to intervention. US-interventions can help the operator avoid perineural injections and allow the operator to choose the path between the skin and the target structure that is the safest, shortest, and easiest. Ultrasound’s portability allows the procedure to be carried out efficiently in the office setting. In the authors’ experience, US-guidance also allows excellent local anesthesia so that the procedure is only mildly unpleasant or even painless for the patient. Finally, many patients enjoy “seeing” the pathology and sometimes even the real-time procedure image. Watching the images can even serve as a helpful distraction from the procedure.
Ultrasound guided procedures can be divided into direct and indirect guidance. Indirect guidance refers to marking the site of the target structure and then performing the intervention without real-time guidance. Direct guidance refers to the technique where the operator monitors the position of the needle in real time. Direct guidance can further be divided into “in plane” or long axis approach and “out of plane” or short axis approach (Figure 1). Both have their advantages and disadvantages. The long axis approach allows visualization of the needle during the entire procedure. The short axis approach is somewhat technically easier to perform and may be desirable for some superficial structures.

For neuromuscular procedures, the authors prefer the long axis approach, because it allows direct visualization of the needle tip during the entire procedure for safer and more accurate needle tip placement. When performing a long axis procedure, it is imperative to make the angle between the needle and the transducer as parallel as possible. This will maximize sound wave reflection and improve visualization of the needle.

While there are many variations in the general approach to ultrasound-guided interventions, the following is the sequence of steps that we employ in our laboratory. The most important principle in performing any procedure is to keep in mind the Boy Scout Motto: “Be Prepared.” In our practice, we have an operator and an assistant present during the procedure at all times. All equipment must be within reach of the operator prior to starting the procedure. Proper ergonomics is essential, as repetitive stress injuries are very common among ultra-
sound users (Figure 2A). As vasovagal reactions happen from time to time, it is generally advisable to have the patient lie down during the procedure. It can be helpful to keep the needle out of view of the patient.

Prior to performing a procedure, the operator should perform a diagnostic scan to identify the target structure. Doppler flow can assist in identifying blood vessels, nerves, and tendons that must be avoided. The skin can then be marked with an indelible pen (Figure 2B). The area is prepped, draped, and an ultrasound transducer cover is applied. Vapocoolant spray is used for surface anesthesia prior to insertion of a small gauge (25 or 27) needle to inject local anesthetic along a tract toward the target (Figure 2C). This confers the advantage of excellent local anesthesia as well as a “dry run” of the procedure. In the case of corticosteroid preparations, the confirmation of successful placement will be made easier by the characteristic hyperechoic crystalline appearance of the injectate.

Needle tracking refers to the technique whereby the operator achieves continuous visualization of the needle during the entire procedure. Several principles are important to keep in mind in order to improve needle tracking to prevent or recover a “lost needle” during the procedure. After the site of entry has been marked with an indelible pen, it is important to meticulously line up the path of the needle with the long axis of the transducer. The needle is then inserted while the operator is viewing the probe and the needle on the skin. After the needle has been inserted at least as far as the transducer itself, then the operator shifts his or her gaze to the screen to “confirm” the needle placement. After this point, the operator must either move the needle or the transducer, but not both at the same time. Often a “caffeine tremor” can be helpful, whereby the needle is gently “jiggled” in the tissue. The resulting movements are used to localize the needle. Some commercially available ultrasound machines have software that can assist in needle tracking. One example of this is “beam steering” in which the angle of the beam is directed in a plane more perpendicular to the needle to improve visualization (Figure 3A). Color flow can also be useful in tracking the needle (Figure 3B). Finally, commercially available echogenic needles are sometimes easier to see than traditional needles.

**ULTRASOUND GUIDED INJECTIONS OF THE CARPAL TUNNEL**

In the electrodiagnostic laboratory, median neuropathy at the wrist is the most commonly encountered entrapment neuropathy in the upper limb. It is also the entrapment neuropathy most amenable to therapeutic intervention.
A recent randomized controlled trial has demonstrated the short-term efficacy of blind carpal tunnel injections. A Cochrane Database Systematic Review has demonstrated improvement in symptoms for one month following a blind carpal tunnel injection; however, improvement beyond one month could not be demonstrated. In 2008, Smith described the ulnar approach for carpal tunnel injections, which is the technique we employ at East Carolina University. In this technique, the median nerve is injected from the ulnar aspect of the tunnel, and the nerve is dissected from both the flexor tendons and the flexor retinaculum. See figures 4 and 5. Evidence suggests that changes in gliding characteristics of the median nerve and changes in the subsynovial connective tissue are important factors in the development of carpal tunnel syndrome. Presumably, these pathologies are addressed in an US-guided carpal tunnel injection, but not in a blind injection.

In our practice, a mixture of 1cc 1% lidocaine and 1cc 40mg kenalog is used for this procedure. Prior to the injection, it is important to inform patients that they will experience numbness for one to two hours. Patients who undergo a bilateral injection may be advised to have an alternative driver available on the day of the procedure.

**ULTRASOUND GUIDED INJECTIONS OF OTHER NERVE ENTRAPMENT SITES**

Several other entrapment neuropathies are amenable to diagnostic and therapeutic US-guided injections. The technique for injecting the lateral femoral cutaneous nerve in patients with meralgia paresthetica has been described by Hurdle. In this procedure, the anterior superior iliac spine (ASIS) is palpated, and the nerve is identified sonographically just medial to the structure. Due to the variable course of the lateral femoral cutaneous nerve, ultrasonography has clear advantages to blind techniques for injection. Ultrasound guided interventions can be used to treat piriformis syndrome. Also, ultrasound guided interventions have been proposed for ulnar neuropathy at the elbow, but studies supporting ultrasound guided injections for ulnar neuropathy at the elbow are not nearly as common as they are for carpal tunnel syndrome.

**ULTRASOUND GUIDED NEUROTOXIN INJECTIONS**

The use of injected botulinum toxin to produce chemodenervation is now common to treat focal dystonias, spasticity, blepharospasm, and a variety of other conditions. Typically, the needle is guided into the target muscle using anatomic landmarks, electromyography (EMG), and sometimes a stimulating needle. However, there are cases in which the muscle may be electrically silent, difficult to specifically stimulate, or difficult to locate using these techniques alone, and in these cases ultrasound guidance has proven very helpful. A recent study demonstrated the benefit of ultrasound guidance for repeat injections for cervical dystonia in patients that had previously developed dysphagia following EMG-guided injections. In this study, ultrasound was used to identify the very thin sternocleidomastoid muscle, and repeat botulinum toxin injections under ultrasound guidance were safe and did not result in
the dysphagia that occurred during EMG guidance. Similar benefit has been demonstrated in using ultrasound to guide botulinum toxin injections into the forearm musculature in those with writer’s cramp.\textsuperscript{19}

In addition to injection into muscles, botulinum toxin can also be injected into salivary glands to decrease sialorrhea in conditions such as Parkinson’s disease and amyotrophic lateral sclerosis. Since glandular tissue is electrically silent, EMG guidance is not helpful in this setting. Ultrasound can be used in either an indirect or direct approach to locate the parotid and submandibular glands and guide the injections safely.\textsuperscript{20}

ULTRASOUND-GUIDED BIOPSIES

Ultrasound can also be used to quickly and painlessly select appropriate tissue for biopsy. For example, myositis can be a patchy condition, particularly dermatomyositis.\textsuperscript{21} Healthy muscle is mainly hypoechoic on cross-sectional ultrasound, with some brighter connective tissue. This has been described as a “starry night” appearance and has also been described as appearing “marbled,” similar to a cut of steak.\textsuperscript{22} Conversely, diseased muscle is more homogeneous and hypechoic, and therefore patches of diseased muscle can be easily identified with ultrasound. This allows the physician performing the muscle biopsy to identify muscle that is affected, but not too damaged, to increase the diagnostic yield of the biopsy.

FUTURE DIRECTIONS

While the advantages to US-guided interventions for the treatment of conditions such as carpal tunnel syndrome have been outlined above, concrete scientific evidence establishing the benefits of these procedures is lacking at present. The benefits and cost-effectiveness of these interventions must be established in the literature in the near future.

Several experimental neuromuscular procedures are on the horizon. One exciting emerging interventional procedure is percutaneous “ligamentomy” of the transverse flexor retinaculum.\textsuperscript{23} In this procedure, the median nerve is dissected away from the transverse carpal ligament with saline (Figure 6). Subsequently, the ligament is repeatedly fenestrated with a needle similar to the technique used for needle tenotomy of the common extensor tendon. If successful, this intervention may provide an alternative attractive to surgical arthroscopic and open releases of the carpal tunnel as the recovery time is only one to two days in the primary author’s experience.