

Ultrasonographic Evaluation of Entrapment Neuropathies in the Upper Limb

Painless and low-cost, neuromuscular ultrasound can be an important adjuvant to clinical and electrodiagnostic findings in the evaluation of peripheral neuropathies.

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A 55-year-old right-hand dominant retired plumber presents to the electrodiagnostic laboratory with a six-month history of mild progressive pain in his right hand and deterioration in his handwriting. The pain is worse at night. On physical examination there is weakness in the right ulnar-innervated finger flexors, first dorsal interosseous, and abductor digiti minimi. Sensation is decreased in the distribution of the ulnar nerve but sparing the medial antebrachial cutaneous nerve. Electrodiagnostic evaluation reveals slowing of motor nerve conduction velocities across the elbow and in the forearm. There is no response in the ulnar sensory nerve. Needle electromyography is negative for abnormalities in the flexor carpi ulnaris, first dorsal interosseous, and abductor digiti minimi.

How can neuromuscular ultrasound further elucidate the diagnosis in this patient?

Introduction

Although there are an increasing number of publications on the field of neuromuscular ultrasound over the past decade, many practitioners remain unaware of the utility of this imaging modality in the evaluation of muscles and nerves.¹

Neuromuscular ultrasound has been defined as the use of ultrasound imaging to evaluate primary disorders of muscle and nerve² and has become an

increasingly important tool in the evaluation of focal and generalized neuropathy and myopathy. In order to perform neuromuscular ultrasound, a thorough understanding of peripheral neuroanatomy and patterns of nerve lesions is required. This is a natural extension of the cognitive and procedural skills that electrodiagnostic consultants possess.³

In this review, we provide an overview of the technical aspects, advantages and limitations of ultrasound in the evaluation of entrapment neuropathies in the upper limb.

Key Practice Points

- Neuromuscular ultrasound is a powerful adjuvant to clinical and electrodiagnostic findings in the evaluation of peripheral neuropathies.
- Neuromuscular ultrasound is painless, available at the point of care, and less costly than other diagnostic modalities.
- Ultrasound provides a means of evaluating nerve and muscle dysfunction in adults or children unable to tolerate standard electrodiagnostic studies.

The Ultrasound Device

Knowledge of the basic science of ultrasound is necessary to understand how it can be applied to the peripheral nervous system. An ultrasound system is composed of two parts: an ultrasound instrument and a transducer. The transducer generates sound waves that are then transmitted through tissue. When these sound waves encounter changes in tissue density, known as an acoustic interface, they are reflected back to the transducer. The transducer then transmits the signals to the ultrasound instrument which can analyze them and generate a two dimensional image in real time. Higher frequencies allow higher resolution of more superficial structures. For relatively superficial nerves, a transducer in the 12 to 20 MHz range is appropriate. A 7.5 MHz transducer can be useful for deeper nerves, such as the sciatic nerve.

Advantages of Neuromuscular Ultrasound

When evaluating a patient with a suspected peripheral neuropathy, there are several advantages of ultrasound. It is the authors' opinion that neuromuscular ultrasound is not a substitute for technologies such as nerve conduction studies (NCS) and electromyography (EMG), but rather a powerful complementary tool when employed in combination with a thorough clinical and electrodiagnostic evaluation. While nerve conduction studies and electromyography provide detailed physiologic information, ultrasound provides detailed anatomic information. High resolution ultrasound provides greater axial detail than Magnetic Resonance Imaging (MRI).^{4,5}

Ultrasound can also be used to evaluate for anatomical variants. Heteropic bone, bone spurs and accessory muscles can be seen using ultrasound. Ultrasound also allows a more flexible field of view where the course of specific nerves can be traced instead of relying on the predetermined slices of an MRI scanner.⁶

Ultrasound can also help in identifying conditions in the differential for an entrapment neuropathy. For example, it is useful for the imaging of

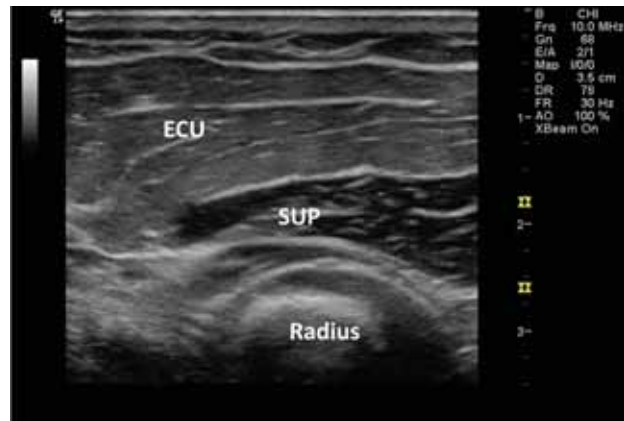


Fig. 1A: The appearance of muscle and bone on ultrasound. Muscle, as demonstrated here by the extensor carpi radialis (ECU) and supinator (S), appears as a generally hypoechoic structure with the intervening hyperechoic connective tissue. Bone as demonstrated by the radius appears as a hyperechoic rim above a hypoechoic area.



Fig. 1B: The median nerve at the elbow. The "honeycomb appearance" is evident in this picture of the median nerve at the elbow. The large hypoechoic structure to the right of the nerve is the brachial artery (A).

polyneuropathies, such as those found in diabetes⁷ and demyelinating polyneuropathies.⁸ It can also help to distinguish musculoskeletal disorders, which can mimic an entrapment neuropathy.

Another advantage of neuromuscular ultrasound is that it can be used to focus imaging on a particular area of concern. One can use the electrodiagnostic evaluation and physical examination to identify the most likely area of entrapment, which can then be examined in detail during the ultrasonographic evaluation. Like electrodiagnosis, ultra-



Fig. 2A: Evaluation of the median nerve (arrowheads) in long axis.



Fig. 2B: Evaluation of the median nerve (arrowheads) in short axis. Note the relatively flattened appearance.

sound allows examination of an asymptomatic contralateral side, or sections of nerve more distal or proximal, to help determine if a finding is abnormal or not. Ultrasound has been shown to be a particularly useful tool to guide surgical approaches to peripheral nerve lesions.⁹

Ultrasound also allows dynamic real-time imaging. Modern ultrasound instruments can record video clips of ultrasound so the dynamic imaging can be stored in the patient's medical record. Dynamic imaging is often used for musculoskeletal issues such as rotator cuff impingement; however one can also use the dynamic nature of ultrasound to evaluate the movement of nerves. One example of this is subluxation of the ulnar nerve at the elbow.

One of the greatest advantages of ultrasound is its convenience. Unlike other imaging modalities,

ultrasound is available at the point of service. This allows rapid integration of the ultrasonographic information into the electrodiagnostic consultation. Ultrasonography is faster and less expensive than a comparable imaging study with CT or MRI. It also is not associated with radiation exposure and presently has no known significant risks. Unlike MRI, ultrasound can be employed in patients who have pacemakers, surgical hardware, or who are claustrophobic.

Additionally, ultrasound can be used for needle guidance.

Having a machine readily accessible in the

electrodiagnostic laboratory allows one to localize technically difficult muscles such as the tibialis posterior or diaphragm for needle examination. Ultrasound guided intervention can be used to guide therapeutic injections to targeted structures for diagnostic and therapeutic indications. This allows integration of interventions such as corticosteroid injections into the electrodiagnostic consultation. In this model of care, patients can have "one-stop shopping" where they can receive the physical examination, electrodiagnostic evaluation, and ultrasound guided intervention to diagnose and treat the condition in one office visit.⁶

While electrodiagnostic findings are often difficult for patients to understand, ultrasound allows them to "see" the pathology. As in obstetric ultrasonography, patients better understand their own anatomy and the cause of their symptoms when

illustrated with real-time ultrasound.

Finally, one of the greatest advantages of ultrasound in comparison to electrodiagnostics is that it is virtually painless. Therefore, ultrasound is very useful in patients who cannot tolerate electrodiagnostic evaluations, such as children.

Limitations

There are several important limitations when using ultrasound in the context of upper limb neuropathies. The biggest limitation of ultrasound is that it is operator dependent. This is further complicated by the fact that ultrasound is not a part of many medical training programs. The general lack of familiarity with the technology, at least in North America, means that surgeons and other physicians who request electrodiagnostic consultations for patient care might not share the same comfort level with ultrasound findings as they do with a more traditional electrodiagnostic study. Ultrasound is also limited in the evaluation of more proximal and deeper disorders such as a radiculopathy, which may be in the differential of peripheral entrapment neuropathies.

Technical Aspects of Ultrasound and Appearance of Neuromuscular Structures

A typical ultrasound image is effectively a slice of the structures directly underneath the transducer. More superficial structures such as subcutaneous fat, appear on the top, and deep structures, such



Fig. 3A: Evaluation of the Ulnar Nerve (arrowheads) in long axis.



Fig. 3B: Evaluation of the ulnar nerve (arrowheads) in short axis.

as bone, appear on the bottom. For all structures imaged, both a longitudinal or long axis view and a transverse or short axis view need to be obtained for a thorough anatomic evaluation.

One of the most challenging technical aspects is recognition of the echotexture of nerves, muscles, and tendons. Structures that reflect sound waves appear white or hyperechoic. Those that allow sound waves to pass through appear dark or hypoechoic. Bones appear as a hyperechoic line with acoustic shadowing deep to the cortex, and muscle is generally hypoechoic with intervening hyperechoic connective tissue that represents perimysium (Fig 1A). Tendons have a tightly compact fibrillar pattern. In long axis, nerves tend to have a fascicular architecture with alternating hypoechoic and hyperechoic bands. In short axis, nerves have hyperechoic dots which appear as a “honeycomb” (Fig 1B).

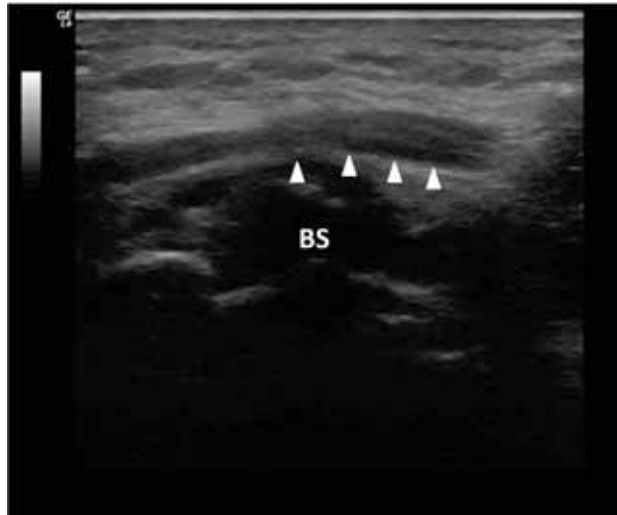


Fig. 4A: Ulnar nerve at medial epicondyle in long axis. There is a bone spur (BS) which is impinging upon the nerve as noted by the overall swollen and hypoechoic appearance.

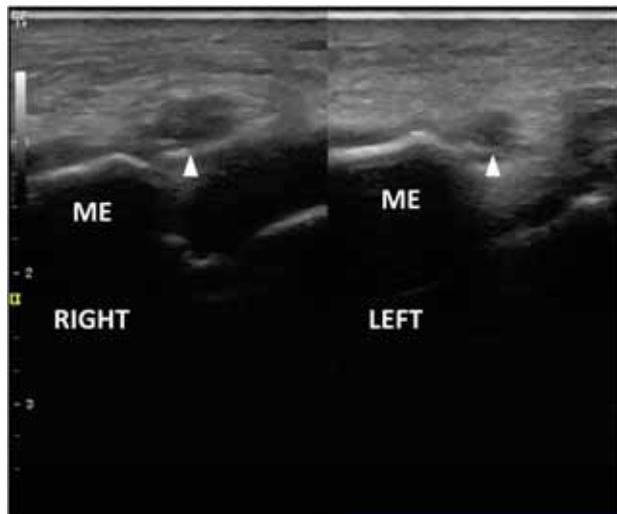


Fig. 4B: Comparison of the right and left ulnar nerve at the level of the medial epicondyle. Note the enlargement of the nerve on the right side.

Median Neuropathy at the Wrist

The carpal tunnel is an osteofibrous structure at the wrist, limited by the carpal bones forming the floor and the transverse carpal ligament that runs from the tuberosity of the scaphoid to the pisiform proximally and distally from the tubercle of the trapezium to the hook of the hamate at the roof.

Ten structures run through the tunnel: four tendons of the flexor digitorum superficialis, the four tendons of the flexor digitorum profundus, the flexor pollicis longus tendon and the median nerve. The normal appearance of the median nerve in long and short axis is shown in Figure 2.

In compressive median neuropathy at the wrist, the median nerve will appear larger just proximal to the flexor retinaculum. This represents swelling of the nerve proximal to the site of compression. The nerve will appear relatively more hypoechoic secondary to edema within the nerve. There are two ways to diagnose median neuropathy at the wrist based upon measurements of the cross-sectional area of the nerve in the transverse axis. The first method is to measure the size of the median nerve proximal to the wrist and compare to normal values. This has been shown to have high interrater reliability.¹⁰ Although other values have been described,^{11,12} in our lab we have used 12mm² as the upper limit of normal for the size of the median nerve in the carpal tunnel.

The second way to diagnose median neuropathy at the wrist is to measure the size of the median nerve at the wrist at the area of maximum swelling and compare this value to the size of the median nerve at the level of the proximal third of the pronator teres. Klauser et al. have described a change in cross sectional area of 2mm² as 99 percent sensitive and 100 percent specific for the diagnosis of carpal tunnel syndrome.¹³ Similarly Hobson-Webb cites a ratio of greater than 1.4 comparing the size of the median nerve at the wrist to the size at the forearm.¹⁴

An advantage of ultrasound in the diagnosis of median neuropathy is that space occupying lesions, such as synovial cysts, lipomas, and hamartomas, can be identified. Additionally, anatomic variants, such as a persistent median artery of the forearm or aberrant flexor muscle of the index finger, or acquired diseases, such as a ganglion, can be identified.¹⁵

Ulnar Neuropathy at the Elbow

Sonography has proven to be a useful tool to diag-

nose ulnar neuropathy at the elbow,¹⁶⁻¹⁸ even when the electrodiagnostic findings are normal.¹⁹ The ulnar nerve can be compressed at multiple sites as it courses around the medial epicondyle. Prominent among these is the retrocondylar groove, humeral ulnar arcade, and deep pronator aponeurosis. While an electrodiagnostic study can give some information as to the exact location of entrapment, ultrasound allows a more precise visualization of the abnormal nerve site. The normal appearance of the ulnar nerve is shown in Figure 3.

A cross-sectional area of greater than 7.5 mm²-8.3mm² has been proposed to be consistent with ulnar neuropathy at the elbow.^{17,19} In our lab, we have generally used the more stringent cut-off of 10mm². Unlike median neuropathy at the elbow, looking at a ratio of swelling comparing the proximal and distal site does not confer a significant improvement in sensitivity and specificity,^{20,21} but this type of comparison can be helpful in individuals with polyneuropathy and suspected superimposed focal neuropathy. The ulnar nerve can sublux during flexion of the elbow, resulting in measurements for NCS that are longer than the actual length of the nerve. This results in an artificially increased calculated conduction velocity.²²

This might mask an actual ulnar neuropathy at the elbow. By using ultrasound in this case, one can increase the diagnostic yield for ulnar neuropathy at the elbow. Subluxation of the ulnar nerve is found in 23 percent of normal patients,²³ and so one must be careful when making a diagnosis on these electrodiagnostic grounds.

Other Entrapment Neuropathies

Median neuropathies about the elbow can also be evaluated with ultrasound. Potential sites of entrapment, such as the ligament of Struthers, the pronator teres muscle, and the sublimus bridge, can all be visualized and associated with a focal area of swelling if present.¹ The anterior interosseous nerve can be entrapped distal to these locations. Since the nerve is sometimes difficult to visualize in the forearm, direct visualization of the nerve is often inconclusive.¹ In this case, one may observe

atrophy of the flexor pollicis longus and pronator quadratus.^{24,25} Likewise, the sonographic diagnosis of surgically confirmed lesions of the posterior interosseous nerve (supinator or posterior interosseous nerve syndrome) have been described.^{26,27} This often happens between the two heads of the supinator and should be considered in the diagnosis of lateral epicondylitis. Proximal to the posterior interosseus, the radial nerve proper can become entrapped. Normal values have been described in the literature.²⁸

Entrapments of the suprascapular nerve and axillary nerve have been described as well.¹

Diagnosing the Current Case

Returning to the case presentation, the electrodiagnostic findings (slowing of ulnar nerve conduction velocities at both the elbow and the forearm) did not fit with a classic ulnar neuropathy. A sonographic evaluation was carried out and revealed an osteophyte impinging upon the ulnar nerve at the level of the medial epicondyle, with swelling of the nerve demonstrated on both transverse and long axis images (Figure 4). Thus, the precise location of the lesion and the cause was determined.

Conclusion

Neuromuscular ultrasound is a powerful tool for the evaluation of peripheral neuropathies of the upper limb. It is quick, cost efficient and comfortable for patients. It allows precise localization of nerve lesions which can be helpful for guiding injections and localization prior to surgical intervention. ■

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