Neurology Asia 2012; 17(1) : 1 – 4

REVIEW ARTICLE

Nerve Ultrasound: Ready for clinical practice?

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Abstract

With the tremendous advance in technology, imaging methods have finally entered clinical routine for the assessment of the peripheral nervous system, after having already been employed for a long time in the realm of the central nervous system. Although both Ultrasound (US) and Magnetic Resonance Imaging (MRI) show good soft tissue resolution, US is more suited to everyday clinical practice, boasting easy accessibility, superior spatial resolution and low cost. MRI's main role lies with the imaging of deeper lying nervous structures and when US imaging is obscured by bony structures. Nerve US quantifies and anatomically pinpoints changes in nerve size and echotexture and is therefore useful for the identification of nerve entrapments, trauma, tumours and inflammation. It is also important for clinicians to realise that US imaging can reveal conditions even in the absence of significant neurophysiological abnormality. Furthermore, developments in nerve blood flow assessments have the potential for quantitating nerve blood flow, and thus providing new assessments of ischemic neuropathies.

INTRODUCTION

Although the investigation of the peripheral nervous system is still the domain of clinico-electrophysiological assessment, imaging methods are increasingly employed to provide supplementary information on the condition of the peripheral nervous system. Both ultrasound (US) and magnetic resonance imaging (MRI) provide high-resolution assessment of peripheral nerves, but US is more assessable, provides dynamic images, is reasonably priced and has better resolution.[1] For these reasons, US is predestined for use in everyday neurological practice and this review will only focus on US nerve imaging. The main domain of MRI peripheral nerve imaging is the assessment of deep lying structures hindered by bone. The following review summarizes the state of US imaging of the peripheral nervous system based upon the personal experience of the author and a supplementary medical literature search via MEDLINE and PUBMED databases from 1998-2011. The search terms used were "ultrasound", "sonography" and "nerve".

BASIC PRINCIPLES OF NERVE IMAGING USING ULTRASOUND

High-resolution US transducers using 18 MHz provide resolution of up to 400 μm.[2] Pay-off for high resolution is loss of tissue penetration and although most nerve trunks in the upper and lower limbs can be easily imaged with MHz ranges between 13-18 MHz, deep seated nerves -such as the sciatic nerve- require 5-8 MHz imaging. The image of a normal nerve in a transverse image can be compared to a bunch of straws viewed from above. In longitudinal views, the fascicular structure of the nerve is depicted as parallel echogenic lines within two bold hyperechoic (white) lines, the epineurium. Nerve pathology is depicted as either an increase in cross sectional area (CSA) or diameter, fascicular discontinuity or a change in echotexture.[3] Additional use of Doppler allows the assessment of blood flow to the nerve and the surrounding tissues. US imaging can best contribute to the evaluation of nerve entrapments, nerve trauma, nerve tumours and nerve inflammation and is considered in the following.

NERVE ENTRAPMENTS

Nerve entrapments despite location, follow a similar pattern of morphological change, which is well visualised by US. At the entrapment, the nerve is flattened and just proximal (1-2cm) to the site

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of entrapment, the nerve increases in CSA giving the appearance of a "pseudoneuroma".[4] The third morphological feature of nerve entrapments is the change in nerve echo-texture, which as it increases in severity, culminates in loss of fascicular pattern. The most reliable diagnostic parameter of nerve entrapment is the increased CSA just proximal to the entrapment.[5] Calculating a ratio with a more proximal nerve CSA further increases diagnostic sensitivity.[6] The best-researched entrapments are carpal tunnel syndrome and ulnar neuropathy at the elbow. Overall sensitivity and specificity for the detection of carpal tunnel syndrome CTS are 77.6% and 86.8%.[7] An important caveat for increasing sensitivity and specificity of diagnosis is to correct for wrist diameter as nerve CSA is dependant on limb circumference.[8] The sensitivity and specificity of ulnar neuropathy at the elbow is 85% with a range of 46-100%.[9] US is useful in the detection of nearly every known nerve entrapment ranging from the more common meralgia paresthetica[10] to tarsal tunnel[11] and includes nerves of small size such as the intrapatellar branch of the saphenous nerve.[12]

Recent meta-analysis examining the use of US for the detection of carpal tunnel syndrome and ulnar neuropathy at the elbow note that there is significant variation in sensitivity and specificity between studies and that this is likely due to different diagnostic parameters and techniques employed.[7,9] An important single source of variation is the non adjustment for wrist circumference.[8] With adherence to standard parameters, it is likely that US will take over from electrodiagnostic testing as the first-line confirmatory test.[7] Recent studies have specified the most useful ultrasound parameters in carpal tunnel syndrome as being the nerve CSA at the carpal tunnel inlet (at the level of the os pisiforme using manual hand tracing techniques with delineation inside the epineural border) and the wrist-forearm difference in nerve CSA (measured at the level of the os pisiforme and at the middle of the forearm).[5,6] In contrast to carpal tunnel syndrome, with ulnar neuropathy at the elbow there are potentially multiple sites of entrapment[13], making it necessary to pay attention to all five sites were entrapment has been described.[14] Future studies will need to address this issue, which until now has not received enough attention.

NERVE TRAUMA

Depending on the force and type of underlying trauma, an injured nerve may develop acute axonal swelling, nerve discontinuity (partial or complete) and neuroma formation. As all of these morphological changes can be demonstrated using US, surgical decisions can be facilitated since determining the extent of nerve damage within the first 6 weeks after trauma is limited using electrophysiological methods.[15] Until reinnervation begins, electrodiagnostic studies cannot differentiate severe axonotmetic lesions from complete nerve transection, or neurotmesis.[16] This is not without consequence since studies show better outcomes with early (< 1 week) surgical interventions in neurotmesis, but less severe nerve injuries mostly do not require surgical intervention.[15] US imaging of the brachial plexus has been in particular advocated as a screening method for the triage of patients with traumatic lesions into surgical and non-surgical candidates.[17] A further study concluded that US can confidently differentiate pre- and postganglionic traumatic brachial plexus lesions making it a useful adjunct in the preoperative diagnosis of brachial plexus lesions.[18]

PERIPHERAL NERVE TUMOURS

US is useful for the delineation of the extension of nerve tumours and differentiates into intrinsic or extrinsic localisation whilst providing the operator with information on the type and degree of vascularity.[19] The two most common nerve tumours, schwannomas and neurofibromas, cannot be confidently differentiated using imaging methods although a cystic structure is more suggestive of schwannoma.[20] Recently US has been shown to provide simple differentiation of a common cause of foot pain, Morton's neuroma, the sonographic feature being a round well-defined hypoechoic mass in the metatarsal region.[21]

NERVE INFLAMMATION

Inflammation of peripheral nerves ultimately results in an increase in nerve size from accumulation of inflammatory cells and subsequent edema. Different types of nerve inflammation result in various patterns and degrees of morphological change.[22] Axonal neuropathies, in contrast to demyelinating neuropathies, infrequently result in nerve enlargement, and when they do, cause less severe enlargement.[22] Charcot-Marie-Tooth 1A (CMT-1A) due to often considerable ongoing remyelination, regularly results in often massively enlarged peripheral nerves, characteristically outside the typical sites of nerve entrapment and US can therefore be conveniently used

for screening purposes.[22] More than 80% of subjects with chronic inflammatory demyelinating polyneuropathy (CIDP) show enlarged nerve trunks.[22] The cervical nerve roots represent a particularly sensitive region to scan and show correlation with the level of CSF protein.[23] In multifocal motor neuropathy, the brachial plexus, median, ulnar, and radial nerves frequently show extensive nerve enlargement.[24] Clinically noteworthy, is the finding by Beekman *et al*. that sonography can reveal more abnormalities than the clinical and electrophysiological examination and shows nerve pathology otherwise not noted in the clinical or electrophysiological exam.[24] It is also interesting to note that US has been able to visualize the site of conduction block in patients with immune neuropathies.[25] Leprosy, a multifocal inflammatory disease of the peripheral nerves, lends itself particularly well for ultrasonic evaluation. Jain et al. found that nerve damage is sonographically more extensive than clinically expected by showing distorted and enlarged nerve echotexture and increased nerve vascularity.[26] An important area of future study is the utilisation of US for the early detection of inflammatory nerve disease.

EMERGING ROLE OF BLOOD FLOW DETECTION IN ULTRASOUND

Over the past years, determining increased blood flow using Doppler as an indicator for quantitating inflammation, has received increasing attention. This has been particularly useful in the field of Rheumatology, where detection of increased synovial blood flow has been implemented as a means of monitoring disease activity.[27] In the field of Neurology, research has shown that increased nerve blood flow plays an important role in the pathogenesis of nerve entrapments and in inflammatory nerve disease. Several studies have shown that one of the characteristic components of nerve entrapment is increased blood flow starting several centimetres proximal to the site of entrapment. These studies showed sensitivity rates equal to or better than nerve conduction at high levels of specificity.[28, 29] There has also been the suggestion that elevated nerve blood flow may be both a useful biomarker of disease activity in carpal tunnel syndrome as well as providing a window on early diagnosis.[28, 30] However, quantification of nerve blood flow abnormality is still unsatisfactory and needs improvement.[31] To date the mere presence of detectable intraneural blood flow has been taken as an indicator of abnormality. However as improved technology of Doppler probes can now even detect intraneural blood flow in normals, quantification will need to delineate more reliable measures of differentiating normal from abnormal blood flow.

ULTRASOUND GUIDED INTERVENTIONS

Anesthesiologists routinely utilize US to improve the effectiveness and safety of nerve blocks.[32] It is also increasingly used to better both the safety and accuracy of medicines delivered to neural structures.[33]

WHAT DO I NEED TO PERFORM ULTRASOUND OF THE NERVES AND HOW DIFFICULT IT IS?

Performing US of nerves requires two basic prerequisites. A firm knowledge of peripheral nerve anatomy and the availability of high resolution US probes, preferably in the range of 13-18 MHz.[34] Imaging of nerve entrapment sites such as the carpal tunnel and ulnar nerve at the elbow are quickly mastered whereas more anatomically complex areas such as the brachial plexus and the groin region require experience.

CONCLUSION

US imaging of the peripheral nervous system has developed into a useful supplementary technique for gathering additional information on the status of the peripheral nerves. US should be seen as complimentary to neurophysiological methods and there is increasing weight of evidence supporting the use of US as a primary test in the diagnosis of nerve entrapments, in particular carpal tunnel syndrome and ulnar neuropathy. The use of nerve blood flow as a biomarker of carpal tunnel syndrome is clinically highly relevant and requires further evaluation. In addition, US provides important additional features of nerve pathology in nerve trauma, nerve tumours and the assessment of inflammatory nerve diseases.

DISCLOSURE

Conflict of interest to declare: None

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