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REVIEW ARTICLE

Ultrasound of Peripheral Nerve: Current Perspective

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Abstract

Nerve ultrasound has become an important method in patient management by providing information on lesion morphology, location, and relationship to adjacent structures, and it also helps to evaluate lesions which are difficult to access with electrodiagnostic methods. Recognition of the patterns of involvement in different peripheral neuropathies, along with quantitative data regarding nerve size, vascularity and stiffness may assist in streamlining diagnostic processes, improving time to diagnosis and cost.

Introduction

Neurological consultation is often sought by patients with features of peripheral neuropathy. The prevalence of peripheral neuropathy is estimated at 2.4% in the general population, which increases with age up to 8% among the population with age 55 years or more.[1] Causes of peripheral neuropathy include entrapment, infections, trauma, tumours, systemic diseases, inflammatory and autoimmune disorders, inherited disorders, and ischemic and paraneoplastic conditions.

In addition to a detailed history, comprehensive physical and neurological examinations, detailed electrodiagnostic (EDX) studies, and possibly additional ancillary testing (such as autonomic testing, skin biopsy and nerve biopsy, there is a need for imaging evaluation of peripheral nerves as well.

Ultrasound (US) and Magnetic resonance imaging (MRI) are imaging modalities used to evaluate the peripheral nerves. In the late 1980s, Fornage published the first paper on nerve US and in 1992 Buchberger and colleagues described US changes in focal nerve disease.[2,3] Findings in diffuse nerve conditions such as polyneuropathy and ALS were reported in 1999.[4] Since then, nerve US has become an important method in patient management by providing information on lesion morphology, location, relationship to adjacent structures, and it also helps to evaluate lesions which are difficult to access with electrodiagnostic methods. With the available systems in the market, the axial resolution can reach up to 70 microns and lateral resolution up to 200 microns.[5] Advantages of US are that it is non-invasive, painless, portable, cheap and enables fast imaging with high resolution as well as dynamic nerve evaluation.[6]

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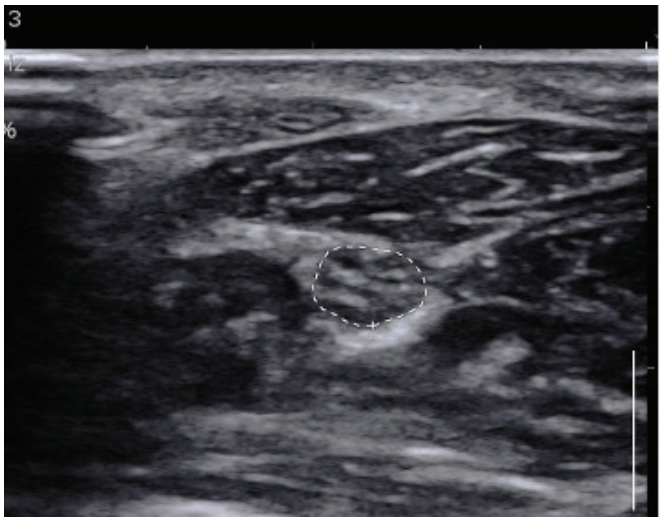

Figure 1: Normal sonographic appearance of peripheral nerve-honeycomb appearance marked with dotted lines).

Normal Sonographic Appearance Of Peripheral Nerves

In the longitudinal axis, a normal peripheral nerve on US looks like multicore electric cables consisting of fascicles in the connective tissue stroma (epineurium). This appearance is similar to a microscopic appearance. This orientation makes it an anisotropic tissue on ultrasound, though less marked than muscles and tendons. In the transverse axis, the nerve has a "honeycomb" appearance with the hypoechoic fascicles surrounded by hyperechoic epineurium and perineural fibrofatty connective tissue (Figure 1).

Systematic Sonographic Approach

i. Identification of nerve

All major nerves are visualised based on knowledge of regional anatomy. Identifying a nerve with some well-established landmarks, preferably bony, is routine practice.

Following identification, the nerves can be traced both proximally and distally(elevator technique).

ii. Picking up focal abnormality trauma/ tumour/ abscess, etc.

Any focal abnormality like mass/ collection/ calcification needs to be picked up and described. The size of the lesion and its relation with normal nerve anatomy can be well seen and help classify the pathology.

iii. Nerve size

Cross-sectional area (CSA) measured in sq. mm is the most commonly studied variable for the size with high reported reproducibility.[7] Measurement is done by tracing the inner margin of perineural hyper-echogenicity (Figure 1). The transducer is placed perpendicular to the nerve. Normative data has been presented by authors in different populations. However, Considering the wide range of normal values and the possibility of correlation (not proved yet) with age/ sex/ body-mass-index/ height, etc, absolute cut-off values have not been universally accepted and should be used cautiously.[8]

iv. Nerve echotexture/ fascicular pattern

Neural echogenicity can be evaluated by eyeballing or comparing the relative contrast of fascicles with interstitial tissue (epineurium). It has also been tried quantitatively with post-processing software using thresholding techniques to determine the hypoechoic fraction and density of the nerve.[9,10] However, these measures can vary with US systems, settings and processing software.

v. Nerve vascularity

Normally, no intraneural or perineural blood flow is detected in any normal nerves using the colour Doppler.[11] Increased blood flow using power Doppler can be seen in acquired infective or inflammatory neuropathies, entrapment neuropathy or neurolymphomatosis. Studies have come up with the use of contrast for documenting pathological vascularity and measuring maximum perfusion intensity (MPI).[12-14]

vi. Nerve stiffness

Elastography measures the stiffness of tissues non-invasively. Stiffness increases in peripheral neuropathies which occur because of myelin loss and its replacement by other tissues which are not as compliant. The output of these different elastography modalities is not comparable, and despite the benefit of quantitative results with shear wave elastography (SWE), the choice of technique is most frequently

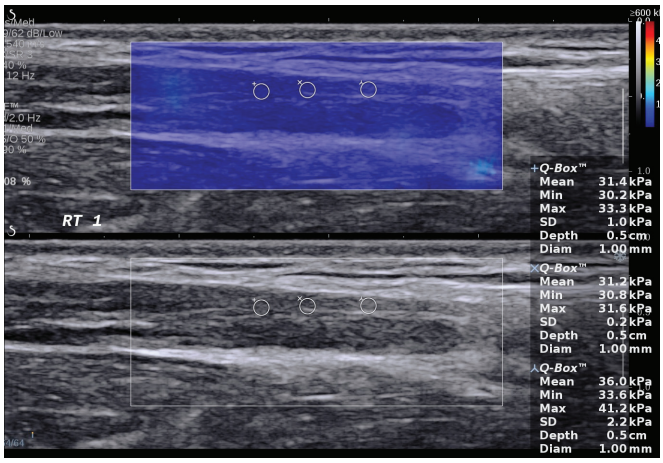

Figure 2: Shear wave elastography of peripheral nerve.

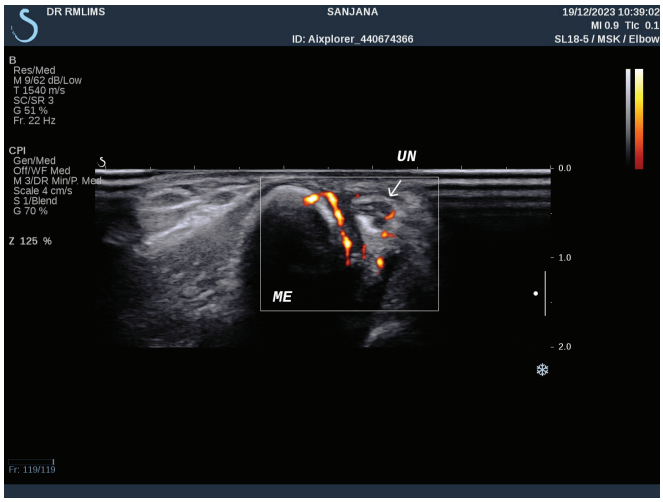

Figure 3: Dyanamic evaluation of ulnar nerve. There is shifting of the ulnar nerve anterior to the medial epicondyle on flexion.

determined by the availability of elastography modules and local expertise. (Figure 2).[15,16]

vii. Nerve mobility

There have been reports of restricted mobility as well as exaggerated nerve mobility (instability) associated with patient symptoms, which can be documented in real-time by specific manoeuvres. Mobility of the median nerve can be assessed at the level of carpal tunnel and mobility of the ulnar nerve can be assessed at the level of cubital tunnel (Figure 3). Several studies have evaluated median nerve mobility in the carpal tunnel.[17] When the median nerve has normal mobility, it passes beneath the flexor tendons during flexion of the wrist and fingers but this movement is restricted in entrapment neuropathy.

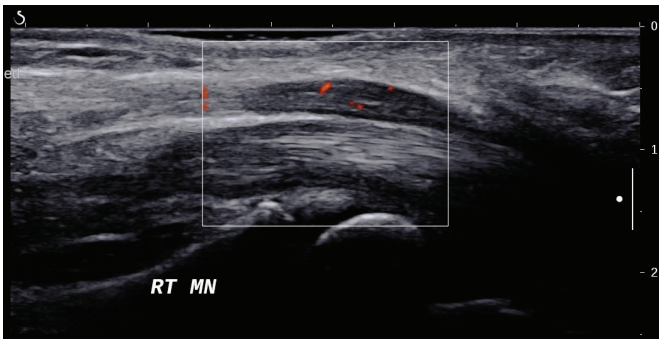

Figure 4: Compressive neuropathy of median nerve at carpal tunnel There is hypoechoic thickening with loss of fascicular architecture.

Common Clinical Scenarios/ Applications

i. Peripheral nerve entrapment

Compressive neuropathy is diagnosed based on history and examination findings and subsequently confirmed by electrodiagnostic tests. Entrapment occurs when the course of the nerve is through osteofibrous tunnels. US enables visualization of the site of nerve compression and there are reference values for nerve CSA which help to establish the diagnosis.[8]

Diagnosis is established by documenting short-segment enlargement of the nerve proximal to compression sites compared to the nerve's size at the proximal location (Figure 4). Absolute cut-off value, as well as the difference in the nerve size measured by subtracting the area of the thickened nerve with proximal measurement, has been vouched for making the diagnosis. The thickened nerve segment is usually hypoechoic (oedematous) and may show loss of fascicular pattern with increased vascularity due to venous congestion.

Dynamic assessment may also show restricted mobility. In addition, the compressed nerve will flatten. In addition to bony outgrowth/ osteophytes or thickening of the fascia, ultrasound may document ganglion cysts, tumours, thrombosed arteries, etc, as the cause of tunnel narrowing. The innervated muscles may show signs of atrophy (increased echogenicity/ loss of muscle bulk as compared to contralateral sides).

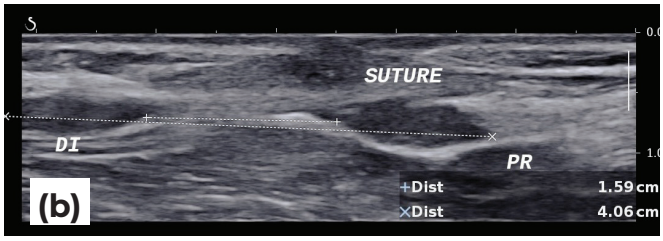

Figure 5a and b: Post-traumatic neuroma in continuity (a) and transacted nerve with proximal and distal neuroma (b).

ii. Traumatic neuropathy

Peripheral nerve injury can be due to stretch, contusion/ laceration, and sharp cuts. These injuries are classified as neurapraxia, axonotmesis, and neurotmesis. US can visualise the site of injury and features such as complete/ partial nerve discontinuity, neuroma (Figure 5a), foreign bodies, and scar tissue.

In chronic cases, the presence of neuroma (seen as focal thickening of stump) and its size and absolute measurement of the gap (Figure 5b) help in presurgical planning for nerve grafts.

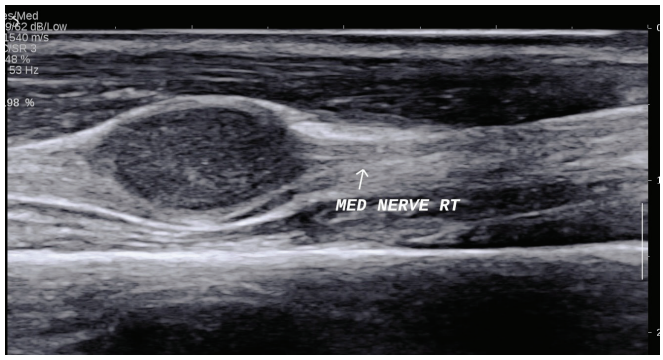

Figure 6: Schwannoma in peripheral nerve. Note the eccentric location and continuity of nerve at the margin.

iii. Tumour

Ultrasound helps evaluate the status of the nerve in tumours and tumour-like conditions. Schwannoma (Figure 6), neurofibroma, malignant peripheral nerve sheath tumour, neuroma-in-continuity, neuro-fibrolipo hamartoma and Morton's neuroma are commonly evaluated tumours.

Specific location and sonographic echo patterns about size and infiltration into adjacent tissue guide us to a diagnosis. Whether the nerve is displaced or passing through the lesion helps in differentiating schwannoma (which is eccentrically placed) from neurofibroma.

iv. Mononeuritis multiplex

Multifocal involvement of the peripheral nerve is seen and presents as enlargement, commonly at a superficial course of the nerve or proximal to entrapment sites with fascicular thickening and increased vascularity (Figure 7). Such presentation can be associated with vasculitis,

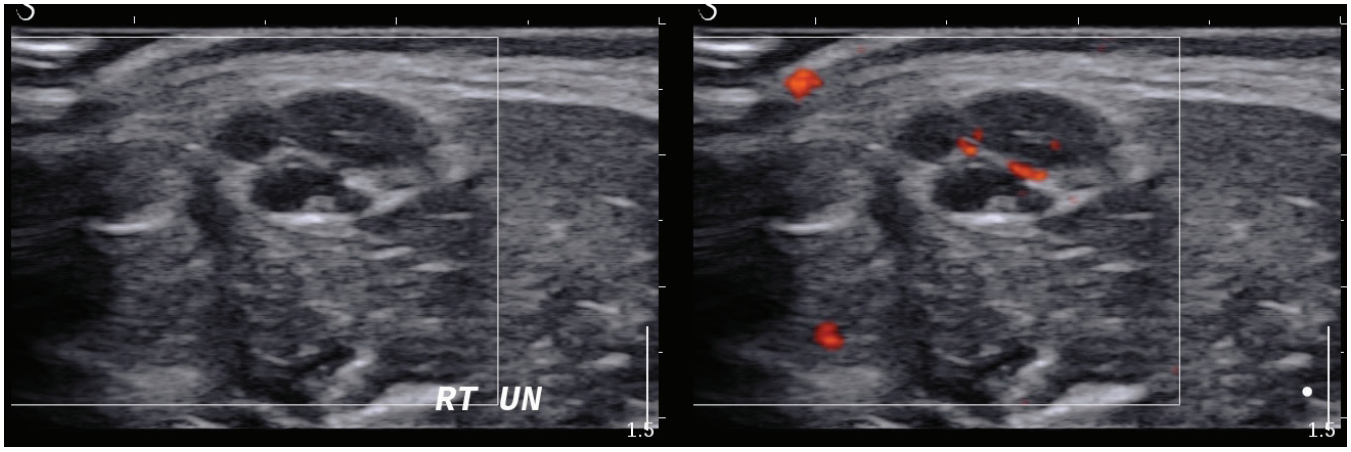

Figure 7: Infective neuritis. Note the fascicular thickening and increased vascularity.

metabolic diseases or infection, and Hansen's disease in the endemic zone like the Indian subcontinent.

v. Polyneuropathy

Recently, US has shown an increase in nerve CSA in various polyneuropathies, including acromegaly, diabetes, vasculitis, Charcot Marie Tooth disease, multifocal motor neuropathy, and others, with or without aberrant vascularity.[18-21] In contrast, a reduction in nerve CSA may be seen in motor and sensory nerves in amyotrophic lateral sclerosis and post-herpetic neuralgia, respectively.[22]

vi. Guidance/ therapeutic

Ultrasound is routinely used for localising peripheral nerves for anaesthesia/ nerve block and electrode placement for more accurate sensory nerve action potential (SNAP). Its role in guiding minimal intervention procedures for carpal tunnel release/ hydro dissections in compressive neuropathy is now well established.

Conclusion

US has become essential in diagnosing and managing peripheral nerve diseases, adding much-needed information about structure and vascularity. Recognition of the patterns of involvement in different peripheral neuropathies, along with quantitative data regarding nerve size, vascularity and stiffness may assist in streamlining diagnostic processes, improving time to diagnosis and cost.

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