# The Clinical Applications of Peripheral Nerve Imaging in the Upper Extremity

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Use of different imaging modalities in the diagnosis of peripheral nerve pathology has been growing steadily. This review attempts to summarize their use, particularly with regard to ultrasound and magnetic resonance imaging, and their practical applications in the clinical setting. (J Hand Surg 2007;32A:1600–1604. Copyright © 2007 by the American Society for Surgery of the Hand.)

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Use of different imaging modalities in the diagnosis of peripheral nerve pathology has been evolving; however, the incorporation of these modalities into common clinical practice remains limited.

The most established uses in the upper extremity involve tumors and injuries to the brachial plexus.[1–8] The utility of the various imaging modalities for more distal injuries and more specifically for compression neuropathies has been the object of many studies but still remains unclear.

There has been a rising demand for more objective, sensitive, and specific testing for compression neuropathies and diseases of the neuromuscular junction due to pressure from within the medical system with workers' compensation and other insurance companies pushing to reliably prove and quantify these conditions. This is compounded by the lack of dependable testing. More surgeons are now specializing in peripheral nerve surgery, also increasing the demand for objective testing.

The current gold standard for these conditions, nerve conduction tests and electromyography (EMG), has well-known limitations,[9–11] and many of the tests are invasive and unpleasant such as nerve or muscle biopsy.

Computed tomography (CT) scan has been used to visualize peripheral nerves, and CT myelograms are used in brachial plexus injuries, but this modality is better for visualizing bony entrapments.[12,13] The most studied imaging modalities in delineation of peripheral nerve pathology have been ultrasound (US) and magnetic resonance imaging (MRI).

## Ultrasonography

Traditionally, US has been used in the acute traumatic setting and for tumor evaluation. It can be used after trauma to help identify edematous nerves as a cause of neurapraxia, and nerve tumors can be identified, especially if the malignancy causes invasion of local tissue.[14]

The advantages of this modality are that it is inexpensive, noninvasive, and safe. It has also been shown to be superior to CT and MRI in spatial analysis. Comparisons are made with the contralateral extremity to calibrate the size of the nerve. Use of US allows for dynamic evaluation of the nerve and tendons during active and passive flexion.[15,16] As with other imaging modalities, abnormalities of the anatomy may be visualized. However, US remains operator dependent rendering it an unreliable modality in some cases.

Kuo et al reported use of high-resolution sonography in the preoperative assessment of neurilemmoma of the median nerve.[15] Ultrasound has also been helpful in detecting stump neuromas[17] and in guiding biopsies and nerve blocks.[18–22] Its use in the diagnosis and treatment of entrapment neuropathies is, however, still limited.[23] For the carpal tunnel, highfrequency linear array transducers of 7 to 15 MHz are used. Using US, only the epineurium can be visualized. In longitudinal section, the median nerve shows multiple hypoechoic and parallel-but-discontinuous lines separated by echogenic bands. During finger flexion, the tendons shift ventrally, then dorsally, as the tension pulls them more or less tightly against the flexor retinaculum. The median nerve remains constant in its location with minimal movements.[23,24] In carpal tunnel syndrome (CTS), there is nerve flattening in the distal carpal tunnel, nerve swelling within the tunnel, and bowing of the flexor retinaculum.[25,26]

Studies have found a sensitivity and specificity of about 80% to 90% using the cross-sectional area of the median nerve. Others have found the bowing of the flexor retinaculum to be more reliable.[27–32]

Imaging of ulnar nerve compression has been studied less. In Guyon's canal, it is difficult to follow.[33,34] In the cubital tunnel, US imaging seems to be sensitive and specific, but this has not been well established.[35–41] Lately, a series of ultrasound examinations for the ulnar nerve in the cubital tunnel suggested this may be a reliable method of diagnosis of cubital tunnel syndrome.[42] Imaging of the radial nerve in the spiral groove has been described. It can then be followed proximally and distally and can be seen under a plate or its continuity assessed.[43,44]

In summary, US has not been proved to be as sensitive or specific as EMG and nerve conduction tests (NCTs) in the diagnosis of CTS. For imaging of the other nerves in the upper extremity, information is still limited. However, anatomic information can be added such as persistent median artery, tumors, and position near plates. It is safe and noninvasive sometimes rendering it the only applicable modality. The operator dependency still limits its use considerably.

Ultrasound is probably most useful in recurrent cases of CTS where clinical diagnosis and electrodiagnostic tests are limited and anatomic detail is difficult.[25]

## Magnetic Resonance Imaging

Magnetic resonance imaging has advanced considerably and plays an increasing role in peripheral nerve pathology diagnosis and treatment.[45–47]

The technique of MRI neurography has greatly increased the ability to visualize peripheral nerves and their pathology.[48–52] This has been applied to peripheral nerves in the lower extremities and to the spine and brachial plexus.[53] Development of specially designed phased array coils with improved high signal-to-noise ratio and a higher resolution has brought MRI to the forefront of peripheral nerve imaging.[54,55] Direct visualization of peripheral nerves and their fascicular pattern is possible as well as nerve edema at the fascicular level. The mechanical deviations in the physical course of the nerve may allude to nerve entrapments from adhesions. Hyperintensities associated with nerve injury may be appreciated in nerves affected so severely as to be associated with marked motor deficits. Physical discontinuity in nerve and the development of traumatic neuromas may be readily appreciated. Metabolic disorders affecting nerves will affect interfascicular lipids, which will become apparent in MRI neurography. There have been limited studies evaluating use of MRI to follow recovery after injury in the peripheral nervous system.[51,56,57]

The current indications for MRI neurography therefore include masses involving a peripheral nerve, traumatic nerve injury, unexplained neuropathy or plexopathy, entrapment neuropathy, and post-treatment evaluation.

Magnetic resonance imaging in compressive neuropathies can evaluate anatomic features and location as well as signal intensity. An abnormal bulbous appearance proximal to the compression site can be seen, with flattening of the nerve at the compression site and a hyperintense signal on both T1- and T2-weighted sequences. The hyperintensity is probably due to excess endoneurial fluid accumulation.[55] In the carpal tunnel, the location of the median nerve can be evaluated relative to the flexor tendons as well as its mobility with changes in hand posture.[58] Also seen are thickening of the tendon sheaths, bowing of the flexor retinaculum (Fig. 1), and changes consistent with denervation in the thenar musculature.[59–63] Studies that have evaluated the accuracy of MRI in diagnosing CTS have shown very promising results.

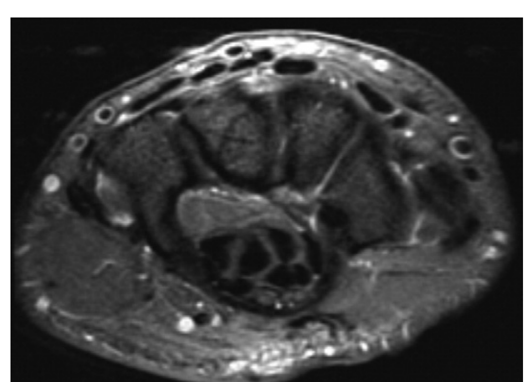

**Figure 1.** Magnetic resonance image of a carpal tunnel with a bowed retinaculum in a 49-year-old man.