High-Resolution Magnetic Resonance Neurography in Upper Extremity Neuropathy

Majid Chalian, MD[a], Ashkan Heshmatzadeh Behzadi, MD[a], Eric H. Williams, MD[a], Jaimie T. Shores, MD[a], Avneesh Chhabra, MD[b,*]

KEYWORDS

• Magnetic resonance imaging • Magnetic resonance neurography • Entrapment neuropathy • Upper extremity • Neurography • Injury

KEY POINTS

- High field strength allows better 3-dimensional (3D) imaging, therefore 3T MR scanning is preferred.
- The imaging around the joints is best accomplished using joint-specific coils.
- Auto-shimming is essential before 3D diffusion-weighted PSIF (reversed steady-state free precession) and diffusion tensor imaging to avoid ghosting and attain uniform fat suppression.
- Additional long-axis fluid-sensitive 2D images (fat-suppressed proton density or short-tau inversion recovery) are acquired to evaluate the joints and other structures in the imaging field of view.
- Nerve variations and magic angle artifact should be kept in mind to avoid overcalling neuropathy.
- Fascicular abnormality or nerve enlargement are definitive MRN imaging signs of neuropathy.
- The critical findings in grading nerve injury are detection of neuroma and nerve transection.

INTRODUCTION

Nerve entrapment and injury of the upper extremity is more common and can be more complex than that of the lower extremity, with the existence of several entrapment sites along the course of major upper limb nerves.[1] These lesions can be diagnosed based on clinical findings and electrophysiologic studies, such as electromyography and nerve conduction studies. However, these studies are invasive, can be uncomfortable, can be falsely negative, frequently show low positive predictive values, and can be nonlocalizing in patients with mild lesions or in cases of severe axonal injury with low distal compound action potentials.[2–5] Such studies are normal in cases of neurapraxia (mild nerve injury) and can be normal up to 7 to 14 days after nerve injury, even when the nerve is physically divided. Ultrasonography has been widely used for common sites of entrapment, such as carpal tunnel or cubital tunnel syndromes, because of its low cost, portability, and real-time capability. However, ultrasonographic study requires operator skill, may be limited by local calcifications/dense scarring, does not demonstrate nerve and muscle signal intensity alterations as with magnetic resonance (MR) imaging, and frequently lacks objectivity.[2,3] Therefore there has been much interest in development and use of high-resolution MR imaging techniques capable

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[a] Johns Hopkins University, Baltimore, MD 21218, USA; [b] The University of Texas Southwestern, 5323 Harry Hines Blvd, Dallas, TX-75390-9178, USA
* Corresponding author.
E-mail address: avneesh.chhabra@utsouthwestern.edu

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of more precisely delineating nerve abnormality and its underlying cause.[4–6] High-resolution MR imaging that provides multiplanar isotropic depiction of the nerves using a combination of 2-dimensional (2D) and 3-dimensional (3D) imaging with and without uniform fat-suppression techniques, also referred to as MR neurography, has been increasingly used for peripheral nerve evaluation.[7–12] MR neurography not only reveals the morphologic characteristics of nerves but also provides information on pathologic processes including nerve inflammation, edema, fibrosis, and fat proliferation.[12] It has been increasingly used in the assessment of lesions affecting peripheral nerves, plexus, and spinal nerve roots.[7,8,13–15] This article reviews the normal 3-T MR neurographic appearance of the upper extremity nerves, and abnormal findings related to injury, entrapment, and other pathologic conditions.

TECHNICAL CONSIDERATIONS IN MR NEUROGRAPHY

Technical considerations in MR neurography are extensively discussed in another article in this issue by Chhabra and colleagues. In brief, some key points should be followed in upper extremity imaging. Higher field strength allows better 3D imaging, therefore 3-T scanning is preferred. The imaging around the joints is best accomplished using joint-specific coils. Contiguous imaging, for example elbow and forearm, should be performed using separate fields of view for elbow and forearm, ideally with separate phased array coils for each. To avoid wraparound artifacts, dead (air) space around the extremity should be avoided or minimized as much as possible to attain the highest possible resolution and contrast. 2D imaging using axial T1-weighted and axial T2 spectral adiabatic inversion recovery (SPAIR) imaging is performed with less thickness than the plexus or lower leg imaging, to keep in-plane resolution between 0.3 and 0.4 mm. The slice thickness is kept at 4 mm, 3 mm, and 2 mm for upper arm, forearm, and wrist, respectively. 3D diffusion-weighted (DW) reversed steady-state free precession (PSIF) imaging is very useful for displaying the anatomy along the long axis of the extremity. 3D SPAIR sampling perfection with optimized contrasts using varying flip-angle evolutions (SPACE) works better in extremities than 3D short-tau inversion recovery (STIR) SPACE, because of its higher signal-to-noise ratio. Auto-shimming is essential before 3D DW PSIF and diffusion tensor (DT) imaging, to avoid ghosting and attain uniform fat suppression.[16,17] Additional long-axis fluid-sensitive 2D images (fat-suppressed proton density or STIR) are acquired to evaluate the joints and other structures in the imaging field of view.

BRACHIAL PLEXUS BRANCHES

The brachial plexus has a complex anatomy, and is formed by the contribution of the ventral branches coming from the 4 lower cervical and first thoracic nerves; it is covered elsewhere in this issue by Lutz and colleagues. The discussion here focuses on brachial plexus branch nerves relevant to the upper extremity. Whereas certain nerves come directly from the plexus, such as the spinal accessory nerve, the most commonly imaged nerves include the 3 peripheral nerves of the upper limb: the median nerve, ulnar nerve, and radial nerve. The radial nerve arises from the posterior cord; the majority of the median nerve arises from the lateral cord while the median nerve and the ulnar nerve receive contributions from the medial cord.[15] It is worth mentioning that brachial plexus abnormality can extend into the peripheral nerves (**Fig. 1**). Proximal plexus abnormality can also cause double-crush syndrome and present with distal peripheral nerve symptomatology at one of the entrapment sites, and this syndrome should be considered in the differential diagnosis, both clinically and during imaging for proper management. For example, thoracic outlet syndrome causing C8 and/or T1 neuropathy may predispose the ulnar nerve to entrapment distally or exacerbate ulnar neuropathy symptoms.

ULNAR NERVE

The ulnar nerve originates from the medial cord of the brachial plexus (C8, T1) with occasional contributions from the C7 nerve root. It courses along the posteromedial compartment of the upper arm in a relatively straight fashion. At the mid-arm level, the nerve penetrates the medial intermuscular septum and courses adjacent to the epimysium of the medial head of the triceps and deep fascia before reaching the cubital tunnel, where it passes between the medial epicondyle of the humerus and the olecranon at the condylar groove. Here, it lies deep to the cubital tunnel retinaculum (CTR), also known as the Osborne fascia, and aponeurosis formed between the 2 heads of the flexor carpi ulnaris.[18–20] The nerve courses straight between superficial and deep compartments of the forearm along its medial side and at the wrist, and passes through a fibro-osseous tunnel known as the Guyon canal (**Fig. 2**).[21,22] The floor of this tunnel is formed by hamate, hypothenar muscles, and flexor retinaculum; the roof is composed of the pisohamate