High-resolution ultrasonography in the diagnosis and intraoperative management of peripheral nerve lesions

Clinical article

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Object. The diagnosis of peripheral nerve lesions relies on clinical history, physical examination, electrodiagnostic studies, and radiography. Magnetic resonance neurography offers high-resolution visualization of structural peripheral nerve lesions. The availability of MR neurography may be limited, and the costs can be significant. By comparison, ultrasonography is a portable, dynamic, and economic technology. The authors explored the clinical applicability of high-resolution ultrasonography in the preoperative and intraoperative management of peripheral nerve lesions.

Methods. The authors completed a retrospective analysis of 13 patients undergoing ultrasonographic evaluation and surgical treatment of nerve lesions at their institution (nerve entrapment [5], trauma [6], and tumor [2]). Ultrasonography was used for diagnostic (12 of 13 cases) and intraoperative management (6 of 13 cases). The authors examine the initial impact of ultrasonography on clinical management.

Results. Ultrasonography was an effective imaging modality that augmented electrophysiological and other neuroimaging studies. The modality provided immediate visualization of a sutured peroneal nerve after a basal cell excision, prompting urgent surgical exploration. Ultrasonography was used intraoperatively in 2 cases to identify postoperative neuromas after mastectomy, facilitating focused excision. Ultrasonography correctly diagnosed an inflamed lymph node in a patient in whom MR imaging studies had detected a schwannoma, and the modality correctly diagnosed a tendinopathy in another patient referred for ulnar neuropathy. Ultrasonography was used in 6 patients to guide the surgical approach and to aid in intraoperative localization; it was invaluable in localizing the proximal segment of a radial nerve sectioned by a humerus fracture. In all cases, ultrasonography demonstrated the correct lesion diagnosis and localization (100%); in 7 (58%) of 12 cases, ultrasonography provided the correct diagnosis when other imaging and electrophysiological studies were inconclusive or inadequate.

Conclusions. High-resolution ultrasonography may provide an economical and accurate imaging modality with utility in diagnosis and management of peripheral nerve lesions. Further research is required to assess the role of ultrasonography in evaluation of peripheral nerve pathology. (DOI: 10.3171/2010.2.JNS091324)

KEY WORDS • peripheral nerve • ultrasound • nerve entrapment • schwannoma

The diagnosis and localization of peripheral nerve lesions relies primarily on the clinical history and physical examination. The diagnostic testing of peripheral nerve lesions has previously been limited to use of NCSs and EMG. The availability of MR neurography may be limited, and the costs can be significant. By comparison, ultrasonography is a portable, dynamic, and economic technology. The authors explored the clinical applicability of high-resolution ultrasonography in the preoperative and intraoperative management of peripheral nerve lesions.

Magnetic resonance neurography provides high-resolution imaging of peripheral nerves; T2-weighted MR imaging sequences combining fat and flow suppression with 3D reconstruction yield good representations of peripheral nerve anatomy. Magnetic resonance imaging technology, however, is limited by difficulties of access, cost, and time. Magnetic resonance neurography is not available at all centers, and considerable variability in imaging quality may be found.

Ultrasonography is a rapid and widely available technology that provides dynamic imaging. In carpal tunnel syndrome, ultrasonography has been shown to provide equal if not superior diagnostic capabilities compared with MR imaging. The development of high-resolution ultrasonography has allowed users to accurately identify a variety of neural pathologies including trauma, tumors, and entrapment neuropathies. Ultrasonography has been used to guide surgical approaches, localize specific lesions, and determine the extent of resections in surgical procedures. The modality is used within the neurosurgical milieu in the removal of brain tumors, where it provides real-time intraoperative localization for precise cortical incision and ongoing guidance for extent of resection. Intraoperative ultrasonography has demonstrated a sensitivity and specificity of 97 and 84%,
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respectively, in differentiating normal brain tissue from tumor, allowing for accurate removal of involved tissue.\(^4\)\(^,\)\(^3\)

Ultrasonography is also a well-recognized tool in the diagnosis of carpal tunnel syndrome. The modality can provide qualitative and quantitative information on the median nerve before and after treatment.\(^4\)\(^,\)\(^3\) High-resolution ultrasonography can accurately identify brachial plexus injuries with high sensitivity and specificity, and it is able to categorize lesions as major or minor to guide surgical decision making.\(^4\)\(^,\)\(^3\)

Ultrasonography remains underused in diagnosing and treating peripheral nerve lesions. There have been limited reports assessing the efficacy of ultrasonography in the evaluation of peripheral nerve lesions. We examine the use of ultrasonography in the evaluation and operative treatment of 13 patients with peripheral nerve lesions. We found the modality to be an effective tool in preoperative assessment and diagnosis as well as an important intraoperative adjunct.

**Methods**

A retrospective review of a single surgeon's (J.K.R.) operative database was conducted. We identified 13 patients who underwent ultrasonographic evaluation and surgical treatment of peripheral nerve lesions (nerve entrapment \([5]\), trauma \([6]\), and tumor \([2]\)). All ultrasonographic studies were performed and interpreted by a single radiologist (L.N.N.). All ultrasonography examinations were completed using a multifrequency linear array probe with peak frequency of 12 MHz (Philips iU22, Philips Medical Systems). Studies were maintained and accessed via Philips ISite Enterprise (version 3.5, Philips Medical Systems). Preoperative, postoperative, and intraoperative records were reviewed. Hospital and clinic charts were reviewed. Ultrasonography was used for diagnostic (12 of 13 cases) and intraoperative (6 of 13 cases) management. Clinical data are reviewed in Table 1. This study was approved by the institutional review board of the Thomas Jefferson University Hospital.

**Results**

**Nerve Entrapment Group**

Five patients presented with signs and symptoms that were consistent with nerve entrapment (Table 1). Ultrasonography identified the site of nerve entrapment in all 5 patients. Ultrasonography confirmed EMG study findings in 2 of these patients, was the initial diagnostic test in 1, and achieved an accurate diagnosis in the face of negative or inconclusive EMG study findings in 1.

The patients in Cases 1 and 4 each presented with clinical symptoms of a peroneal nerve lesion; both presented with dorsiflexion weakness and paresthesias over the lateral aspect of the lower leg in the involved extremity. Initial EMG demonstrated peroneal nerve entrapment, which was subsequently confirmed on ultrasonography studies. In these patients, ultrasonography was used to confirm compression at the fibular head. One patient underwent surgical exploration of the compressed peroneal nerve. The patient in Case 3 presented with pain compatible with ilioinguinal nerve entrapment, which was confirmed with ultrasonography as the initial diagnostic test (Fig. 1).

The patient in Case 2 presented with severe left foot and ankle pain. Initial EMG studies demonstrated a chronic radiculopathy with no evidence of focal nerve entrapment. The patient had undergone 2 previous lumbar decompressive surgeries without relief of his lower-extremity symptoms; electromyographic alterations due to the patients' previous surgery may have degraded this modality's diagnostic utility. Clinical suspicion for nerve entrapment led to subsequent ultrasonography, which demonstrated peroneal nerve entrapment at the fibular head. Surgical decompression yielded reduction in pain but, at the time of this submission, no change in the patient's motor deficit. The patient in Case 5 presented with a significant right lower-extremity motor deficit and an evident foot drop. Magnetic resonance imaging and ultrasonography of the right knee revealed a ganglion cyst that produced severe compromise of the peroneal nerve as it crossed the fibular head.

In cases of nerve entrapment, surgical decompression was performed in 4 of 5 patients. One patient chose to pursue conservative treatment. In Case 4, intraoperative ultrasonography was used to guide resection; ultrasonography served to localize the site of nerve entrapment at the fibular head, allowing for more limited dissection focused at the site of nerve compression, and confirmed the adequacy of decompression.

**Tumor Group**

Two patients were evaluated with tumors or mass lesions. Ultrasonography was able to correctly identify the site of the pathological lesion in both patients. An intraoperative ultrasonography-guided surgical approach and resection was completed, and it confirmed lesion removal in both patients. Ultrasonography led to a correct preoperative diagnosis when the MR imaging and EMG findings were less useful. All patients had improvement in symptoms following surgery.

The patient in Case 6 presented with a palpable deformity of the left elbow, which was initially identified as an ulnar nerve tumor, likely schwannoma, by MR imaging. Subsequent ultrasonography correctly identified the lesion as a reactive lymph node with abundant blood flow suggesting an inflammatory process (Fig. 2). Due to concerns over malignancy in this young patient, operative exploration was completed. Intraoperative exploration and postoperative pathology confirmed the preoperative ultrasonography diagnosis.

The patient in Case 7 presented with a painless mass in the left thigh. The patient was neurologically intact with 5/5 strength in the lower extremity. Over time, he developed discomfort and local pain over the site of the mass. Ultrasonographic evaluation demonstrated a sciatic neurofibroma (Fig. 3).

**Trauma Group**

Six patients presented with peripheral nerve trauma: stretch injury, nerve compression from trauma, or intro-
genic injury from previous surgical exploration. Ultrasonography was able to correctly identify the site of nerve trauma in all patients. The findings directed choice of conservative treatment in 1 patient, led to acute surgical exploration in another patient, and provided a correct diagnosis in an additional case in which MR imaging was nondiagnostic.

Intraoperative ultrasonography was particularly useful for surgical exploration of postoperative neuromas. The patient in Case 8 presented with left upper-extremity pain with paresthesias; findings on EMG and MR imaging studies had been normal. Subsequent ultrasonography demonstrated a 6 × 4 × 4–mm hypoechoic nodule lateral to the axillary vein, most likely representing a neuroma. The patient in Case 9 presented with severe left axillary pain radiating to the chest wall. Pertinent history included a mastectomy with axillary node dissection in 1995. Magnetic resonance imaging demonstrated central disc protrusion and mild cervical stenosis not consistent with the patient’s symptoms and signs. Subsequent ultrasonography revealed an ovoid lesion, likely representing a postsurgical neuroma. In each case, ultrasonography was used to directly localize the neuroma preoperatively via generating a Tinel sign with direct compression of the mass, and then used intraoperatively to localize and confirm extirpation of the lesion. This allowed for more limited dissection and provided real-time intraoperative confirmation of neuroma excision.

The patient in Case 10 presented with significant wrist drop following a motor vehicle accident. Electromyographic and ultrasonographic studies confirmed the diagnosis of traumatic radial nerve injury. The patient in Case 11 presented with severe right upper-extremity pain in the distribution of the ulnar nerve following a motor vehicle accident and subsequent anterior cervical discectomy. There was strong clinical suspicion of right ulnar entrapment, but EMG/NCSs revealed no focal abnormalities. Ultrasonography demonstrated severe calcific tendinosis of the common flexor tendon at the level of the medial epicondyle. The ulnar nerve was normal in caliber with no compressive signs.

The patient in Case 12 presented with lower-extremity weakness and pain following excision of a basal cell carcinoma. The patient presented to our facility 4 days after dermatological excision of the basal cell lesion. Evaluation with EMG/NCSs would likely be normal due to the acuity of the injury. An MR imaging study of the knee was completed and revealed no postoperative hematoma and a normal-appearing course of the peroneal nerve. Initial ultrasonographic evaluation demonstrated a suture penetrating the posterior third of the peroneal nerve (Fig. 4). Acute surgical decompression was subsequently performed with excellent relief of pain symptoms and limited return of ankle dorsiflexion.

### Discussion

**Magnetic Resonance Neurography**

The ability to visualize the physical characteristics of the nerves (position, gross shape, continuity, and response to injury [such as inflammation and edema]) has augmented the diagnostic and treatment capabilities that traditional EMG previously offered. These advances have improved the clinical management of nerve disorders. The use of MR neurography to assist in the diagnosis and treatment of peripheral nerve disorders has been documented repeatedly in various clinical applications. In the management of nerve trauma, MR neurography is able to demonstrate true discontinuities in the nerve using fat-suppressed T2-weighted imaging sequences that
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highlight the nerve fascicular signal and demonstrate nerve continuity. Magnetic resonance neurography may have capabilities in distinguishing between several types of thoracic outlet syndromes, allowing physicians to appropriately place patients in different surgical and treatment classifications. Magnetic resonance neurography may diagnose systemic neuropathies in conjunction with traditional nerve conduction studies.

While MR neurography has been shown to have a wide range of clinical applications, its broad use remains limited. Many radiologists and MR imaging centers have limited experience with nerve imaging. The modality is expensive and time-consuming, which limits its widespread use, and intraoperative applications are not available.

Surgical Treatment of Postoperative Neuromas

The incidence of intercostal neuralgia following thoracotomy or breast surgery is high. Questionnaires given to patients after breast surgery have shown that 53% continue to experience pain following implant reconstruction after mastectomy, 38% following breast augmentation, 31% with mastectomy alone, and 22% after breast reduction. The specific cause of intercostal neuralgia is unknown, but it may be due to chronic nerve irritation, neuroma formation, or herpes zoster. Treatment of intercostal neuralgia, especially postsurgical, has traditionally been difficult.

Surgical approaches to intercostal neuralgia have
been described. Some studies reported clinical efficacy in surgically targeting affected branches based on clinical examination, tenderness to palpation, presence of the Tinel sign, and response to pain with a local anesthetic.\cite{8,19,20}

In a series of 5 patients reported on by Wong,\cite{20} dissection was carried out immediately below the site of the positive Tinel sign. In a case report of 5 patients by Williams et al.,\cite{19} affected branches were identified after pain was relieved by an intercostal nerve block. Dissection was then carried to the affected intercostal nerve, which was followed proximally to the intercostal space. The neuroma was then resected. However, if the neuroma had not been found, the nerve was resected at a more proximal site in an unscarred bed.

Small case series demonstrated efficacy in the surgical treatment of postoperative neuromas. Surgical dissections in these case series relied on physical examination findings and response to nerve blocks, modalities unavailable in an anesthetized patient. Surgical explorations in these patients may require more extensive dissections to safely identify normal neural elements and to isolate and resect neuromas. Identifying the actual neuroma is often difficult.

We used preoperative and intraoperative ultrasonography to localize and identify painful postoperative neuromas. These lesions were correlated to clinical findings, usually by identifying a positive Tinel sign over the site of the lesion during ultrasonographic examination. Surgical approaches were tailored to limit extensive dissections and to focus on the offending neuroma alone, using intraoperative ultrasonographic guidance. We were able to immediately confirm successful removal of neuroma intraoperatively with real-time ultrasonography.

**Ultrasonography and Peripheral Nerve Lesions**

Relatively few studies have examined the use of ultrasonography in the preoperative and intraoperative treatment of patients with peripheral nerve lesions. In the initial diagnostic workup of these 13 patients with peripheral nerve lesions, ultrasonography was an effective imaging modality that augmented electrophysiological and other neuroimaging studies. Ultrasonography provided immediate visualization of a sutured peroneal nerve after a basal cell carcinoma. **Lower:** Axial view of the peroneal nerve at the level of the laceration (arrow) showing the 2 components of the lacerated nerve (N) as well as portions of the suture material (arrowheads) tethering the nerve. Operative exploration confirmed focal nerve injury at the site of basal cell excision.
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Intraoperative ultrasonography requires the availability of appropriate equipment and personnel. Intraoperative use may increase operative times, perhaps increasing the risk of perioperative adverse events and complications. While ultrasonography may reveal external continuity of nerve ultrastructure, functional continuity of nerve fibers must be assessed based on clinical and electrophysiologic examinations.

Allowing for these limitations, based on our findings we believe that high-resolution ultrasonography provides an economical and accurate imaging modality that is underutilized in the diagnosis and operative treatment of peripheral nerve lesions.

Conclusions

Further research is necessary to determine the exact role ultrasonography should play in the workup of peripheral nerve lesions. Given the small sample size and the retrospective nature of this study, it is difficult to generalize that ultrasonography should be undertaken for all forms of peripheral nerve lesions. Ultrasonography may be a useful adjunct to traditional EMG studies in cases in which entrapment neuropathy is suspected and also in those in which a mass lesion is suspected based on history and physical examination.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

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Author contributions to the study and manuscript preparation include the following. Conception and design: JK Ratliff, LN Nazarian. Acquisition of data: JK Ratliff, FC Lee, H Singh, LN Nazarian. Analysis and interpretation of data: JK Ratliff, H Singh, LN Nazarian. Drafting the article: JK Ratliff, FC Lee, H Singh, LN Nazarian. Critically revising the article: JK Ratliff. Reviewed final version of the manuscript and approved it for submission: JK Ratliff, FC Lee, H Singh, LN Nazarian. Study supervision: JK Ratliff, LN Nazarian.

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