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Multimodality Image-Guided Management of Iatrogenic Peroneal Nerve Injury

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ABSTRACT

Peripheral nerve injury may result from acute trauma or iatrogenic causes. The emergence of improved imaging techniques including high resolution ultrasound, MR neurography, and diffusion tensor imaging, enables more accurate assessment of peripheral nerve injury. We review two cases of iatrogenic peripheral nerve injury and the manner in which peripheral nerve surgeons may utilize multimodality perioperative imaging to guide management.

Keywords: Neurography, Ultrasound, Neurotisation, Diffusion tensor, Tractography

Abbreviations: EMG: Electromyography; MR: Magnetic Resonance; DTI: Diffusion Tensor Imaging; US: Ultrasound

INTRODUCTION

Injury to peripheral nerves is increasingly recognized as a source of morbidity in the traumatized patient. One study from a level I trauma center demonstrated a 2.8% prevalence of peripheral nerve injury in its trauma population. The radial nerve and peroneal nerves were the most frequently injured peripheral nerves in the upper and lower extremities respectively [1]. Although the frequency of iatrogenic peripheral nerve injury has not been well characterized, functional limb impairment, such as foot drop in our cases, can be quite disabling. The Seddon and Sunderland classification schemes have been long used to characterize peripheral nerve injury. The relative simplicity of the three category Seddon scheme is useful to peripheral nerve surgeons as it correlates well with the necessity for surgical management. Grade 1 injury, or neurapraxia, in the Seddon system represents conduction block secondary to demyelination at the site of injury and corresponds to grade 1 injury in the Sunderland classification. Conduction is maintained distal and proximal to the site of injury and therefore neurapraxia is typically reversible. Grade 2 injury, or axonotmesis, represents axonal loss with preservation of surrounding connective tissue layers and corresponds to grade 2 injury according to Sunderland. Recovery is possible through axonal regeneration, a process that occurs at approximately 1 mm per day. The severest form of peripheral nerve injury in the Seddon classification system is neurotmesis, which involves disruption of myelin and surrounding connective tissue elements. Frank discontinuity of the nerve or intervening scar tissue prevents axonal regeneration and surgical intervention is required for recovery of function [2]. The Sunderland scheme further subdivides neurotmesis into three categories. Grade 3 injury involves disruption of the endoneurial tubes while Grade 4 injuries extend to the perineurium and may result in a neuroma-in-continuity [3]. A neuroma-in-continuity represents the disorganized attempt of an injured but uninterrupted nerve to unite its fascicles at the site of injury with the distal uninjured nerve.

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It may also result from lower grade injuries [4]. Grade 5 injury, according to Sunderland, involves the epineurium and frank disruption of the nerve, often resulting in formation of a terminal neuroma. As in the Seddon classification system, grades 4 and 5, and often grade 3 injuries, require surgical repair for recovery of function [3]. Recent advances in imaging, including magnetic resonance imaging (MRI) and ultrasound, enable clinicians to accurately characterize the location, nature and extent of peripheral nerve injury noninvasively, thus expediting the surgical plan. In cases of higher grade injury, the gap between a severed nerve can be determined and nerve avulsion injuries can be identified. In addition, advances in surgical technique afford the opportunity for improved functional outcome. We present two cases of iatrogenic peroneal nerve injury and the relevant imaging studies utilized to more precisely characterize the pathologic anatomy and help the treating peripheral nerve surgeon guide surgical management. In one case, the injured nerve was surgically repaired with preoperative and intraoperative imaging providing useful information. The other case was deemed non-operable.

Case 1

***History and Examination**:* The patient is a 60 year-old man who sustained a right hamstring tendon injury during a fall. He underwent surgical repair at a separate institution approximately one month later and was noted to have right foot drop postoperatively. An iatrogenic nerve injury was suspected and the patient was referred to our center for further care 9 months after the initial injury.

EMG studies demonstrated findings most consistent with a right sciatic mononeuropathy between the surgical scar in the upper thigh and the semitendinosus muscle. The peroneal division was primarily affected with no recruitment of the tibialis anterior or peroneus longus muscles and poor recruitment of the biceps short head muscle compared to the semitendinosus. MR neurography was performed on a 3T MRI scanner (MAGNETOM Skyra, Siemens, Erlangen, Germany). It demonstrated abnormal separation of the peroneal and tibial components of the sciatic nerve in the proximal thigh over a distance of approximately 8 cm (**Figure 1a, 1b**). The peroneal component demonstrated an unusual course posteromedial to the tibial component and appeared to terminate in the region of the ischial tuberosity (**Figure 1c**). Further analysis with diffusion tensor imaging (DTI) demonstrated evidence of functioning axons in the tibial component of the sciatic nerve but no fibers were detected in the nonfunctioning peroneal component distal to the point of presumed suture repair (**Figure 2a, 2b).**

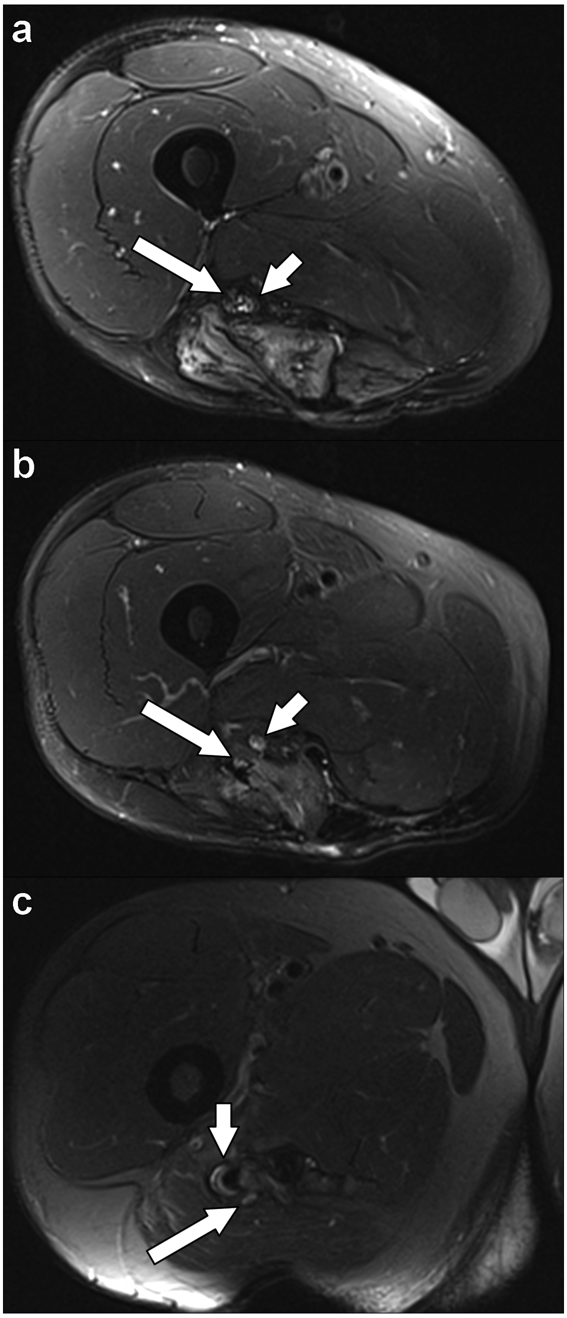

Figure 1. Axial T2-weighted fat suppressed images of the thigh. The peroneal and tibial components of the sciatic nerve are nearly apposed in the distal thigh (A, long arrow, peroneal nerve; short arrow, tibial nerve). The peroneal and tibial components are separated in the upper thigh (B, long arrow, peroneal nerve; short arrow, tibial nerve). There is abnormal posteromedial course of the peroneal nerve more proximally (C, long arrow, peroneal nerve; short arrow, tibial nerve).

***Operation**:* Ultrasound was performed intraoperatively using an iU22 ultrasound machine with a high frequency, 12MHz transducer (Philips Medical Systems, Bothel, WA). The course of the right sciatic nerve was delineated (**Figure 3a**). It was noted to have an unusual twisted configuration in the proximal thigh/buttocks junction. An incision was made along the course of the sciatic nerve using ultrasound guidance. Leads were placed in the tibial and peroneal nerve-supplied muscles to monitor sensory and motor function throughout the surgery.

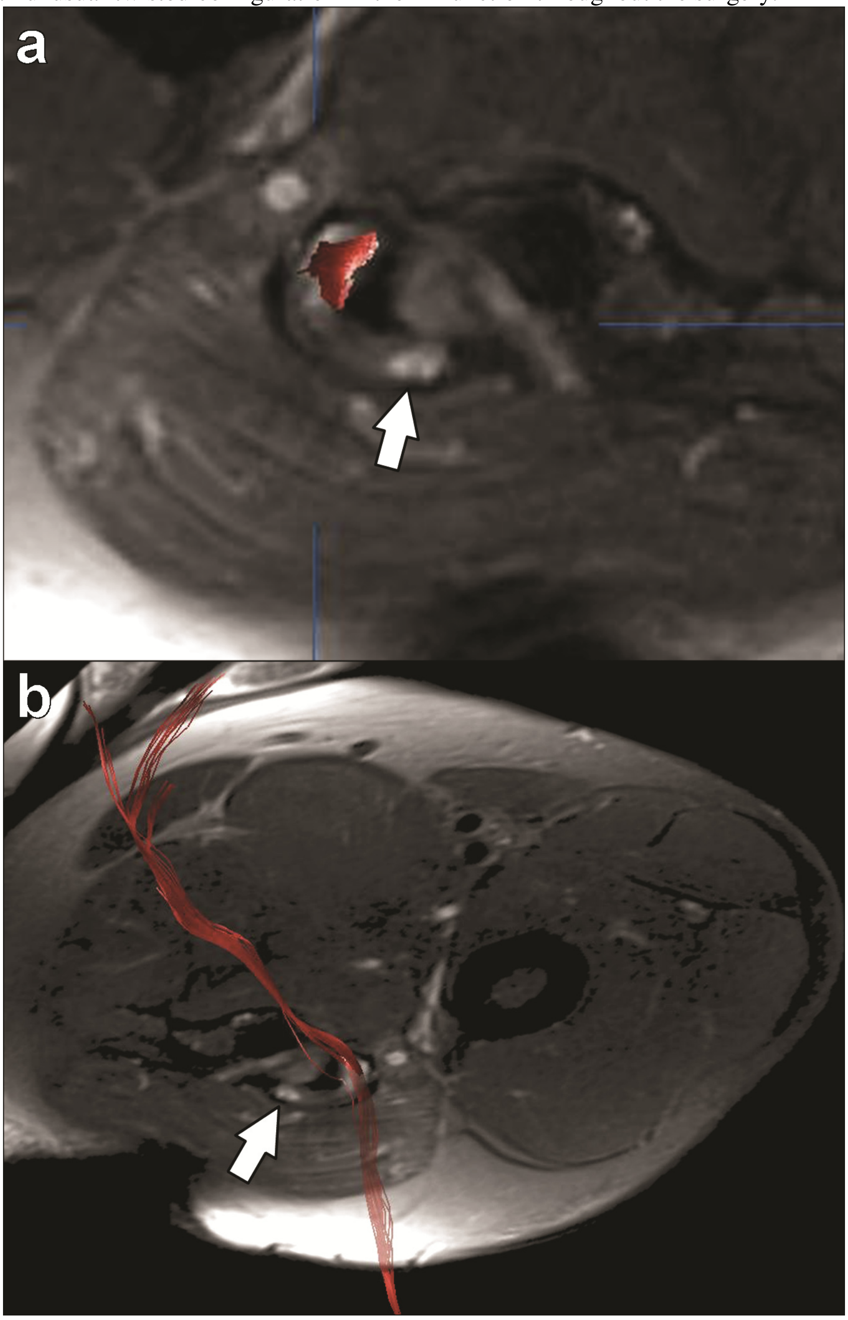

Figure 2. Diffusion tensor tractography demonstrates functional, trackable tibial nerve fibers in the upper thigh (red fibers), but no trackable peroneal nerve fibers (arrow).

Stimulation of the tibial component of the sciatic nerve above the level of the popliteal fossa evoked expected responses in the tibial nerve-supplied muscles and unexpected small responses in the peroneus longus and tibialis anterior muscles. Stimulation of the peroneal component at this level elicited no muscle response.

Proximal dissection of the sciatic nerve confirmed the preoperative imaging findings. The tibial and peroneal components of the sciatic nerve were identified as distinct structures in the proximal thigh **(Figure 3b)**. Dissection of the proximal tibial component was relatively routine. However, the peroneal component was scarred, requiring circumferential neurolysis to expose the nerve. The proximal peroneal component was then identified coursing posteromedial to the tibial component, as suggested on MR neurography, deviating from its normal lateral location (**Figure 3c**). The nerve was sutured to scar and muscle near the ischial tuberosity(**Figure 3d**). More proximal dissection to the level of the sciatic notch did not reveal a proximal peroneal nerve stump. At this point, stimulation of the proximal tibial component of the sciatic nerve evoked responses in the tibialis anterior and peroneus longus, suggesting a distal anastomosis between the two components of the sciatic nerve. Expected tibial nerve-supplied muscles also demonstrated a vigorous response.

Since a proximal stump could not be identified, the patient had essentially sustained an avulsion injury of the peroneal nerve. A decision was made to perform end-to-side neurotisation of the distal peroneal nerve stump to the side of the tibial nerve. The distal, avulsed segment of the peroneal nerve was cut in the distal mid thigh in a fish mouth configuration. The tibial component was examined under magnification. Stimulation of a posterolateral region of the nerve evoked motor responses in the peroneus longus and tibialis anterior muscles. The epineurium in this region was incised and the fishmouthed end of the peroneal component was sutured to the side of the tibial component.

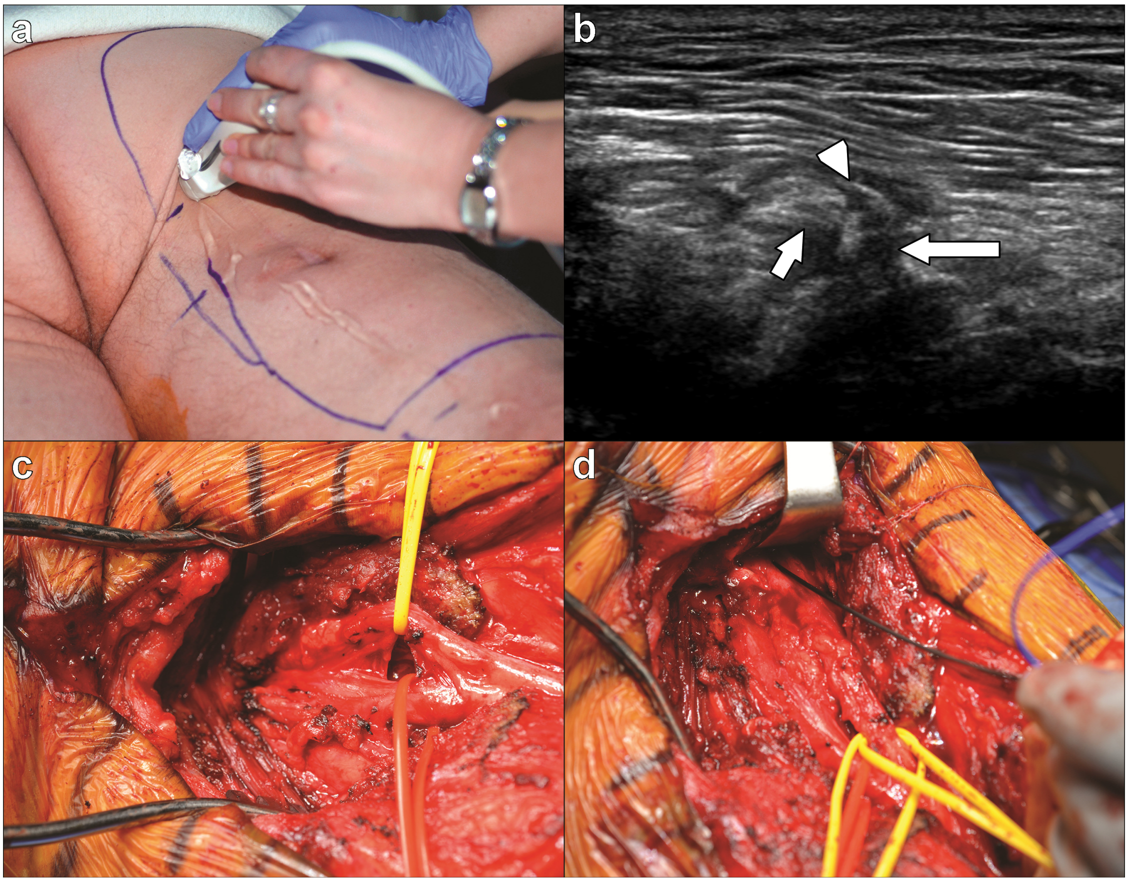

Figure 3. Intraoperative ultrasound and intraoperative images of the proximal thigh dissection.Intraoperative ultrasound confirms unusual posteromedial course of the peroneal component of the sciatic nerve in the region of injured hamstring tendon (b, arrowhead, peroneal nerve; short arrow, hamstring tendon; long arrow, tibial nerve). Dissection of the proximal thigh demonstrates separation of the peroneal and tibial components of the sciatic nerve (c, red retractor, peroneal nerve; yellow retractor, tibial nerve). Dissection near the ischial tuberosity confirms abnormal posteromedial course of the peroneal component (d).

Case 2

History and Examination: The patient is a 54-year-old female with history of right hamstring injury 4 years prior to presentation. Surgical repair was attempted shortly after the injury, but she suffered from severe pain and foot drop postoperatively. Subsequent pain management and physical therapy resulted in no significant improvement. Physical examination revealed 0/5 strength for right foot eversion and toe dorsiflexion consistent with a complete foot drop. There was also diminished sensation along the dorsum of the foot. An old posterior right buttock incision was identified.

Imaging**:** MR neurography demonstrated separation of the tibial and peroneal components of the proximal sciatic nerve after exiting the sciatic notch **(Figure 4a).** The lateral, peroneal component was edematous and enhancing. It was noted to course posteromedially in the region of prior hamstring tendon repair where it appeared to terminate (**Figure 4b**).There was fatty atrophy of the biceps femoris short head muscle compatible with injury to the peroneal component of the sciatic nerve. Probable tibial nerve injury was also demonstrated as evidenced by fatty atrophy of the biceps femoris long head, semimembranosus, and semitendinosus muscles (**Figure 4c**). Diffusion tensor imaging confirmed abnormal separation of the proximal sciatic nerve into its peroneal and tibial components. No trackable peroneal fibers were identified distal to the ischial tuberosity, where the peroneal nerve appeared to terminate, possibly having been sutured to the ischial tuberosity (**Figure 4d).**

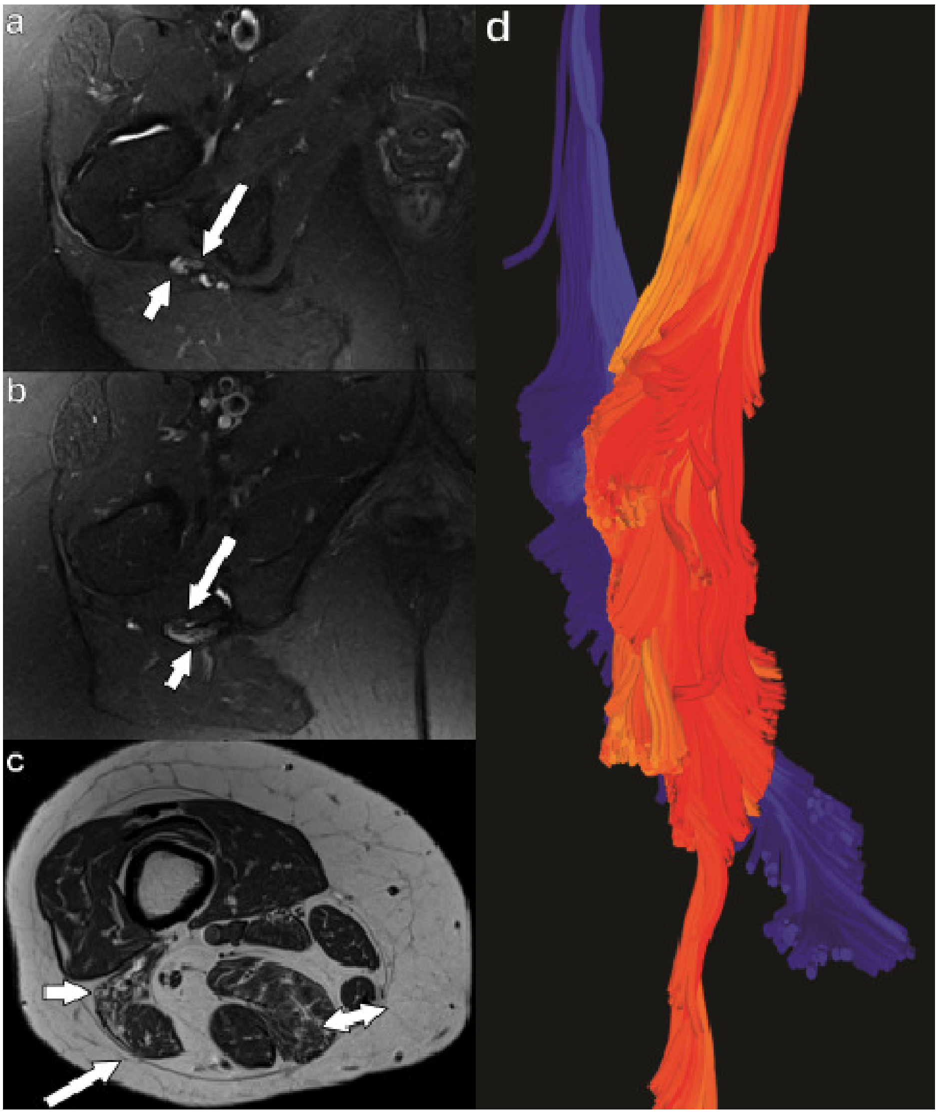

Figure 4. MR neurography and DTI study of the right thigh. (a) Axial T2-weighted fat suppressed image demonstrates abnormal separation of the tibial and peroneal components of the proximal sciatic nerve (long arrow, tibial nerve; short arrow, peroneal nerve). (b) The peroneal nerve is edematous and appears to terminate at the ischial tuberosity (short arrow, peroneal nerve; long arrow, tibial nerve). (c) Axial T1-weighted image through the mid thigh demonstrates fatty atrophy of both tibial and peroneal supplied muscles (short arrow, biceps femoris short head; long arrow, biceps femoris long head; double arrow, semitendinosus). (d) Tractography demonstrates no trackable peroneal fibers after it terminates in the region of the ischial tuberosity (blue, peroneal nerve; red, tibial nerve).

Management: The chronic nature of the injury precluded surgical repair in this case. Implantation of a sciatic nerve stimulator was discussed as a tool for pain management, however the patient opted for continued medical pain management.

DISCUSSION

One surgical approach to peripheral nerve injury is neurorrhaphy, whereby distal and proximal nerve stumps are directly anastomosed. A large gap between nerve stumps precludes neurorrhaphy and the gap may be bridged by an interposition nerve graft or conduit. More severe injury such as nerve root avulsion may be addressed with nerve root reimplantation, nerve transfer, or neurotisation. Neurotisation procedures are well described in the setting of brachial plexus avulsion injuries. The goal of neurotisation is to decrease the distance between the target muscle and regenerating axons, thus decreasing the time to potential recovery. During neurotisation, the distal portion of an injured nerve is sutured to an intact, uninjured nerve. Successful recovery of target muscle function has been reported with side-to-side, end-to-side, and end-to-end techniques [5]. A number of findings are important in determining the management of patients with peripheral nerve injuries, including the site and degree of injury as well as its chronicity. Imaging can be helpful to better characterize these injuries and provide peripheral nerve surgeons with valuable information to better plan appropriate management and possible surgical intervention.

Preoperative MR neurography, DTI and intraoperative ultrasound can be used in conjunction with intraoperative electrical stimulation to direct surgical management.

MR neurography utilizes high signal-to-noise, high spatial resolution T1-weighted nonfat-suppressed and heavily T2-weighted fat-suppressed sequences as well as isotropic 3D images to evaluate the course, caliber, and fascicular architecture of nerves. Peripheral nerve edema, abnormal fasciculation, aberrant course of a nerve, and frank disruption of a nerve can all be assessed with MR neurography (6). Sunderland Grades 1-3 nerve injury may result in diffuse nerve swelling without focal enlargement. Signal changes in the target muscle secondary to denervation may be seen with Grade 2 and Grade 3 injuries, although distinguishing between these grades is not possible on imaging as the endonuerium is below the resolution of current MRI techniques. This is of doubtful clinical significance because these lower grade injuries are typically treated medically. MR neurography can be helpful in assessing grade 4 or 5 injuries to ensure timely surgical intervention. Neuroma-in-continuity or frank disruption of a nerve, including the gap between its proximal and distal stumps, can be accurately characterized with MR neurography [3]. Limitations of MR neurography primarily relate to the limits of its spatial resolution and field signal inhomogeneity, which may obscure the detection of subtle peripheral nerve abnormalities.

Du and colleagues demonstrated that MR neurography provided additional diagnostic information in 45% of patients with spinal and peripheral nerve disorders, beyond the information provided by electromyography and nerve conduction studies [7]. In case #1, MR neurography yielded a more precise anatomic characterization of the injury than preoperative EMG studies which were only able to localize the injury to somewhere in the upper thigh. Abnormal morphology of the proximal right sciatic nerve and the aberrant course of its peroneal component were MR neurography findings corroborated intraoperatively. In case #2 MR neurography provided anatomic correlation for the patient’s clinically apparent foot drop. Associated muscle fatty atrophy in the peroneal and tibial nerve distributions confirmed the irreversible nature of the injury and helped the treating peripheral nerve surgeon determine that surgical management would not likely be helpful to this patient.

MR neurography may also provide functional information by utilizing diffusion tensor imaging. Various quantitative parameters can be obtained from this technique including fractional anisotropy, axial diffusivity, radial diffusivity, and apparent diffusion coefficient. These parameters have been shown to be reproducible in the evaluation of peripheral nerves [8]. It has been shown that axial diffusivity correlates with axon integrity while fractional anisotropy reflects myelin sheath integrity [9]. DTI can be used to develop tractograms which represent a 3-dimensional graphical depiction of a nerve and its course. It must be noted that DTI and tractography are extremely labor intensive techniques and the selection of mathematical parameters such as fractional anisotropy and diffusivity can greatly impact the accuracy of tractograms. Selection of strict parameters may result in the false identification of peripheral nerve disruption due to exclusion of intact fascicles. Conversely, overly inclusive parameters may result in the false interpretation of intact fascicles when in fact none exist. The quality of this technique also greatly varies with magnetic field strength, offering much greater spatial resolution and decreased imaging time with 3 Tesla magnets. It should be emphasized that tractograms provide functional information and not the anatomic characterization of individual nerve fibers [10].

DTI in case #1 demonstrated an intact tibial component of the sciatic nerve and disruption of the peroneal component, which corroborated findings on EMG and intraoperative electrical stimulation of the proximal sciatic nerve. It did not identify the unexpected distal anastomosis between the tibial and peroneal components of the sciatic nerve identified during intraoperative electrical stimulation. This finding may have been below the threshold of included parameters. Alternatively, scarring or inflammation may have altered diffusivity. In case #2, the DTI study demonstrated no trackable peroneal fibers distal to the ischial tuberosity where the peroneal nerve appeared to terminate (**Figure 4d**). This was consistent with the patient's clinically apparent complete foot drop.

Ultrasound may provide additional preoperative and intraoperative evaluation to guide surgical management. It offers the advantages of being dynamic, cost effective, and fast. The depiction of nerve pathology by high-resolution ultrasound parallels that of MR neurography, including abnormal caliber, fascicular architecture, course, or discontinuity of a nerve [11]. In addition, intraoperative ultrasound can be used to map the location of peripheral nerves to guide surgical approaches. Sonographic evaluation of peripheral nerves may be limited when imaging deep structures. The nerve of interest may also be obscured by bone, gas, and surgical material such as sutures.

CONCLUSION

We demonstrate the utility of a multimodality imaging approach in the assessment of patients with peripheral nerve trauma and the synergistic value of preoperative and intraoperative imaging in a patient deemed to be a surgical candidate. Image-based anatomic and functional characterization of the patient's injury serve not only to confirm findings suggested by clinical and electrophysiologic assessment, but may also to help expedite a precise and well informed surgical approach. In other patients, such as in our second case, the imaging findings of chronic nerve injury can help the peripheral nerve surgeon deem that medical management rather than surgical intervention would provide a better result. Therefore, imaging may add significant value for the surgeon and ultimately improve outcomes for peripheral nerve trauma patients.

REFERENCES

1. Nobe J, Munro CA, Prasad VS, Midha R (1998) Analysis of upper and lower extremity peripheral nerve injuries in a population of patients with multiple injuries. J Trauma 45: 116-122.
2. Grant, GA, Goodkin R, Kliot M (1999) Evaluation and Surgical Management of Peripheral Nerve Problems. Neurosurgery 44: 825-839.
3. Chhabra A, Ahlawat S, Andreseik G (2014) Peripheral nerve injury grading simplified on MR Neurography: As referenced to Seddon and Sunderland classifications. Indian J Radiol Imag 24 : 217-224.
4. Chhabra A, Williams EH, Wang KC, Dellon AL, Carrino JA (2010) MR neurography of neuromas related to nerve injury and entrapment with surgical correlation. AJNR 31: 1363-1368.
5. Simon NG, Spinner RJ, Kline DG, Kliot M (2016) Advances in the neurolgocical and neurosurgical management of peripheral nerve trauma. J Neurol Neurosurg Psychiatry 87: 198-208
6. Chhabra A, Andreisek G, Soldatos T, Wang KC, Flammang AJ, et al. (2011) MR Neurography: past, present, future. AJR 197: 583-591.
7. Du R, Auguste, KI, Chin CT, Engstom JW, Weinstein PR (2010) Magnetic resonance reurography for the evaluation of peripheral nerve, brachial plexus, and nerve root disorders. J Neurosurgery 112: 362-371.
8. Simon NG, Lagopoulos J, Gallagher T, Kliot M, Kierman MC (2016) Peripheral nerve diffusion tensor imaging is reliable and reproducible. J Mag Reson Imag 43: 962-969.
9. Heckel A, Weiler M, Xia A, Ruetters M, Pham M, et al. (2015) Peripheral nerve diffusion tensor imaging: assessment of axon and myelin sheath integrity PLoS One 10.
10. SantarelliX, GarbinG, UkmarM, Longo R (2010) Dependence of the fractional anisotropy in cervical spine from the number of diffusion gradients, repeated acquisition and voxel size. Magn Reson Imag 28: 70–76.
11. Yablon CM, Hammer MR, Morag Y, Brandon CJ, Fessell, DP (2016) US of the peripheral nerves of the lower extremity: a landmark approach. Radiographics 36.