

**The Role of MRI in the Diagnosis and Treatment of Peripheral Nerve Problems:
Application to “Tumors”**

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Radiologists experienced in the interpretation of high resolution MR imaging form an important component of a multidisciplinary team approach in the comprehensive evaluation and treatment of patients with peripheral nerve disorders. I will emphasize the role of MRI in clinical decision making by specifically discussing 3 different types of neural lesions producing enlarged nerves or masses. In all of these examples, patient outcomes are improved by this integrated approach.

- 1. patients with idiopathic diseases who have nonspecific imaging abnormalities in whom fascicular biopsy proved diagnostic.**
- 2. patients with intraneural ganglia in whom understanding the controversial pathogenesis can be elucidated with imaging**
- 3. patients who had “unresectable” mass lesions (sciatic notch dumbbell tumors) but in whom high resolution MRI predicted that they could be resected safely.**

Example 1: Defining “idiopathic” peripheral nerve disorders. The role of fascicular or rootlet biopsy in patients with abnormal nerves on MRI.

The diagnosis of many neuropathies, plexopathies and radiculopathies remains elusive despite thorough physical examination, laboratory evaluation, routine MR imaging and even, distal cutaneous nerve biopsy. Empiric treatment (be it medical or surgical) is typically attempted with limited success for neurologic recovery. In the past five years, over 100 patients with severe, progressive non-compressive neurologic disorders were evaluated by physical examination, electrodiagnostic studies and high resolution MR imaging. Mass lesions per se were excluded. MR images were abnormal but inconclusive, consisting of signal abnormality and/or enlargement of nerves. These imaging abnormalities, which were often subtle, were identified prospectively by a radiologist with expertise in peripheral nerve imaging, but were not generally appreciated by the initial reading by a general radiologist. Targeted fascicular biopsy of a major proximal peripheral nerve (e.g., sciatic nerve, femoral nerve, brachial or lumbosacral plexus, etc) or a nerve rootlet biopsy (i.e., cauda equina) was performed in these patients by a single peripheral nerve surgeon. The site of biopsy was selected based on the neurologic localization and surgical accessibility and was correlated with the site of imaging abnormalities. One or two fascicles or rootlets were chosen by the pattern of preoperative maximal neurologic deficit and the pathologic appearance, if observed at operation. In our experience, the diagnostic yield was approximately 80%, providing either diagnostic or highly suggestive histology of a specific pathologic alteration, including lymphoma, metastatic carcinoma, sarcoidosis, perineurioma, inflammatory/immune suggestive of vasculitis and inflammatory demyelinating disorders. Neurologic worsening or other complication was seen in approximately 5% of patients directly resulting from the biopsy (in general, lower for fascicular biopsies than cauda equina biopsies).

MRI targeted biopsy based on clinical and radiographic assessment is a useful operative technique for previously undiagnosed neurologic conditions. This technique, when performed at a center specializing in peripheral nerve diseases and surgery, can frequently establish a diagnosis and be performed safely. High resolution MR images have proved useful in localizing focal or multifocal nerve lesions. Although they were

not by themselves diagnostic of the pathologic process, we believe that with additional experience and histologic correlation, new radiographic patterns will be identified, potentially avoiding the need for biopsy. At the current time, proximal biopsies at sites of imaging abnormality provide specific diagnostic information not identified in distal nerve, and despite being invasive may be justified because of therapeutic implications in select patients with imaging abnormalities of nerve.

Example 2: The “Tail” of Intra-neural Ganglia: Treating the joint connection is a necessary part of surgery.

We have utilized high resolution imaging to tackle a century-old controversy related to the pathogenesis and treatment of intra-neural ganglia. Because of inexperience with these rare peripheral nerve lesions, radiologists and surgeons do not identify joint connections on routine imaging or at surgery which leads to recurrences when they are not treated and increases the skepticism about an articular origin of the cysts. Even those who are experienced with these connections may miss them because they may be small or distant from the bulk of the cyst. Ironically, joint connections are often identified after recurrences; in these cases, retrospective review of the initial images can typically reveal the connections. Understanding that these cysts derive from neighboring joints rather than form de novo (as commonly believed) has important implications: guiding operative interventions, improving outcomes and eliminating recurrences. By developing and refining specific radiological techniques to delineate joint-related connections with the cysts, we have shed further light on the disputed origin of these types of ganglion cysts.

First we analyzed a large series of peroneal intra-neural ganglia and demonstrated a connection to the superior tibiofibular joint in every case.¹ We demonstrated that the clinical presentation, electrodiagnostic studies, imaging characteristics, operative findings, and histological features are predictable – facts which point to a common denominator. Based on these data and an exhaustive review of the literature, we proposed a unified (articular) theory to explain the formation of these cysts, using the peroneal nerve as a prototype.² Our theory is that intra-neural ganglia derive from joints, penetrate through a capsular rent, and dissect via the path of least resistance up the epineurium of nerves via articular branches, typically causing intrinsic compression of

nerve. In contrast, we proposed that the more common simple or extraneural ganglia dissect in the soft tissue outside of nerves, but on occasion may extrinsically compress them. Increased intraarticular pressure increases the likelihood of cyst dissection through a one-way valve.

We then embarked on testing our unified theory by analyzing peroneal intraneural ganglia reported by others in whom the authors' claim was that there was no joint connection identified at surgery. Review of the original MRI's in selected cases revealed previously unrecognized joint connections. Because the joint connections were not addressed operatively, these same cases were predicted to fail; they were demonstrated to have cyst persistence or recurrences when postoperative MRI's were subsequently performed.¹ We believe that MRI's may be easily misinterpreted due to technical factors – such as thickness of cuts, poor view of joints and interpretation errors - limited knowledge or experience of radiologists interpreting the films.

We then postulated that our unified theory could be substantiated at several rare sites of intraneural ganglia, including the tibial nerve at the superior tibiofibular joint³ as well as the suprascapular nerve at the glenohumeral joint.⁴ In all of these examples, we documented joint connections and communications for the first time. Recently, another group^{5,6} has also verified our unified theory in a large series testing multiple sites.

Various imaging modalities have been used to diagnose intraneural ganglia and establish a joint connection, including ultrasound, CT, and MRI. In order to help radiologists and surgeons visualize the connections and communications preoperatively, we have refined radiographic techniques. High resolution MRI with thin slices routinely delineate joint connections, but ultimately CT arthrography and MRI arthrography^{1,7} are needed to demonstrate a communication between the joint of origin and the cyst. In cases of “occult” connections, demonstration of the communication may require delayed and/or stress imaging, presumably by increasing intraarticular pressure.⁷ Even these refinements of standard imaging modalities provide only two-dimensional representation of complex three-dimensional anatomic problems. To support this concept, we have investigated the application of a new 3D rendering technique. We believe that 3D rendering of MRI data sets will prove to be a useful tool in demonstrating joint connections that may be “occult”

with routine data display and illustrating the relationship of the cysts to important structures such as nerves and vessels.⁸

Improvements in imaging will facilitate our understanding of the pathophysiology of these cysts and ultimately our treatment of patients with this disorder.

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Example 3: Making the unresectable...resectable. Safe resection of extensive sciatic notch dumbbell tumors can be predicted (and achieved) using high resolution MRI to enhance visualization of the relationships of nerves to mass lesions.

The operative management of symptomatic patients with sciatic notch dumbbell (combined intra- and extrapelvic) tumors is challenging. Their relative rarity and extent of disease have made it difficult for surgeons to establish definitive surgical indications or predict favorable neurologic outcomes based on preoperative imaging. In the past three years, we have managed five patients with benign sciatic notch dumbbell tumors who presented with radiating leg pain affecting seven limbs. Three of these patients with unilateral leg symptoms underwent a combined one-stage transabdominal and posterior transgluteal approach after radiologic interpretation of high resolution MR images determined that the extensive tumors appeared discrete from the sciatic nerve and the lumbosacral plexus. In view of the extent and location of pathoanatomy as evident on

interpretation of the initial MR images, neurosurgeons at other institutions presumed direct intrinsic neural involvement and considered these lesions to be unresectable. Gross total resection was achieved in these cases and histology revealed two plexiform neurofibromas (in patients with NF-1) and one myxoma. These three patients maintained normal neurologic status postoperatively. At follow-up more than one year postoperatively, these patients had no recurrence radiographically. Two patients with bilateral symptoms, who did not undergo surgery, had a diagnosis of NF-1 and extensive tumor burden; they had previous biopsies from these limb lesions which were diagnostic of plexiform neurofibromas. These lesions had the classic radiographic appearance of plexiform neurofibromas affecting the sciatic nerve complexes bilaterally; innumerable tumors directly involved the entire cross-sectional area of the sciatic nerves which extended longitudinally to the lumbosacral plexuses as visualized on serial MR images. In them, tumor debulking or resection would have resulted in neurologic deficit, would not have addressed the neuropathic pain and was not performed. They were treated pharmacologically and were recommended to have life-long tumor surveillance for the possibility of malignant transformation. A combined transabdominal and transluteal approach allows safe resection of selected benign but extensive sciatic notch tumors. High resolution MRI is a useful adjunct in the management of these patients in that it allows visualization of the anatomic relationships of the tumor to the sciatic nerve. We believe that advancements in this technology will provide surgeons with a means to predict definitively which sciatic notch tumors displace rather than directly involve the sciatic nerve or lumbosacral plexus, suggesting which tumors can be resected safely and completely. This application of high resolution MRI has implications for resection of other more common neurogenic or non-neurogenic tumors at other locations as well: definitive identification of the relationships of the nerve to masses can distinguish those tumors in close proximity to nerve from those intrinsically involving nerve, enabling surgeons to plan operative interventions and predict neurologic outcomes.