Magnetic resonance neurography evaluation of chronic extraspinal sciatica after remote proximal hamstring injury: a preliminary retrospective analysis

Clinical article

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Object. Extraspinal sciatica can present unique challenges in clinical diagnosis and management. In this study, the authors evaluated qualitative and quantitative patterns of sciatica-related pathology at the ischial tuberosity on MR neurography (MRN) studies performed for chronic extraspinal sciatica.

Methods. Lumbosacral MRN studies obtained in 14 patients at the University of California, San Francisco between 2007 and 2011 were retrospectively reviewed. The patients had been referred by neurosurgeons or neurologists for chronic unilateral sciatica (≥3 months), and the MRN reports described asymmetrical increased T2 signal within the sciatic nerve at the level of the ischial tuberosity. MRN studies were also performed prospectively in 6 healthy volunteers. Sciatic nerve T2 signal intensity (SI) and cross-sectional area at the ischial tuberosity were calculated and compared between the 2 sides in all 20 subjects. The same measurements were also performed at the sciatic notch as an internal reference. Adjacent musculoskeletal pathology was compared between the 2 sides in all subjects.

Results. Seven of the 9 patients for whom detailed histories were available had a specific history of injury or trauma near the proximal hamstring preceding the onset of sciatica. Eight of the 14 patients also demonstrated soft-tissue abnormalities adjacent to the proximal hamstring origin. The remaining 6 had normal muscles, tendons, and marrow in the region of the ischial tuberosity. There was a significant difference in sciatic nerve SI and size between the symptomatic and asymptomatic sides at the level of the ischial tuberosity, with a mean adjusted SI of 1.38 compared with 1.00 (p < 0.001) and a mean cross-sectional nerve area of 0.66 versus 0.54 cm² (p = 0.002). The control group demonstrated symmetrical adjusted SI and sciatic nerve size.

Conclusions. This study suggests that chronic sciatic neuropathy can be seen at the ischial tuberosity in the setting of prior proximal hamstring tendon injury or adjacent soft-tissue abnormalities. Because hamstring tendon injury as a cause of chronic sciatica remains a diagnosis of exclusion, this distinct category of patients has not been described in the radiographic literature and merits special attention from clinicians and radiologists in the management of extraspinal sciatica. Magnetic resonance neurography is useful for evaluating chronic sciatic neuropathy both qualitatively and quantitatively, particularly in patients for whom electromyography and traditional MRI studies are unrevealing.

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KEY WORDS • extraspinal sciatica • sciatic nerve • peripheral nerve • magnetic resonance neurography • peripheral neuropathy • hamstring tear

Abbreviations used in this paper: FOV = field of view; MRN = MR neurography; NEX = number of excitations; ROI = region of interest; SI = signal intensity.
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were sprinters) who presented with several months of sciatica and who reported a remote history of proximal hamstring tear. Complete pain relief was obtained in 52 of 59 patients after surgical division of “tight, tendinous structures” at the lateral proximal origin along the ischial tuberosity, adjacent to the sciatic nerve. Magnetic resonance neurography (MRN) is a powerful tool for imaging peripheral nerves. In contrast to routine MRI of the lumbosacral spine, MRN uses high-resolution thin-section sequences to image the course of the sciatic nerve (Fig. 1). Basic science studies have shown that pathological and electrophysiological changes of abnormal nerves clearly correlate with abnormal nerve signal, caliber, and/or course on MRN. Additionally, prior case studies have demonstrated that MRN is very useful in the diagnosis of extraspinal sciatica. The technique can clearly demonstrate both abnormalities of the sciatic nerves and the diverse etiologies of sciatic neuropathy that are not readily appreciated on routine MRI studies of the lumbosacral spine.

The purpose of this study was 1) to characterize adjacent soft-tissue abnormalities at the level of the ischial tuberosity in a sample of patients with abnormal sciatic nerve signal intensity (SI) on MRN, and 2) to perform a quantitative assessment of the nerve in patients with unilateral sciatica who had qualitative nerve abnormalities at the level of the ischial tuberosity.

Methods

Study Subjects

This study was approved by the local institutional review board. The radiology and hospital databases were searched for patients in whom lumbosacral MRN was performed between January 2007 and January 2011, who had chronic symptoms of sciatica (≥ 3 months), and whose MRN reports qualitatively described unilateral increased sciatic nerve SI at the ischial tuberosity. Fifteen potential cases were identified of patients who had been referred by neurologists and neurosurgeons and had a history of unilateral sciatica. The neurological examination and clinical notes for each patient were reviewed for the following data: 1) any specific trauma or injury history previous to the development of symptoms; 2) any history of targeted (minimally invasive or surgical) therapy for the symptoms of sciatica; and 3) long-term clinical follow-up for patients who had had treatment. All prior routine MR lumbosacral imaging was also reviewed to identify any patients with spinal abnormalities that could cause sciatica. One of the 15 patients had severe lower lumbar neuroforaminal stenosis ipsilateral to the clinically affected side and was excluded from the study. Lumbosacral MRN was also performed prospectively in 6 healthy volunteers with no lower-extremity pain or sciatica symptoms. Written informed consent was obtained from the healthy volunteers before their MRN studies were performed.

Protocol for MRN

The MRN studies were performed with the patient supine on 1.5-T (10 patients) and 3-T (4 patients) MR units in which a phased-array body/torso coil (GE Healthcare) was used. In the 6 healthy volunteers all images were obtained at 1.5 T (Avanto, Siemens). Imaging covered the course of the sciatic nerve from the L3–4 level through the midpoint of the femur, with the following sequences: coronal and axial T1 (TR 600 msec, TE minimum achievable with full echo acquisition, FOV 20–36 cm, NEX 3); T2 fat saturation in 10 patients (TR 4200 msec, TE 90 msec, FOV 20–36 cm, NEX 3); STIR in 4 patients (TR 2200 msec, TE 20 msec, TI 150 msec, FOV 20–36 cm, NEX 3). Three radiologists with 32, 17, and 4 years of radiology experience evaluated all examinations in consensus on a PACS workstation (Impax). The readers were blinded to the patients’ clinical history and prior reports.

Analysis of the MRN Images

The neurograms were evaluated in blinded fashion by 3 radiologists in consensus (M.B., L.S., and C.C., who have 6, 27, and 12 years of experience, respectively, with MRI). (Please note that although the radiologists were blinded to the studies, it was not possible to blind them to differences in image quality particular to either the GE or Siemens scanners.) To measure sciatic nerve size, the measurement tool on the PACS workstation was used to outline the exact sciatic nerve circumference on the T1-weighted images. The ovoid region of interest (ROI) automatically produced a measurement of the area within the ovoid region in square centimeters. This measurement was performed at the ischial tuberosity, adjacent to the level of the proximal hamstring tendon origin and at the sciatic notch, bilaterally.

To evaluate changes in sciatic nerve T2 SI, an ovoid ROI was placed at the center of the location of the highest apparent sciatic nerve SI on the axial T2-weighted images. This generated a value for SI in arbitrary units. A...
similar ROI was placed in the normal ipsilateral posterolateral gluteus maximus muscle at the same level, and the ratio of the former to the latter was used to calculate an adjusted SI (a unitless ratio). These measurements were also performed adjacent to the level of the proximal hamstring tendon origin and at the sciatic notch.

The sciatic nerves and adjacent skeletal muscles, tendons, and ligaments of the pelvis and thighs were qualitatively evaluated bilaterally at the level of the ischial tuberosity for changes in SI and size. Four categories were denoted: 1, normal adjacent soft tissues; 2, abnormal proximal hamstring tendon signal; 3, abnormal muscle signal adjacent to the ischial tuberosity; and 4, other pathology adjacent to the ischial tuberosity (for example, bony or ligamentous pathology).

Statistical Analysis

Statistical analysis of the sciatic nerve area and SI obtained at the 2 levels of measurement were analyzed with Wilcoxon matched-pairs signed-ranks tests to compare the sciatic nerves between the 2 sides in both the patient and control cohorts. The 95% confidence intervals were also calculated. Data analysis was performed with commercially available software (InStat 3.1a, GraphPad). The reproducibility of nerve cross-sectional area and SI has been validated in prior work by our group. Receiver operating characteristics curves have demonstrated an area under the curve of 0.88 for nerve area and 0.82 for nerve relative SI.

Results

There were 11 women and 3 men with a mean age of 56 years (range 36–85 years) among the symptomatic patients (Table 1). In all patients the results of clinical examinations were consistent with sciatica. Thirteen patients had buttock pain radiating down the posterior thigh into the leg. One patient had subtle lower leg sensory impairment and weakness. Seven of the 9 patients for whom detailed histories were available had a specific history of injury or trauma preceding the onset of sciatica. The remaining patients had no history of a specific inciting event. All 14 patients had unremarkable results on routine MRI studies for lumbosacral radiculopathy prior to undergoing MRN. Additionally, the MRN reports for all patients described qualitative differences in sciatic nerve SI on the affected side when evaluated at the level of the ischial tuberosity, in comparison with the contralateral side. Additionally, there were 4 women and 2 men in our control cohort with a mean age of 31 years (range 24–50 years). The 6 individuals in our control cohort were asymptomatic at the time of imaging, with no relevant clinical history over the prior 3 months.

Qualitative categorization and quantitative measurements are listed for each patient in Table 2. Among our 14 patients, 8 demonstrated focal qualitative differences of the soft tissues in the region of the ischial tuberosity on the side of the patient’s symptoms. Seven of those 8 demonstrated asymmetrical, abnormal increased T2 signal at the proximal hamstring tendon origin and adjacent soft tissues (Categories 2 and 3) compatible with partial tear or peritendinosis (Fig. 2). Also, 2 of the 8 patients demonstrated increased T2 signal of both the adjacent obturator internus and quadratus femoris muscles (Category 3) (Figs. 3 and 4). The remaining 6 patients, and all 6 individuals in our control group, had normal tendon, marrow, and muscle signal in the region of the ischial tuberosity (Category 1) (Fig. 5).

Quantitative differences in the ratio of the adjusted sciatic nerve SI relative to normal muscle (posterolateral gluteus maximus at the interrogated level) and the sciatic nerve cross-sectional diameters were compared between the 2 sides with Wilcoxon matched-pairs signed-rank tests (Tables 3 and 4) at 2 sites—the ischial tuberosity, and more proximally near the sciatic notch. At the ischial tuberosity,

### Table 1: Demographic data in 14 patients with chronic extraspinal sciatica*

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs), Sex</th>
<th>Duration of Sciatica Sxs</th>
<th>Specific Trauma Hx?</th>
<th>If so, What?</th>
<th>Exam Consistent w/ Sciatica?</th>
<th>EMG Available?</th>
<th>EMG Consistent w/ Sciatica?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>67, M</td>
<td>13 mos</td>
<td>yes</td>
<td>hamstring injury, squash</td>
<td>yes</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>61, F</td>
<td>2 yrs</td>
<td>yes</td>
<td>blunt force to hip/hamstring</td>
<td>yes</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>45, F</td>
<td>6 mos</td>
<td>NA</td>
<td></td>
<td>yes</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>41, F</td>
<td>9 mos</td>
<td>yes</td>
<td>hamstring injury, yoga</td>
<td>yes</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>55, F</td>
<td>6 mos</td>
<td>NA</td>
<td></td>
<td>yes</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>59, F</td>
<td>11 mos</td>
<td>no</td>
<td></td>
<td>yes, yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>7</td>
<td>85, M</td>
<td>4 yrs</td>
<td>yes</td>
<td>It total hip replacement</td>
<td>yes</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>54, M</td>
<td>6 mos</td>
<td>NA</td>
<td></td>
<td>yes</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>56, F</td>
<td>3 mos</td>
<td>NA</td>
<td></td>
<td>yes</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>36, F</td>
<td>3 mos</td>
<td>NA</td>
<td></td>
<td>yes</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>65, F</td>
<td>3 mos</td>
<td>yes</td>
<td>hamstring injury, marathon walking</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>12</td>
<td>50, F</td>
<td>5 yrs</td>
<td>yes</td>
<td>hamstring injury, basketball</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
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<tr>
<td>13</td>
<td>40, F</td>
<td>2.5 yrs</td>
<td>yes</td>
<td>hamstring injury, long-distance running</td>
<td>yes</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>44, F</td>
<td>10 yrs</td>
<td>no</td>
<td></td>
<td>yes</td>
<td>yes</td>
<td>no</td>
</tr>
</tbody>
</table>

* EMG = electromyography; Hx = history; NA = not available; Sxs = symptoms.
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the sciatic nerves demonstrated a significantly larger caliber and increased T2 SI on the symptomatic side relative to the contralateral asymptomatic side. The mean adjusted SI on the symptomatic side was 1.38 compared with 1.00 on the contralateral side, and the distributions between the different sides differed with high statistical significance (W+ [the sum of all positive ranks] = 103.0, W− [the sum of all negative ranks] = −1.0; p < 0.001 on 2-tailed t-test). The mean sciatic nerve cross-sectional area was also significantly greater in the affected limb compared with the contralateral side: 0.66 cm² compared with 0.54 cm² (W+ = 98.5, W− = −6.5; p = 0.002 on 2-tailed t-test). As a comparison, the same sciatic nerve measurements were performed just distal to the sciatic notch. At this more proximal level there were no significant differences in sciatic nerve adjusted SI or cross-sectional area between the symptomatic and contralateral sides.

In all patients the management was initially conservative, in part with medication, which did not provide complete symptom relief. Three patients underwent targeted surgery or intervention. One patient had a CT-guided nerve block at the level of the ischial tuberosity, I had palpation-guided injection of ropivacaine at the level of the ischial tuberosity, and I had surgical sciatic neurolysis. All patients with surgical or percutaneous interventions reported marked relief of symptoms following the intervention.

Discussion

Extraspinal sciatica is a challenging clinical syndrome
to diagnose and treat. Because classic spine-related sciatica is such a pervasive condition among adults, patients with extraspinal causes can end up lost among the multiple pathways of clinical diagnostic studies, which are most often designed to home in on classic spine-related pathology. Magnetic resonance neurography has shown a wide range of novel applications in recent years for evaluating peripheral neuropathies, and has previously been shown to demonstrate abnormal sciatic nerve SI and size in addition to characterizing pathology originating extrinsic to the nerve that may result in sciatic symptoms. However, even with this advanced imaging technique, misdiagnosis persists because of the extended length of the sciatic nerve and an incomplete understanding of specific patterns of sciatic neuropathy.

Sciatica related to hamstring injury and trauma to the ischial tuberosity region has been described predominantly in rare case reports and has not previously been studied specifically by using MRN. Although sciatic neuropathy can be caused by lesions involving the nerve at many different levels along its course, our results suggest the possibility of a unique subset of patients who experience neuropathy as a result of nerve pathology at the level of the ischial tuberosity, in association with adjacent soft-tissue abnormalities. Most often there was concomitant increased SI within the ipsilateral proximal hamstring tendons and muscles in our cohort of patients. These changes may reflect associated trauma, reactive changes to hamstring tendon injury, and/or focal denervation. The precise clinical correlation is not well understood, and more detailed studies with extended clinical follow-up will be necessary to more completely elucidate the relationship between pathological imaging findings and the course of a patient’s illness.

Additionally, although our control group did not demonstrate significant asymmetry in hamstring tendon signal, we recognize that asymmetrical hamstring tendinosis is a frequent finding on MRI studies of the lumbosacral spine and pelvis. Many of these patients will not have sciatica. Thus, it is important that alternative etiologies of sciatica are excluded prior to attributing a patient’s symptoms to hamstring tendon pathology.

There may be several mechanisms responsible for the concomitant abnormalities within the sciatic nerve and at the adjacent hamstring tendon origin. It is possible that there could be mechanical compression of both structures from a single or repetitive traumatic event. Alternatively, reactive changes predominantly related to indolent hamstring tendon injury might lead to collateral involvement of the nerve. Previous surgical exploration in patients with this constellation of findings noted dense adhesions that had developed between the nerve and tendons, again confirming the radiographic findings of the close anatomical relationship between these structures. Finally, in the few patients with abnormal sciatic nerves at the level of the ischial tuberosity and no evidence of adjacent abnormal marrow, muscle, or tendon signal, the underlying etiology may be one of mechanical compression of the nerve against the bony ischial tuberosity, given the

![Fig. 3. Partial hamstring tear and quadratus femoris myopathy.](Image)

Upper: Axial T1-weighted image demonstrates thickening of the right sciatic nerve with obliteration of the normal fat planes compared with the contralateral side (dashed arrow). The adjacent proximal hamstring tendons are noted (solid arrow). Lower: Axial T2-weighted image with fat saturation demonstrates increased SI at the attachment of the right proximal hamstring tendons (solid arrow) consistent with a partial tear with edema extending to the nerve (dashed arrow) and the adjacent quadratus femoris.

![Fig. 4. Quadratus femoris myopathy.](Image)

Axial T2-weighted image with fat saturation demonstrates focal increased SI within the quadratus femoris muscle just superior to the level of the lesser trochanter (solid arrow). The coursing sciatic nerve is indirectly compressed by the edema within the quadratus femoris and demonstrates increased SI (dashed arrow).

![Fig. 5. Isolated abnormal sciatic nerve.](Image)

Axial T2-weighted image with fat saturation demonstrates focal increased SI within the right sciatic nerve without adjacent soft-tissue abnormality (solid arrow). The hamstring tendon origin at the adjacent ischial tuberosity appears normal.
close anatomical location of the nerve to the ischium, and possible adhesions between the two structures.

Our study provides additional evidence that a quantitative approach to evaluation of the sciatic nerve is possible to help confirm qualitative observations of sciatic nerve abnormalities. Previous work has also suggested that a quantitative approach in conjunction with qualitative interpretation can help to increase the sensitivity and specificity of MRN in the diagnosis of sciatic neuropathy. Although differences in both the SI and size of the affected sciatic nerve suggested the diagnosis, the differences in SI were much more pronounced than those in cross-sectional diameter: on average there was an approximately 40% increase in adjusted SI on the affected side relative to the contralateral side, compared with a 20% increase in cross-sectional diameter, suggesting that the former metric may be the most robust measurement tool in this region for use in routine clinical practice.

Intrinsic T2 hyperintensity of the sciatic nerve is one potential confounder in quantitative analysis for neuropathy. It has been well established that normal peripheral nerves may exhibit mild T2 signal hyperintensity. This finding can result from magic angle artifact, variable amounts of endoneurial fluid, or subclinical pathology. Notably, with regard to the sciatic nerve, others have suggested that this finding occurs most often just distal to the level of the greater sciatic notch. This level was used as a reference standard in our study and there was no significant asymmetry in the nerve size or SI at this level in comparison with the marked asymmetry in SI and mild asymmetry in nerve size at the level of the ischial tuberosity.

Variability in the chosen internal SI reference can similarly be a potential source of error in the calculation of an adjusted nerve SI. We chose to use an adjacent muscle signal reference, whereas others have had success using adjacent vessel SI. Both of these are potentially subject to error from associated pathology, but because the tendency would most likely be an associated increase in T2 SI in the reference, any artifactual change in the ratio would most likely result in increased excessive specificity of the calculation. Regardless, we hesitate to recommend an absolute cutoff for sciatic nerve pathology because the numbers we report may vary significantly with differences in technique at different imaging centers.

There were several limitations to our study. This was a small retrospective study and there was no practical way in which the radiologists reviewing the studies could be blinded to the presence or absence of adjacent soft-tissue pathology when evaluating the nerve, and vice versa. Next, our control group was not age matched with respect to our patient cohort. Additionally, we used the contralateral limb for comparison, and any changes within that limb as a result of pathology on the affected side could lead to error in our observations, calculations, and comparison. Finally, we excluded patients with predominantly bilateral symptoms from our study, and our approach, which relied on a comparison between the affected and unaffected sides, would be relatively insensitive to bilateral pathology.

**Conclusions**

This study is the first to specifically evaluate the sciatic nerve on MRN in patients with sciatic nerve pathology at the level of the ischial tuberosity. We describe a distinct subset of patients who demonstrate an abnormal sciatic nerve related to injury at the ischial tuberosity with associated pathology of the proximal hamstring tendon origin and/or adjacent soft tissues. Qualitative as well as quantitative techniques can be used at MRN to help define the source of the pain and facilitate precisely targeted surgical and minimally invasive approaches to relieve symptoms. In patients for whom conventional diagnostics do not elucidate a cause of chronic sciatica symptoms, MRN is an important and sensitive diagnostic tool that may reveal an alternative etiology of symptoms, such as chronic hamstring tendon injury. However, because clinical correlation with MRN findings is not precisely understood, the latter should remain a diagnosis of exclusion.

**TABLE 4: Sciatic nerve cross-sectional areas compared between the 2 sides in the patient and control groups**

<table>
<thead>
<tr>
<th>Structure</th>
<th>Patients</th>
<th>Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Affected</td>
<td>Contralat</td>
</tr>
<tr>
<td>IT</td>
<td>0.66 (0.51–0.81)</td>
<td>0.54 (0.43–0.64)</td>
</tr>
<tr>
<td>SN</td>
<td>0.60 (0.51–0.69)</td>
<td>0.63 (0.55–0.72)</td>
</tr>
</tbody>
</table>

* Significant results (p < 0.05) are given in bold type.
Disclosure

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

Author contributions to the study and manuscript preparation include the following. Conception and design: Bucknor, Steinbach, Chin. Acquisition of data: all authors. Analysis and interpretation of data: all authors. Drafting the article: Bucknor, Steinbach. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Bucknor. Statistical analysis: Bucknor, Chin. Administrative/technical/material support: Bucknor, Saloner, Chin. Study supervision: Bucknor, Chin.

References


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