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RESEARCH

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The value of magnetic resonance neurography in evaluation of sciatic neuropathy

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Abstract

Background Sciatic neuropathy is one of the most common neuropathies of the lower extremities. One of the most common presentations of sciatic neuropathy is foot drop and may also be associated with several other clinical (sensory and/or motor) presentations. In recent years, magnetic resonance imaging (MRI) has established itself as an important tool for the study of peripheral nerves, especially after the development of protocols including sequences optimized for this purpose, referred to as magnetic resonance neurography (MRN), being used as noninvasive means of diagnosing peripheral nerve disease. Such high-resolution imaging protocols aimed to image the nerves at hip, thigh, knee, leg, ankle, and foot and can demonstrate traumatic or iatrogenic injury, tumor-like lesions, or entrapment of the nerves, causing a potential loss of motor and sensory function in the affected area. This study aimed to be familiar with MRI and MRN findings in patients with sciatic neuropathy.

Results In this prospective study, thirty patients presented with clinical manifestations and/or electrophysiological studies having sciatic neuropathy and underwent MRI and MRN at a university Hospital from March 2021 to March 2022. In view of clinical presentation, muscle weakness (66.67%), numbness and tingling (60%), and sensory manifestation (60%) were the most prevalent presenting manifestation followed by back pain (43.33%), foot drop (33.33%), and urinary and bowel incontinence (23.33%). MRN and MRI results showed a strong correlation with the presenting symptoms of participants, in the form of increased sciatic nerve caliber in 23.33%, muscular atrophy in 13.33%, nerve root impingement in 26.67%, and lumbar spondylosis in 36.67%. MR neurography sequences gave additional findings to the conventional MRI in the form of increased nerve signal intensity in 53.33%, perineural edema in 50% of cases, neural structure disruption in 26.67%, muscular impend denervation in 16.67%, bone marrow edema in 30.33%, pseudo-meningocele in 13.33%, and nerve root avulsion in 3.33% with no correlated findings in MRI.

Conclusions MRN is an additional accurate tool in the study of different sciatic nerve diseases and can also give detailed knowledge of the nerve anatomy, adding value to electrophysiological studies and conventional MRI.

Keywords Sciatic neuropathy, Sciatic nerve diseases, Peripheral nerves, Magnetic resonance imaging, Magnetic resonance neurography

Background

The sciatic nerve is the largest nerve in the body with a diameter of 16 to 20 mm, originating in the lower back and traveling posteriorly through the lower limb as far down as the heel of the foot. The sciatic nerve innervates a significant portion of the skin and muscles of the thigh, leg, and foot [1].

Sciatic plexus originates from the ventral rami of spinal nerves L4 through S3 and contains fibers from both

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the posterior and anterior divisions of the lumbosacral plexus. After leaving the lower vertebrae, the nerve fibers converge to form a single nerve. It exits the pelvis through the greater sciatic foramen inferior to the piriformis muscle along with the pudendal nerve and vessels, inferior gluteal nerve and vessels, nerve to obturator internus, and posterior cutaneous nerve [2].

Sciatica is the most frequently encountered symptom in neurosurgical and clinical practice and is the common cause of pain and limitation in the lower limb movement. It is observed in about 40% of adults over the course of their lives [3].

Detailed knowledge of the anatomy of the sciatic nerve is essential for recognizing the degree of alterations and diseases involving the nerve. The alterations and diseases involving the nerve could be due to neoplastic, compressive, hereditary, traumatic, iatrogenic, or inflammatory causes [4–6].

Clinical and electrophysiological examinations are usually the first diagnostic step in the evaluation of sciatic nerve injuries. However, due to the complexity of the injury mechanism and the delay in the setting of the symptoms and electrophysiological changes, it is not easy to establish an accurate diagnosis of the exact injury site and sciatic nerve damage severity. At this point, morphological imaging techniques, such as magnetic resonance imaging (MRI), allow an adequate visualization of sciatic nerve and its pathologic conditions [7].

In recent years, magnetic resonance imaging (MRI) has established itself as an important tool for the study of peripheral nerves, especially after the development of protocols including sequences optimized for this purpose, generally referred to as magnetic resonance neurography (MRN) [8].

Magnetic resonance neurography is a high-resolution imaging technique that combines magnetic resonance imaging (MRI) with specially designed phased-array surface coils that allows for visualization of the peripheral nerves and now is being used as noninvasive mean of diagnosing peripheral nerve disease. These imaging protocols aimed at imaging the nerves of the hip, thigh, knee, leg, ankle, and foot and can demonstrate traumatic or iatrogenic injury, tumor-like lesions, or entrapment of the nerves, causing a potential loss of motor and sensory function in the affected area, and a good understanding of normal MR imaging and gross anatomy [9].

Methods

Patient populations

A single-center prospective study was conducted on 30 patients with clinical manifestations and/or on electrophysiological studies with sciatic neuropathy referred from neurosurgery or rheumatology and physical rehabilitation out-clinics to radiodiagnosis and medical imaging department, from March 2020 to March 2022; the ethical committee of our institution has approved this study.

The age of patients in the study ranged from 4 to 78 years; eighteen patients were males and twelve of them were females.

Inclusion criteria

All age-groups were included in the study. No gender predilection. Patients were diagnosed by clinical examinations and/or electrophysiological examinations to evaluate sciatic neuropathy.

Exclusion criteria

Un-cooperative patients, patients with mental or behavioral disorder, patients with metallic implants as cochlear implants, metallic foreign bodies, or any other electronic or magnetically activated implants as well as claustrophobic patients were excluded from the study.

MR imaging protocol

Conventional 2D lumbosacral magnetic resonance imaging examination was done using pelvis phase array coil. The scan area extended from L3-L4 to mid-thigh to show roots of sciatic nerve in 29 patients except one patient with mid-thigh swelling around the course of sciatic nerve that needs the field of view to be extended from pelvis to popliteal fossa to cover the ROI. All MRI scans were performed by MRI 1.5 Tesla closed magnet right-handed system. One child aged 4 years was not able to maintain stationary position on MRI table throughout the whole procedure time and received choral hydrate syrup with a dose of 50 ml/kg. The scanning time ranged from 20 to 45 min in maximum.

MR neurography sequences

MRN included the following sequences: T1-weighted images (TR: 676 ms, TE: 14.4 ms), T2-weighted images (TR: 5430 ms, TE: 117 ms), short tau inversion recovery (STIR) image (TR: 5290 ms, TE: 37.5 ms), 3D-study including fast imaging employing steady-state acquisition (FIESTA) (TR: 4.5 ms, TE: 1.7 ms). Field of view (FOV) 24×18 mm; matrix, 310×620; slice thickness, 1.8 mm and slice gap, 0.4 mm. Bilateral sciatic nerve MRN examination for comparison was performed; the application of intravenous gadolinium-based contrast agents was given to two patients with neoplastic conditions with a dose of 1.5 ml/kg, after renal function test results. All data and results were interpreted by radiology experts (H.M) radiology consultant with 35 years of experience, (R.A) radiology consultant with 25 years of research experience, and (R.S) radiology consultant with 15 years of nerve imaging experience in conjoint reading sessions.

MRN data analysis

In sciatic nerve pathology, there were direct and indirect signs that could be detected by MRN, like size (focal or diffuse enlargement), disruption or loss of fascicular pattern, signal intensity with asymmetric hyper-intensity on STIR images due to high fluid sensitivity as well as good fat suppression. Continuity and course (focal/diffuse deviation or discontinuity). Alterations of signal, size, and course of the abnormal nerve segments are compared with the ipsilateral normal side on STIR and 3D images. The muscle denervation was completely replaced by fat.

Statistical analysis of the data

Data entry, processing, and statistical analysis were carried out using Statistical Package for Social Sciences (IBM SPSS software package version 20.0) (Armonk, NY: IBM Corp). Qualitative data were described using number and percent. Quantitative data were described using range (minimum and maximum), mean, standard deviation, chi-square, and ROC curve.

Results

In this single-center prospective study, 30 cases with sciatic neuropathy detected either with clinical examination or with electrophysiological studies. Male cases were 18 and females were 12, 60% and 40%, respectively; the mean age was 37.433 years and min–max 4–78 as given in Table 1.

Muscle weakness was the main complaint among 66.67%, numbness and tingling (60%), sensory manifestation (60%), back pain (43.33%), foot drop (33.33%), and 23.33% complained of urinary and bowel incontinence. The etiology of lesions among cases was divided into lesions of discogenic etiology in about 23.33% of cases, while 76.67% of cases showed non-discogenic etiology; the cases with non-discogenic etiology were subdivided into spinal lesions (6.67%) and extra-spinal lesions (70%) as given in Table 2.

At conventional MRI study, 70% of cases showed abnormal findings in the form of lumbar spondylosis in 36.67%, nerve root impingement in 26.67%, increased sciatic nerve caliber in 23.33%, muscular atrophy in 13.33%, bone lesions (mets and tumors) in 6.67% of cases, vertebral bone fracture in 3.33%, pelvic bone fracture in 6.67%, decrease nerve caliber in 13.33%, and congenital bone defect (spina bifida) in 3.33% of cases as shown in Fig. 1.

The added radiological findings of magnetic resonance neurography to these of conventional MRI were in the form of: increased nerve signal intensity in 53.33%, high bifurcation of sciatic nerve in 6.67%, perineural edema in 50%, neural structure disruption in 26.67%, muscular impend denervation in 16.67%, nerve root avulsion in 3.33%, pseudo-meningocele in 13.33%, and bone marrow edema in 30.33% of cases as given in Table 3.

Comparison between conventional MRI and MRN findings showed that MRN and MRI gave the same findings in the form of increased sciatic nerve caliber in 23.33%, muscular atrophy in 13.33%, nerve root impingement in 26.67%, lumbar spondylosis in 36.67%, bone lesions (mets and tumors) in 6.67% of cases, vertebral bone fracture in 3.33%, pelvic bone fracture in 6.67%, decrease nerve caliber in 13.33%, and congenital bone defect (spina bifida) in 3.33% of cases. However, MRN gave additional findings to these of conventional MRI in the form of increased nerve signal intensity in 53.33%, high bifurcation of sciatic nerve in 6.67%, perineural edema in 50%, neural structure disruption in 26.67%, muscular impending denervation in 16.67%, nerve root avulsion in 3.33% pseudo-meningocele in 13.33%, bone marrow edema in 30.33% and 30.00% of cases with no findings in MRI, but in MRN there were no cases with any findings as given in Table 4.

Comparison between conventional lumbosacral MRI and electrophysiological studies showed that sensitivity of conventional MRI was 1.82%, while specificity was 100%, negative predictive value was 66.67%, positive predictive value was 100%, and accuracy was 86.67%, while comparison between electrophysiological studies and MRN showed that the sensitivity of MRN was 100%, specificity was 75%, positive predictive value was 91.67%,

Table 1 Distribution of the studied cases according to demographic data ($n = 30$)

		Number of patients	Percent
Gender	Male	18	60
	Female	12	40
Age	Range	4–78	
	Mean ± SD	37.433 ± 20.837	

Table 2 Distribution of the studied cases according to etiology of lesions ($n = 30$)

Etiology of lesions		Number of patients	Percent (%)
Non-discogenic	Extra-spinal	21	70.00
	Spinal	2	6.67
Discogenic		7	23.33
Total number of patients		30	100.00

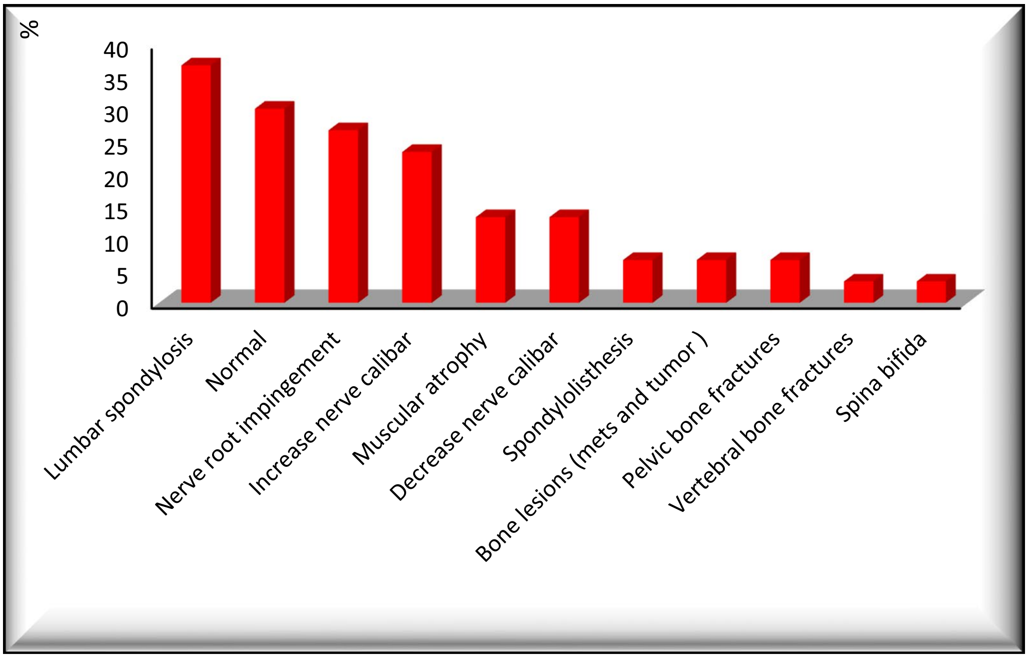

Fig. 1 Distribution of studied cases according to MRI findings. N.B: One patient may have more than one MRI finding

Table 3 Distribution of the studied cases according to additional MRN findings ($n = 30$)

MRN findings	Number of patients	Percent (%)
Perineural edema	16	53.33
Bone marrow edema	15	50.00
Neural structure disruption	9	30.00
Muscular impend denervation	8	26.67
Pseudo-meningocele	5	16.67
High bifurcation	4	13.33
Nerve root avulsion	2	6.67
Increased nerve signal intensity	1	3.33

negative predictive value was 100%, and accuracy was 93.33%, and there was a statistical significance relation between electrophysiological studies and MRN (P value ˂0.001) as shown in Fig. 2.

Discussion

Magnetic resonance neurography (MRN) is becoming increasingly popular in the assessment of peripheral neuropathy and visualize complex nerve structures along their entire pathway and distinguish nerves from surrounding vasculature and tissue in a noninvasive manner via nerve characteristic imaging criteria [10].

The main objective of the current study was to assess the sensitivity of magnetic resonance neurography and its valuable added value to conventional MRI in diagnosis of sciatic neuropathy in comparison with electrophysiological studies and clinical examination (Figs. 3,4,5).

This prospective study enrolled 30 cases with clinical manifestations and/or on electrophysiological studies that proved to have sciatic neuropathy from March 2020 to March 2022. As regards age and sex, the age ranged from 4 to 78 years with the mean age of 37.433 ± 20.837 SD (standard deviation) and the male-to-female ratio was 3:2. Regarding gender, males were more frequently affected by sciatic neuropathies than females. Our results were supported by the study of Geyik et al. [11].

Regarding this study, muscle weakness was found among 66.67% of patients, 60% complained of numbness and tingling, 60% complained of sensory manifestations, 43.33% complained of back pain, 33.33% complained of foot drop, and 23.33% complained of urinary incontinence. This was supported by the study of Cherian et al. [12] which agreed that the most common complaint at presentation is a combination of sensory symptoms (paresthesia or pain) and motor weakness.

Sciatic neuropathy etiologies among cases were divided into: lesions affect lumbosacral disks (discogenic etiology in origin) in about 23.33% of cases and 76.67% of cases were with the non-discogenic etiology which were subdivided into 6.67% spinal lesions and 70% extra-spinal lesions. We found also etiology of the

Table 4 Comparison between conventional MRI and MRN findings

Findings	MRI		MRN	
	Number of patients	Percent (%)	Number of patients	Percent (%)
Normal	9	30	0	0
Nerve root impingement	8	26.67	8	26.67
Increased nerve caliber	7	23.33	7	23.33
Muscular atrophy	4	13.33	4	13.33
Decrease nerve caliber	4	13.3	4	13.3
Bone lesions (Mets and tumor)	2	6.6	2	6.6
Spina bifida	1	33.3	1	33.3
Increased nerve signal intensity	0	0	16	53.3
Perineural edema	0	0	15	50
Bone marrow edema	0	0	9	30
Neural structure disruption	0	0	8	26.67
Pseudo-meningocele	0	0	4	13.3
Nerve root avulsion	0	0	1	3.33

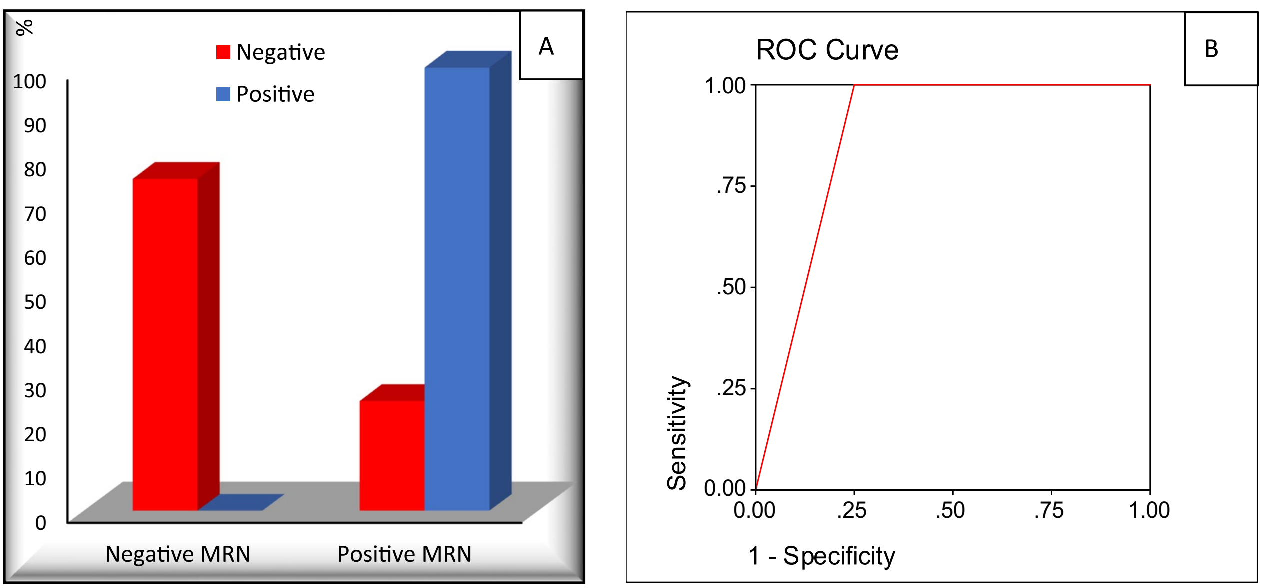

Fig. 2 Comparison between MRN and electrophysiological studies (**A**) and receiver operating characteristics (ROC) curve (**B**) shows sensitivity and specificity of MRN

non-discogenic lesions was mostly inflammatory in 43.48% of cases, 17.39% with traumatic lesions, 17.39% with compressive lesions, 8.70% of cases with piriform syndrome, 8.70% of cases with iatrogenic etiology, and 4.35% of cases with congenital etiology (spina bifida); these results disagreed with the study by Chhabra et al. [13], who reported that 64.3% of cases were iatrogenic after operations and 14.7% were compressive.

In the current study, the conventional MRI examination showed that 18 (60%) cases have sciatic neuropathy, 9 (30%) cases were normal, and 3 (10%) cases have other diagnosis rather than sciatic neuropathy, and after addition of MRN sequences (STIR and FIESTA images) 24 (80%) cases had sciatic neuropathy, 6 (20%) cases with other diagnosis rather than sciatic neuropathy, and there are no normal cases; this agreed with the study of Dessouky et al. [14], who revealed that MRN detects 63% (52/83) more findings than the conventional lumbar MRI and changed the diagnosis and treatment in 12% and 48% of failed back surgery syndrome cases, respectively,

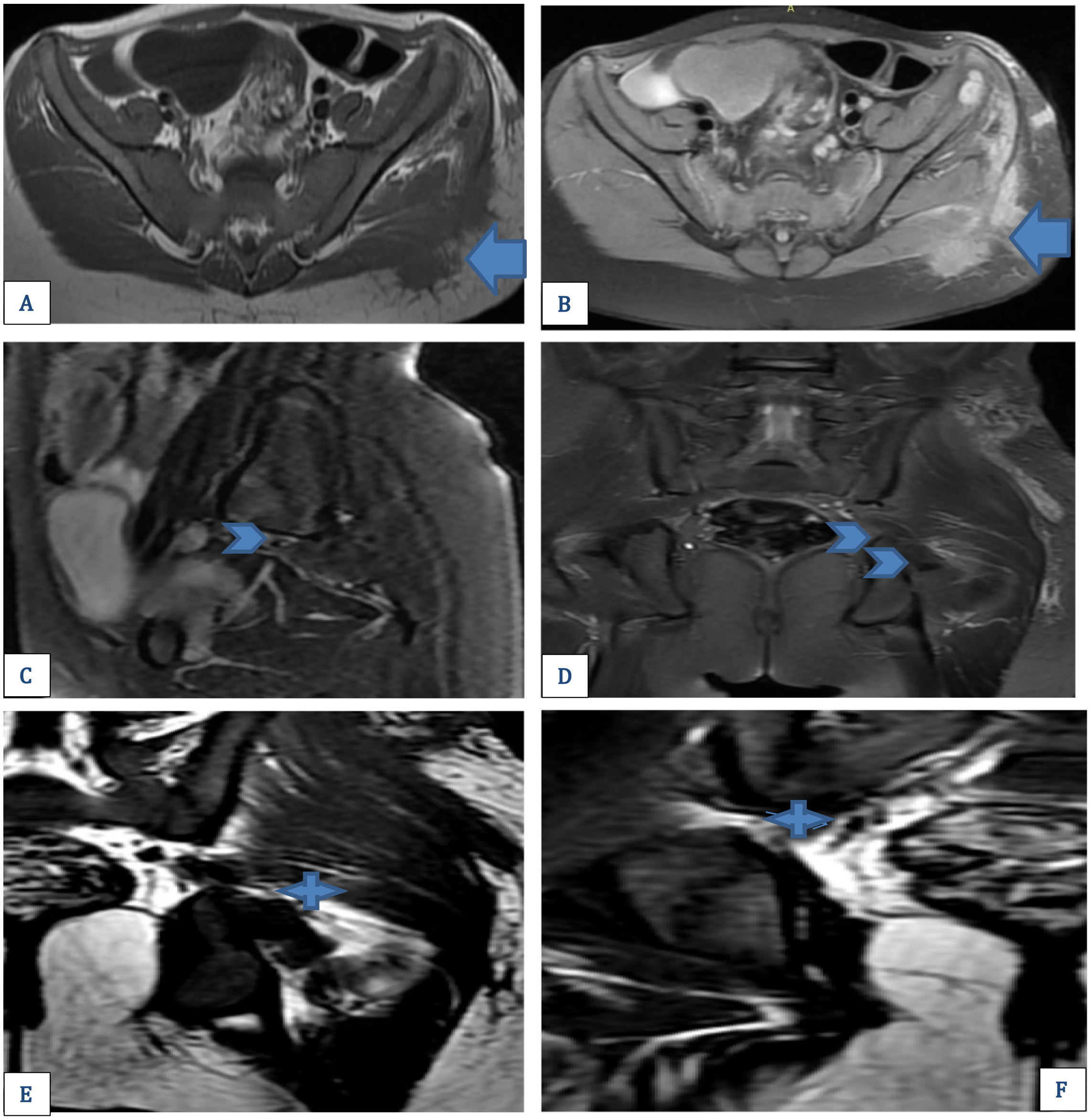

Fig. 3 A 10-year-old boy patient, with a history of leukemia, previous left gluteal injection and followed by severe pain and gradual muscle weakness at the left thigh and foot. Electrophysiological studies revealed a + ve ipsilateral straight leg raising; MRI of the pelvis showed area of subcutaneous and left gluteal muscles collections associated with a focus of bone marrow leukemic infiltration in the left iliac crest (arrows in **A** and **B**). MRN shows a perineural edema related to the left sciatic nerve with mildly reduced thickness (open arrow in **C** and **D**), compared with the normal right-sided nerve (Arrow in **E** and **F**)

and favorable outcomes were recorded in 40% to 67% of patients following MRN-guided treatments.

In our study, the added MRN findings to the conventional MRI findings were in the form of increased nerve signal intensity in 53.33% of the studied patients, high bifurcation of sciatic nerve in 6.67%, perineural edema in 50%, neural structure disruption in 26.67%, muscular impend denervation in 16.67%, nerve root avulsion in 3.33%, pseudo-meningocele in 13.33%, and bone marrow edema in 30.33% of cases, and this matched the study of Chazen et al. [15], who revealed also in their study the statistically significant correlation between abnormal intraneural signal on MRN and findings of active denervation on nerve conduction study (NCS)/electromyography (EMG) (P .001).

There was an agreement in diagnostic information in the current study between magnetic resonance neurography and electrophysiological studies in 28 (93.33%) of

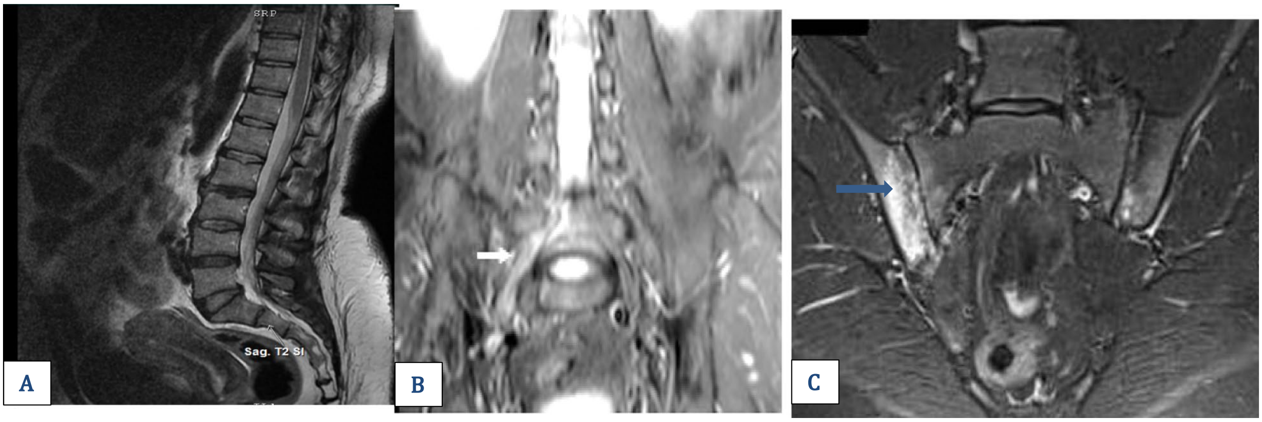

Fig. 4 A 45-year-old female patient (a known case of seronegative arthropathy), presented clinically with severe right sciatic pain referred to the right buttock and thigh with numbness and weakness. Electrophysiological studies showed prolonged F wave latency, + ve ipsilateral straight leg raising test. Sagittal LS MRI shows no significant disk lesions (**A**). Pelvic MRN shows thickened and high signals in the right sciatic nerve with bilateral sacro-iliitis, more on the right side (Arrows in **B** and **C**)

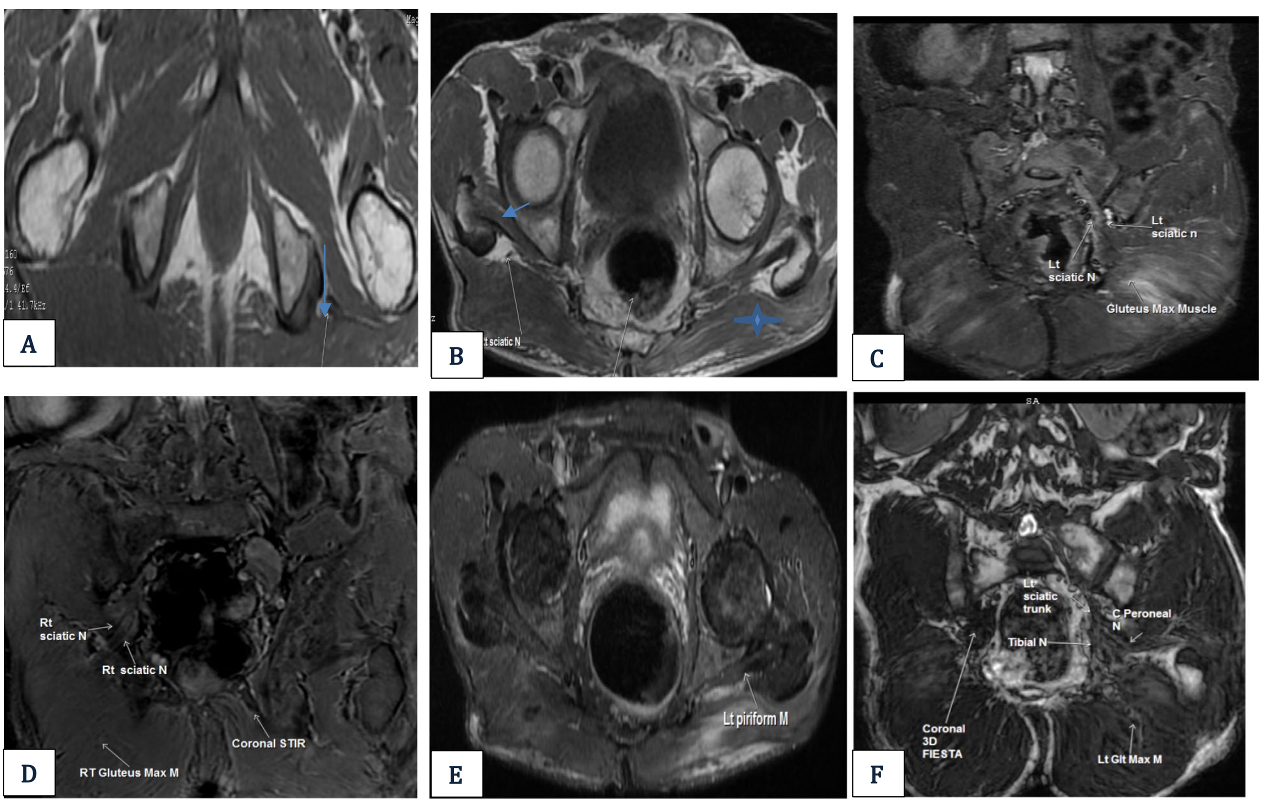

Fig. 5 A 24-year-old female patient, having a history of intermittent left lower limb pain and cramps. Electrophysiological studies revealed prolonged F wave latency, with + ve ipsilateral straight leg raising test; MRI of the pelvis shows a relatively reduced left gluteus maximum muscle bulk (marks in **B**) and left sciatic nerve arrowed in (**A**). MRN shows high signals in the fore-mentioned muscle as well and high bifurcation of the left sciatic nerve at the upper border of left piriformis muscle with relatively increased thickness and signal intensity (**C–F**), denoting a left piriformis syndrome

studied patients and disagreement in the remaining 2 patients. Du et al. [16] showed that MRN is found to give the same information in 29 patients (32%), additional diagnostic information in 41 (45%), less information in 15 (17%), and a different diagnosis in 6 (7%).

Limitations of the study

The major limitation faced during this study was the follow-up studies which were not undertaken to assess the progression of the disease.

Conclusions

Electrophysiological studies and clinical examination can provide functional information about sciatic nerve, yet are unable to accurately determine the exact anatomical lesion localization and its extension. MRI can help in identification of structural lesions that may be pressing against the nerve, yet it is not an effective method for direct visualization of different components of the nerve. MRN is an additional accurate tool in the study of different sciatic nerve diseases and can also give detailed knowledge of the nerve anatomy and disturbed intraneural structure.

Recommendations

A large sample volume with the use of 3 Tesla for more accurate results and data analysis should be considered. Also, follow-up is highly indicated for assessment of treatment efficacy, either medical or surgical. We also recommend adding other MRN functional sequence (DTI) to the future studies.

Abbreviations

MRI	Magnetic resonance imaging
MRN	Magnetic resonance neurography
FIESTA	Fast imaging employing steady-state acquisition
STIR	Short tau inversion recovery
DTI	Diffusion tensor imaging

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Author contributions

All authors read and approved the final manuscript.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

This study was approved by the ethics committee of Tanta University Hospital. Ethics committee reference numbers is 33646\1\20. The patients provided verbal and/or written consent, and the ethics committee approved this procedure as it suits this research project; written consent is unnecessary according to national regulations.

Consent for publication

The patients provided verbal consent and the ethics committee approved this procedure as it suits this research project; written consent is unnecessary according to national regulations. All patients included in this research gave informed verbal and/or written consent to publish the data contained within this study. All participants enrolled in the study provided informed consent to participate.

Competing interests

The authors declare no competing interests.

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