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MRI and MR neurography of lumbosacral plexus in diagnosis of lower extremity radiculopathy

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Abstract
Background: Electromyography (EMG) and nerve conduction studies can assist in identifying the source of dysfunction. Computed tomography (CT) or magnetic resonance imaging (MRI) can identify pelvic masses and visualize the major nerves of the plexus. The objective of this study was to assess the significance of MRI and magnetic resonance neurography (MRN) in diagnosing lumbosacral (LS) radiculopathy and to establish a correlation between the findings of these imaging techniques and the patient's medical history, physical examination, and nerve conduction study results.
Methods: The present study was conducted on a sample of 30 individuals experiencing radicular pain in the lower extremities. Every patient underwent both MRI and MRN.
Results: There were insignificant associations between MRI findings and clinical manifestations and electrophysiological studies. There were insignificant associations between MRN findings and clinical manifestations and electrophysiological studies. All the 6 cases with root abnormalities in MRN had a non-disc etiology. All the 6 cases with root abnormalities in MRN had a non-disc etiology. MRN showed no abnormalities in LS plexus in 24 cases. The remaining 6 cases showed root abnormalities. Nerve root compression and thickening was seen in all the six cases. Perineural edema was seen in 5 cases, and altered signal intensity was seen in 3 cases.
Conclusion: MRN appears to detect LS nerve root abnormalities in a portion of patients with clinical symptoms of lower extremity radiculopathy and radiculopathy on EMG. Our finding may support the growing evidence on the utility of MRN as a useful adjunct to electrodiagnostic testing for the diagnosis of LS radiculopathy.

Keywords: Electromyography, magnetic resonance imaging, magnetic resonance neurography, lumbosacral plexus, lower extremity radiculopathy

Introduction
Lumbosacral (LS) plexopathy refers to the damage of the nerves that originate from the lumbar and/or sacral plexus [1]. It is a prevalent condition, yet it might be difficult to identify and control. Nevertheless, brachial plexopathy is significantly more prevalent than this condition [2, 3].

Individuals suffering from LS plexopathy typically experience symptoms such as lumbar pain and/or pain in the lower extremities. In addition, individuals may experience motor weakness, numbness, paresthesia, and/or sphincter dysfunction [2, 3].

LS plexopathy can result from various causes. Diabetes mellitus, trauma, tumors, and pregnancy are significant causes. Treatment frequently varies considerably based on the root cause [3, 4].

LS plexus injury can result from pelvic trauma that causes harm to the roots or nerves. This injury can be caused by birth defects, trauma, or LS (carcinomatous) neuropathy [5]. Tumour affecting the intestines, bladder, or prostate can lead to infiltration of the LS plexus. Additional masses can exert direct stress on the roots or trunk as well [6].

The lumbar plexus provides neural supply to the posterior buttock, abdominal region, inguinal area, thighs, knees, and calves. The sacral plexus nerves provide innervation to the pelvis, buttocks, genitals, thighs, calves, and feet [6].

The lumbar plexus provides neural supply to the posterior buttock, abdominal region, inguinal area, thighs, knees, and calves. The sacral plexus nerves provide innervation to the pelvis, buttocks, genitals, thighs, calves, and feet [7]. Computed tomography (CT) or magnetic resonance imaging (MRI) can identify pelvic tumors and visualize the major nerves

of the plexus [8].

In the past, the evaluation of peripheral neuropathies depended solely on neurophysiology and examination in order to identify the precise location of the disease. EMG studies are subject to several limitations, primarily associated with patient discomfort, non-specific findings in approximately one-third of cases, and insufficient information regarding the specific location, severity, and cause of the nerve injury [8].

Magnetic resonance neurography (MRN) has been conducted using stronger magnetic field strengths (1.5 or 3.0-T) and high-resolution multiplanar sequencing [9]. MRI neurography (MRN) can assess nerve pathologies by directly analyzing alterations in nerve size and signal intensity, or indirectly by observing indications of muscle denervation [10].

The treatment approach differs based on the cause of plexus dysfunction. Corticosteroids have been recommended during the initial stage of an autoimmune inflammation or compression. The proven benefits are extremely limited [11].

The objective of this study was to assess the contribution of MRI and MRN in the diagnosis of LS radiculopathy and establish a correlation between the findings and the patient's medical history, physical examination, and nerve conduction study results.

Patients and Methods

The present study was conducted on a cohort of 30 individuals experiencing radicular pain in their lower extremities. The study was conducted between January 2021 and October 2022, following approval from the Ethical Committee of Tanta University Hospitals in Tanta, Egypt. The patients provided their informed written consent. The exclusion criteria for this study included patients who had contraindications to undergoing an MRI examination, such as having any metallic prosthesis, artificial cardiac pacemakers, ferromagnetic cerebral aneurysm clips, intra-ocular foreign body, metallic cochlear implant, or claustrophobia. All patients underwent a comprehensive evaluation, including medical history assessment, thorough physical examination, and magnetic resonance imaging (MRI) scans. The MRI scans included T_1-weighted, T_2-weighted images obtained in the coronal, sagittal, and axial planes. Contrast was used when necessary. Additionally, MR neurography (MRN) was performed using short time inversion recovery (STIR) imaging and fast Imaging Employing Steady-state Acquisition (FIESTA) techniques.

Magnetic Resonance Imaging

The MRI studies were conducted using a General Electric 1.5 tesla system (specifically, the signal high speed model from GE medical systems) at the MRI unit of the Radiodiagnosis department in Tanta University Hospital. The patients were queried regarding any contraindications for MR imaging examination, such as the presence of a cardiac pacemaker, artificial valves, or aneurysm clips. The individuals were given directions to eliminate any metallic items, such as hairpins, coins, or earrings. Next, the procedure was elucidated to provide reassurance, and the patients were notified about the duration of the examination and the importance of maintaining complete stillness without any movement. Each patient underwent examination while lying flat on their back and was secured in a comfortable position to prevent movement.

Type of coils used: GEM flex coil 16- L array 1.5 T receive only GE signa explorer 1.5 T scanner closed magnet.

The imaging protocol included the following pulse sequences: [Scout 3 planes T_1 weighted images (T_1WI) were obtained to determine the position of the subsequent slices. These included axial T_1WI (TR/TE = 600-800/15-30) and axial T_2 weighted images (TR/TE = 2000-5000/60-120), sagittal T_1, T_2, and gradient weighted images (TR/TE = 500-600/12-20), additional sequences for MRN 3D STIR imaging (3D Coronal STIR) (TR/TE = 4000-6000/20-40), coronal T_1 and T_2 weighted images, and FIESTA. The MRI scan was conducted with a field of view (FOV) that varied from 12 to 16 cm. The matrix size was 256 x 256, and the slice thickness ranged from 2 to 4 mm with an inter-slice gap of approximately 0.2 to 0.5 mm.

Statistical analysis

The statistical analysis was conducted using SPSS v26 software (IBM Inc., Chicago, IL, USA). Quantitative variables were presented as mean and standard deviation (SD) and compared between the two groups utilizing unpaired Student's t-test. The qualitative variables were displayed as frequency and percentage (%) and was examined using the Chi-square or Fisher's exact test, depending on the circumstances. A two-tailed P value less than 0.05 was deemed to be statistically significant.

Results

Male cases were 12(40%) and females were 18(60%). Their mean ages were 52.6±13.3. All the studied patients complained of back pain radiating to the lower limbs. 19 patients had sensory manifestations, 7 patients had LL weakness, and 2 patients had foot drop. Table 1.

Table 1: Demographic characteristics and clinical picture of the studied patients

	Female (n=12)	**Male (n=18)**
Age	52.6±13.3	
20- <30	3(10.0%)	0(0.0%)
30 -<40	2(6.67%)	0(0.0%)
40-<50	1(3.33%)	2(6.67%)
50-<60	2(6.67%)	10(33.3%)
≥60	4(13.33%)	6(20.0%)
Clinical picture (n=30)		
Back pain	30(100%)	
LL pain	30(100%)	
Tingling and numbness	19(63.3%)	
Weakness	7(23.3%)	
Foot drop	2(6.7%)	
Duration of symptoms (years)	3 (2-4)	

Data are presented as mean ± SD or frequency (%) or median (IQR). LL: lower limb

There were 21 patients who had electrophysiological studies, 3 patients showed abnormal motor NCS, 7 patients showed abnormal sensory NCS, and 17 patients showed abnormal EMG. Conventional MRI showed that 23 cases had disc pathologies and 7 cases had other etiologies

11 cases had only L4-L5 disc pathology, 4 cases had only L5-S1 disc pathology, and 5 patients had both L4-L5 and L5-S1 disc pathology. 2 patients had L3-L4 disc pathology, 1 patient had L1-L2 and L2-L3 disc pathology. Patients with non-disc etiology include 4 patients with metastasis, 2 patients with spondylolithesis, and 1 patient had MRI picture of GBS. MRN showed no abnormalities in LS

plexus in 24 cases. The remaining 6 cases showed root abnormalities. Nerve root compression and thickening was seen in all the six cases. Perineural edema was seen in 5 cases, and altered signal intensity was seen in 3 cases. Table 2.

Table 2: Electrophysiological studies, MRI, MRN findings and root abnormalities in MRN of the studied patients

		N=30
Motor NCS	Abnormal	3(10.0%)
	Normal	18(60.0%)
	Not available	9(30.0%)
Sensory NCS	Abnormal	7(23.3%)
	Normal	14(46.7%)
	Not available	9(30.0%)
EMG	Abnormal	17(56.7%)
	Normal	4(13.3%)
	Not available	9(30.0%)
MRI finding	Disc	23(76.7%)
	Non-disc	7(23.3%)
Disc level	L4-L5	11(47.8%)
	L4-L5 L5-S1	5(21.7%)
	L3-L4	2(8.7%)
	L5-S1	4(17.4%)
	L1-L2 L2-L3	1(4.3%)
Non-Disc findings	Bone metastasis	4(57.1%)
	Spondylolithesis L5-S1	2(28.6%)
	GBS	1(14.3%)
MRN	Root abnormalities	6(20.0%)
	NO added data	24(80.0%)
Root abnormalities (n=6)	Nerve root compression	6(100.0%)
	Thickening of nerve root	6(100.0%)
	Perineural edema	5(83.33%)
	Altered signal intensity	3(50.0%)

Data are presented as frequency (%). LL: lower limb, NCS: Nerve conduction study, EMG: Electromyography, GBS: Guillain Barré syndrome, MRI: magnetic resonance imaging, MRN: magnetic resonance neurography

There were insignificant associations between MRI findings and clinical manifestations and electrophysiological studies. Table 3.

Table 3: Associations between MRI findings and clinical manifestations and electrophysiological studies

		MRI		P
		Disc	Non-disc	
Clinical Manifestations				
Sensory		14(60.9%)	5(71.4%)	1.00
Weakness		5(21.7%)	2(28.6%)	1.00
Foot drop		2(8.7%)	0(0.0%)	1.00
Electrophysiological studies				
Motor NCS	Abnormal	2(11.1%)	1(33.3%)	0.386
	Normal	16(88.9%)	2(66.7%)	
Sensory NCS	Abnormal	5(27.8%)	2(66.7%)	0.247
	Normal	13(72.2%)	1(33.3%)	
EMG	Abnormal	12(80.0%)	5(83.3%)	1
	Normal	3(20.0%)	1(16.7%)	

Data are presented as frequency (%). NCS: Nerve conduction study, EMG: Electromyography, MRI: magnetic resonance imaging

There were insignificant associations between MRN findings and clinical manifestations and electrophysiological studies. Table 4.

Table 4: Associations between MRN findings and clinical manifestations and electrophysiological studies

		MRN		P
		Disc	Non-disc	
Clinical Manifestations				
Tinglin and numbness		15(62.5%)	4(66.7%)	1.00
Weakness		5(20.8%)	2(33.3%)	0.603
Foot drop		2(8.3%)	0(0.0%)	1.00
Electrophysiological studies				
Motor NTCS	Abnormal	2(66.7%)	1(33.3%)	1
	Normal	17(94.4%)	1(5.6%)	
Sensory NCS	Abnormal	3(42.9%)	4(57.1%)	0.603
	Normal	13(92.9%)	1(7.1%)	
EMG	Abnormal	12(70.6%)	5(29.4%)	1
	Normal	4(100.0%)	0(0.0%)	

Data are presented as frequency (%). NCS: Nerve conduction study, EMG: Electromyography, MRN: magnetic resonance neurography

All the 6 cases with root abnormalities in MRN had a non-disc etiology. Table 5.

Table 5: Association between MRI and MRN findings

		MRN Signal change	
		No	Yes
MRI findings	Disc	23(95.8%)	0(0.0%)
	Non-disc	1(4.2%)	6(100.0%)

Data are presented as frequency (%). MRI: magnetic resonance imaging, MRN: magnetic resonance neurography

Case 1: Female patient aged 65 years complaining of back pain with left lower limb pain of 2 years duration. The patient is known to have a breast cancer. Electrophysiological studies: Normal motor and sensory NCS with abnormal EMG. Figure 1.

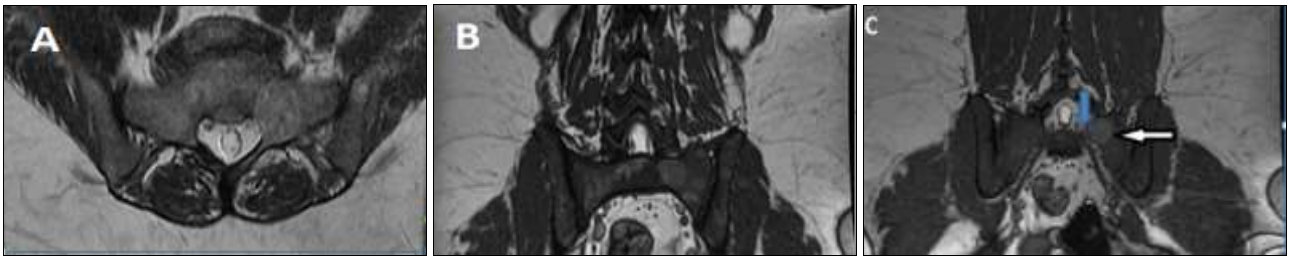


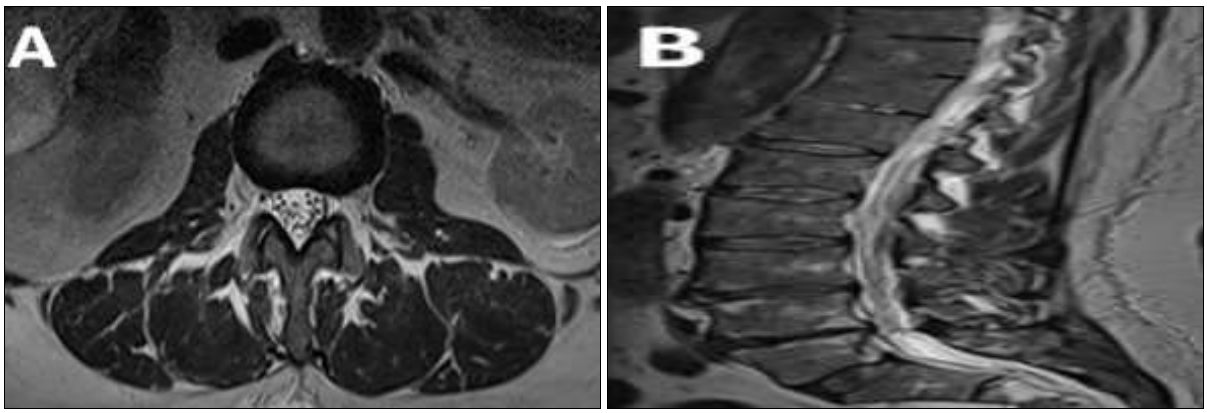
Fig 1: Axial T_2 (A) and Coronal T_2 (B): Abnormal altered bone marrow signal intensity with multiple osteolytic bony lesions seen at lumbar vertebrae and pelvic bones, MRN (C): Left L5-S1 exit nerve root thickening and compression with altered signal intensity (blue arrow)

Case 2

Male patient aged 68 years complaining of back pain radiating to right lower limb associated with tingling, numbness (mainly at upper thigh), and limping of 4-year duration.

Electrophysiological studies

Abnormal motor NCS, sensory NCS, and EMG. Figure 2.



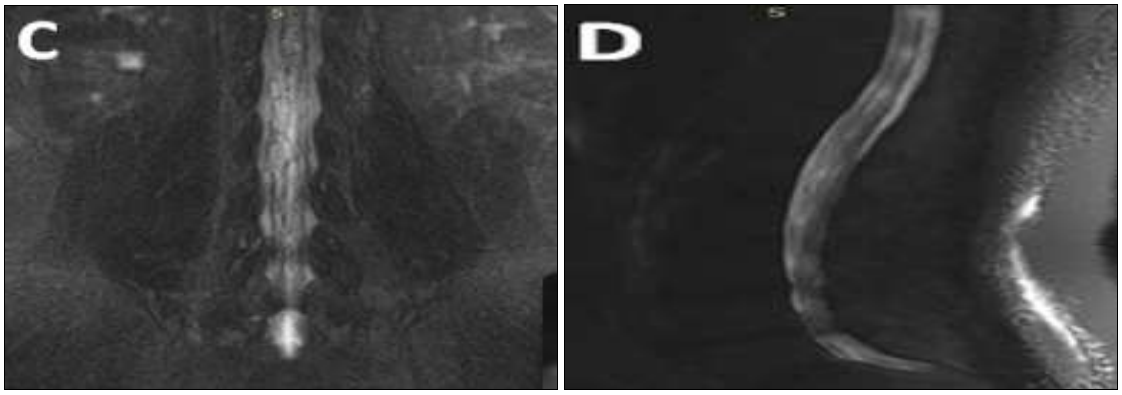


Fig 2: Conventional MRI: axial T_2 (A) and sagittal T_2 (B): abnormal distribution of central nerves within thecal sac (suggesting arachenoiditis), MRN: 3D coronal STIR (C) & sagittal myelogram (D): perineural edema and altered nerve signal intensity at right exit foramina

Case 3: Female patient aged 54 years complaining of back pain radiating to right lower limb of 1 year duration with past history of lumbar spine operation to fix spondylolithesis 3 years ago. Figure 3.

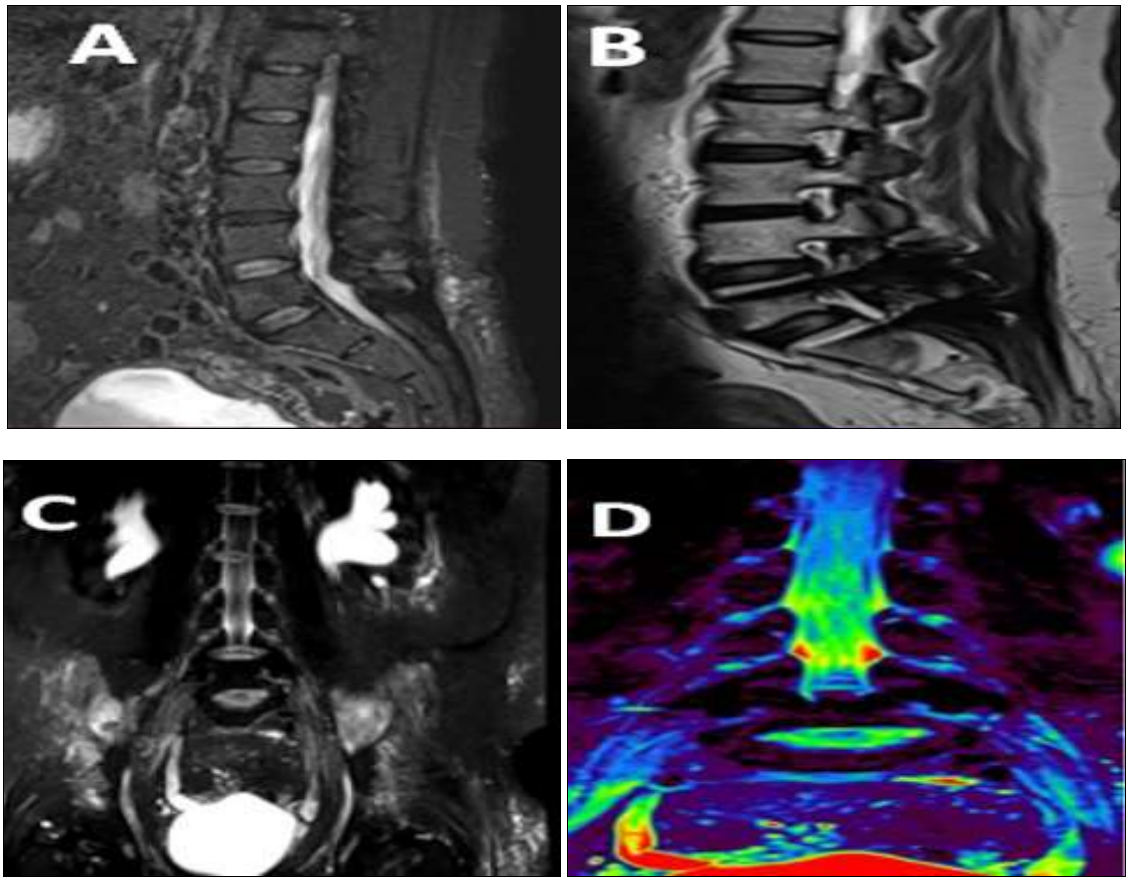


Fig 3: Conventional MRI: sagittal STIR (A) and sagittal T_2 (B):degenerated disc at the level of L3-L4. Old fixation screws for previous spondylolithesis at level of L5 and S1. MRN: 3D STIR (C): no root abnormalities could be seen

Discussion

LS plexopathy refers to the damage that occurs to the nerves in the lumbar and/or sacral plexus. Lumbosacral plexopathy is a prevalent condition, yet it can pose challenges in terms of diagnosis and treatment [2, 3].

All the studied patients complained of back pain radiating to the lower limbs. 19 patients (63%) had sensory manifestations, 7 patients (23.3%) had LL weakness, and 2 patients (6.7%) had foot drop. Approximately 48.4% of the patients examined in the study conducted by Chazen *et al.* 93 exhibited reduced sensation in their lower extremities during physical examination. Additionally, 36% of the patients displayed objective weakness. Yousif *et al.* [12] reported that 53.3% of cases had sensory manifestations, while 60% of patients had abnormal gait.

Duration of symptoms in our studied patients ranged from 0 – 6 years with a mean 3.1. However, Chazen, *et al.* [13] showed that the duration of symptoms in the studied patients ranged from 1-312 months with a mean 26 months. Yousif *et al.* [12] reported that the average duration of patients' symptoms was 21.47±26 months, with 60% of the patients experiencing symptoms for over 6 months. Conventional MRI showed that 23 cases (76.7%) of our studied patients had disc pathologies and 7 cases (23.3) had other etiologies.

We reported that 11 cases (47.8%) had only L4-L5 disc pathology, 4 cases (17.4%) had only L5-S1 disc pathology, and 5 patients (21.7%) had both L4-L5 and L5-S1 disc pathology. 2 patients (8.7%) had L3-L4 disc pathology, 1 patient (4.3%) had L1-L2 and L2-L3 disc pathology. In the study done by Yousif *et al*. [12] Out of the 9 patients, 30% had only L4/5-disc involvement, 23.3% had only L5/S1 disc involvement, and 46.7% had involvement at both the L4/5 and L5/S1 disc levels, as shown by their MRI scans. Nafissi, *et al*. [14] reported that Positive MRI findings were observed in 64% of the patients. The L5 root was involved in 43% of cases, while the S1 root was involved in 40% of cases.

Our study showed that 20% of our cases had MRN root abnormalities (6 out of 30 cases). Nerve root compression and thickening was seen in all the six cases. Perineural edema was seen in 5 cases, and altered signal intensity was seen in 3 cases. This result isn't consistent with Chazen, *et al*. [13] reported that 21.05% of cases who were complaining of tingling and numbness (4 cases out of 19 cases) had abnormal MRN root abnormalities.

In the present study we reported that there was no significant correlation between MRN root abnormalities and subjective clinical abnormalities. This result is consistent with Chazen, *et al*. [13] noted that Out of the 17 cases with abnormal EMG, 29.4% (5 cases) showed abnormal MRN root abnormalities. The sensitivity of MRN is 29%, and its specificity is 100% when compared to EMG, which is considered the standard. This result isn't consistent with Chazen, *et al*. [13] showed that there was There is a significant a statistical relationship between the presence of abnormal nerve root on MRN (Magnetic Resonance Neurography) and the detection of radiculopathy (nerve root disorder) on EMG (Electromyography). Our study failed to show a statistically significant correlation between abnormal physical findings and MRI detection of nerve root compression. This is consistent with Yousif *et al*. [12] showed that there was no significance between abnormal NCS findings and the presence of nerve root compression in MRI.

Our study showed that 21 patients had electrophysiological studies, 3 patients showed abnormal motor NCS, 7 patients showed abnormal sensory NCS, and 17 patients showed abnormal EMG. Nafissi, *et al*. [14] found that Electrophysiological abnormalities were observed in 82% of the patients. A total of 73% of individuals exhibited abnormal electromyography (EMG) results in the muscles of their lower extremities. In Nafissi, *et al*. [14]. The existence of chronic clinical symptoms was associated with a significant rise in the frequency of electrophysiological abnormalities.

Our results showed that 80.9% (17 of 21) of cases which had performed an EMG showed an EMG abnormality consistent with clinical radiculopathy. However, According to the research conducted by Nardin, *et al*. [15] 55% of the participants exhibited an electromyography abnormality that was in line with the diagnosis of clinical radiculopathy. Also, in the study done by Reza, *et al*. [16] 56% of those involved exhibited an electromyography abnormality that was in line with the clinical diagnosis of radiculopathy. Our study showed that sensitivity of EMG was 100% in comparison to MRN in detecting root abnormalities. In the investigation conducted by Reza, *et al*. [16] For patients who are suspected to have radiculopathy, the sensitivity of electromyography (EMG) was found to vary between 49% and 86% when assessed through history and physical examination. Also, Mondelli *et al*. [17] found The EMG sensitivity is 41.7%, and that's lower than what is usually stated in the literature. The study was limited by the relatively small sample size. So, we recommended that further research is needed to make this more evident, and to study the prognostic role of MRN to guide therapeutic decision-making.

Conclusion

MRN appears to detect LS nerve root abnormalities in a portion of patients with clinical symptoms of lower extremity radiculopathy and radiculopathy on EMG. Our finding may support the growing evidence on the utility of MRN as a useful adjunct to electrodiagnostic testing for the diagnosis of LS radiculopathy.

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Conflict of Interest: Nil.

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