Section: Radiology

Original Research Article

MAGNETIC RESONANCE NEUROGRAPHY IN PERIPHERAL NERVE IMAGING

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ABSTRACT

Background: Aims: The aim of the study is to study Peripheral Nerve Diseases by Magnetic Resonance Neurography in a group of 54 patients who were referred to Department of Radio-diagnosis.

Materials and Methods: The study was conducted in the department of Radio-Diagnosis in 54 patients who were referred for peripheral nerve imaging for a period of 2 years. Patients of age group 0 – 79 & of both the sex, suspected to have a significant nerve related symptoms or mass lesion from adjacent soft tissues / bone causing nerve compression or any nerve injury were subjected to MRN are included in study.

Results: In this study 54 cases of Peripheral Nerves were evaluated by Magnetic Resonance Neurography, 40 were male and 14 were female. Most common age group of presentation is in two peaks. First peak is between 30-39 years of age. Second peak is in between 60-69 years. Out of 54 cases11cases showed positive results in the form of nerve lesions like schwannomas, neuromas and neurofibromas, nerve compression and infiltration by adjacent soft tissue and bone tumors and nerve injury in the form of edema. All the brachial plexus studied (4) showed positive and promising results.

Conclusion: MR neurography plays a crucial role in the evaluation of peripheral nerve pathologies by delineating the nerve's size, course, continuity, and signal intensity, as well as the integrity of surrounding perineural fat planes.

Keywords: MR Neurography**,** Peripheral Nerve Pathologies**,** Nerve Continuity**,** Nerve Signal Intensity**,** Perineural Fat Planes.

INTRODUCTION

The term Magnetic Resonance Neurography (MRN) is used to describe the new techniques for nerve imaging that greatly improve the reliability of identification of peripheral nerves. To study Peripheral Nerves by MRN and describe the clinical application and utility of MRN techniques to image the peripheral nerves and its distortion by mass lesions, trauma and demyelination. This current study is done over a period of 18 months on 54 patients referred to the department of radiology for peripheral nerve imaging. In all studies MRN imaging will be performed with a clinical 1.5 Tesla system (General electrical medical systems, Milwaukee, USA). A dedicated phased array extremity coil is used. MRN is a tissue specific selective MRI technique directed at identifying and assessing the fine morphologic characteristics of the peripheral nerve, such as nerve caliber, alterations in signal intensity , relations with the near by space occupying lesions and focal fibrosis/thickened fascia.[1,2] These images enable the physician to examine the peripheral nerve for anatomical abnormalities.

MRN technique may be broadly categorized as T1, T2, STIR and DW based sequences. T2 based imaging is currently performed and has many advantages such as good anatomic and pathologic imaging, wide availability and ease of protocol implementation. DW imaging is novel technique, which allows nerve signal quantification and potential functional imaging, however it is currently in experimental and feasibility stages.[2,3] Good quality MRN examination include spin echo type

contrast, thin sections (2-4 mm) T1W, T2W and Fat suppressed T2W (Fat sat T2W) MR images with slice thickness varying (1- 5mm) depending upon the field of view (FOV) and imaging time available, uniform and good fat suppression, high echo times (TE>60 ms) to minimize magic angle artifacts and high resolution (156 x392 or higher) with a prudent combination of both 2D nerve perpendicular as well as 3D isotrope (sub-1mm) images.[1,4]

MATERIALS AND METHODS

The study was conducted in the department of Radio-Diagnosis at NRI General Hospital, Chinnakakani, Mangalagiri, Guntur, in 54 patients who were referred for peripheral nerve imaging. The duration of the study period was from October 2012 to September 2014.

54 patients with significant nerve related symptoms were subjected to MRN examination after obtaining informed consent.

Inclusion Criteria

Patients of age group 0 – 79 & of both the sex, suspected to have a significant nerve related symptoms or mass lesion from adjacent soft tissues / bone causing nerve compression or any nerve injury were subjected to MRN.

Exclusion Criteria

1. Patients with cardiac pace makers
2. Patients with metallic implants
3. Uncooperative patients
4. Relative contraindications like patients with renal insufficiency
5. Other contraindications pertaining to MR imaging.

A total of 54 consecutive patients from October 2011 and September 2014 who were referred to the department of radiology as having significant nerve related symptoms were included in the study after obtaining an Informed consent.

Informed consent was obtained from all participants for MRN and for review of patients records and images.

In all studies MR imaging was performed with a clinical 1.5 T system (General electrical medical systems, Milwaukee, USA). A dedicated phased-array body coil was used.

Sequences

1. T1- weighted SSFSE with TR = 654 ms, TE = minimum (30 ms), Slice 3 mm, Matrix (MA) = 256x256.
2. T2- weighted SSFSE with TR = 4000-5000 ms, TE = 80 ms, Slice 3 mm, Matrix (MA) = 512 x 512 or 384 x 384.
3. STIR with TR = 6500 ms, TE = 50 ms, Slice 3 mm, Matrix (MA) = 320x320.

On MRN the nerve features like size, signal, course, perineural fat planes are assessed. On the basis of signal characteristics peripheral nerves are distinguished as normal or abnormal. Assesment of diffuse or focal nerve swelling, nerve angulation or displacement, neuroma formation and gross nerve discontinuity can be done. Maximum intensity projections (MIP) reconstructions may be used to demonstrate the abnormal nerve.

RESULTS

The present study was a prospective study carried out in the Department of Radiodiagnosis, NRI Medical College, to study the peripheral nerves in clinically indicated patients using 1.5T MRI and comparing its efficacy and significance in diagnosing peripheral involvement in various conditions using various sequences. The present study sample included 54 patients.

Table 1: Demographic distribution in present study

Age	No. Of Patients	Percentage
0-9	2	3.70
10-19	8	14.81
20-29	8	14.81
30-39	10	18.52
40-49	7	12.96
50-59	8	14.81
60-69	10	18.52
70-79	1	1.85
Grand Total	54	100
Gender distribution		
Females	14	26
males	40	74
Peripheral nerve involved/not		
Nerve involved	11	20.37
Nerve not involved	43	79.62

Out of total 54 cases , most common age group of presentation is in two peaks. First peak is between 30-39 years of age(18.5%). Second peak is in between 60-69 years (18.5%).14.8% of cases are in between 10-19 years, 20-29 years and 50-59 years.12.9% are between 40-49 years.3.7% between 0-9years.1.8% are in between 70- 79 years. Male preponderance is seen with 62 % of patients are males and 38% are females. In this study of 54 cases 11 cases showed positive result in the form of nerve lesions like schwannomas, neuromas and neurofibromas, nerve compression and infiltration by adjacent soft tissue and bone tumors and nerve injury in the form of edema. This accounting for about 20.3 %.

Table 2: Distribution in region of interest

IMAGING ROI	Number of Patients	Percentage
Arm	2	3.70
Axilla	1	1.85
Cervical Spine	14	26.0
Dorsal Spine	1	1.85
Dorsolumbar Spine	2	3.70
Elbow	3	5.55
Hip	3	5.55
Knee	6	11.11
Leg	2	3.70
Lumbar Spine	5	9.25
Neck	3	5.55
Shoulder	3	5.55
Thigh	8	14.81
Wrist	1	1.85
Total	**54**	**100**

In this study most of the cases are cervical spine related 26%, 14.8% are thigh, 11% are knee, 9.2% are lumbar spine, 5.5% are elbow, hip, neck and shoulder related, 3.7% are arm, D-L spine and Leg cases and 1.8% are axilla, dorsal spine and wrist cases.

Table 3: Distribution of peripheral nerves studied

PN Studied	Number of Patients	Percentage
Axilla	5	9.25
Brachial Plexus	4	7.40
C1-C7 Nerve Roots	12	22.22
Dorsolumbar Nerve Roots	2	3.70
Dorsal Nerve Roots	2	3.70
Femoral	9	16.66
Lumbar Plexus	5	9.25
Median	2	3.70
Radial	2	3.70
Sciatic	2	3.70
Tibial	8	14.81
Ulnar	1	1.85
Total	54	100

Studied nerves are cervical nerve roots accounting for 22.2% as most of the cases are cervical spine cases. 16.6% are femoral nerve cases, 14.8 % are tibial nerve cases, 9.2% are axillary nerve cases, 7.4% are brachial plexus cases, 3.7% cases are dorsal and lumbar nerve roots, dorsal nerve roots, median nerve, radial and sciatic nerves, 1.8% are ulnar nerve cases.

Table 4: Distribution of imaging features on t1w

PN STUDIED -- T1W	HYPO	ISO
Axillary	0	5
Brachial Plexus	4	0
C1-C7 Nerve Roots	2	10
Dorsolumbar Nerve Roots	1	1
Dorsal Nerve Roots	0	2
Femoral	0	9
Lumbar Plexus	0	5
Median	1	1
Radial	0	2
Sciatic	2	0
Tibial	0	8
Ulnar	1	0
Total	11	43

On MRN in T1 sequence involved nerves show hypointensity where as normal nerves appear as isointense. Of all 11 cases, in 4 cases brachial plexus is involved, 2 cases cranial nerve roots are involved, 2 cases sciatic nerves are involved, in 1 case dorsal and lumbar nerve roots are involved, in 1 case median nerve and in 1 case ulnar nerve involved.

Table 5: Distribution of imaging features on T2W

PN Studied -- T2W	HYPER	ISO
Axillary	0	5
Brachial Plexus	4	0
C1-C7 Nerve Roots	2	10

Dorsolumbar Nerve Roots	1	1
Dorso Nerve Roots	0	2
Femoral	0	9
Lumbar Plexus	0	5
Median	1	1
Radial	0	2
Sciatic	2	0
Tibial	0	8
Ulnar	1	0
Total	11	43

On MRN in T2 sequence involved nerves show hyperintensity where as normal nerves appear as isointense. Of all 11 cases, in 4 cases brachial plexus is involved, 2 cases cranial nerve roots are involved, 2 cases sciatic nerves are involved, in 1 case dorsal and lumbar nerve roots are involved, in 1 case median nerve and in 1 case ulnar nerve involved.

Table 6: Distribution of imaging features on stir

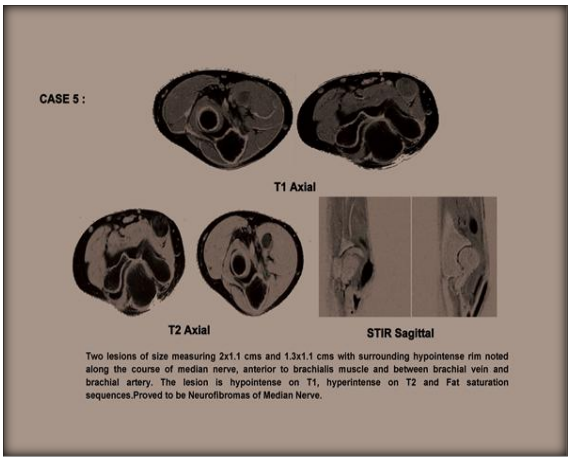
PN studied -- STIR	HYPER	ISO TO HYPER
Axillary	0	5
Brachial Plexus	4	0
C1-C7 Nerve Roots	2	10
Dorsolumbar Nerve Roots	1	1
Dorsal Nerve Roots	0	2
Femoral	0	9
Lumbar Plexus	0	5
Median	1	1
Radial	0	2
Sciatic	2	0
Tibial	0	8
Ulnar	1	0
Total	11	43

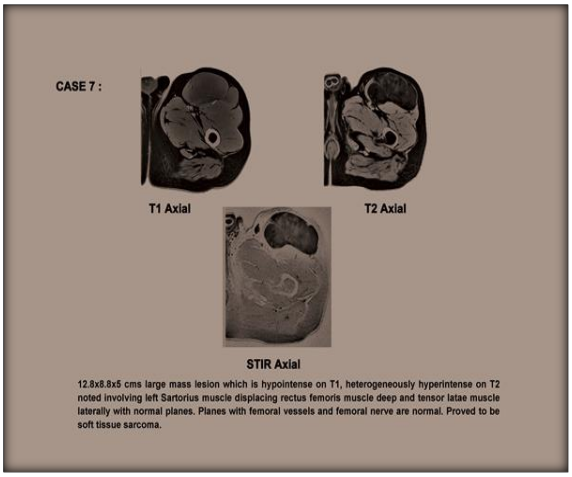
Involved nerves show hyperintensity where as normal nerves appear as isointense. Of all 11 cases, in 4 cases brachial plexus is involved, 2 cases cranial nerve roots are involved, 2 cases sciatic nerves are involved, in 1 case dorsal and lumbar nerve roots are involved, in 1 case median nerve and in 1 case ulnar nerve involved.

Table 7: Distribution of nerve involvement of all peripheral nerves studied

Peripheral Nerve Studied	Total Studied	Involved	Percentage
Axillary	5	0	0%
Brachial Plexus	4	4	100%
C1-C7 Nerve Roots	12	2	16.6%
Dorsolumbar Nerve Roots	2	1	50%
Dorsal Nerve Roots	2	0	0%
Femoral	9	0	0%
Lumbar Plexus	5	0	0%
Median	2	1	50%
Radial	2	0	0%
Sciatic	2	2	100%
Tibial	8	0	0%
Ulnar	1	1	100%

In the present study, Of all the peripheral nerves studied most commonly involved nerves are brachial plexus, sciatic and ulnar corresponding 100%, median and dorsolumbar nerve roots are next frequently involved peripheral nerve corresponding 50%, cervical nerve roots involved 16.6% and rest of the peripheral nerves studied are not involved in this study.





DISCUSSION

Magnetic resonance neurography is capable of generating high resolution longitudinal and cross-sectional images of major peripheral nerves, and has been studied to supplement diagnostic evaluations by electromyography and nerve conduction studies in patients with suspected peripheral nerve tumors, traumatic injury, post-irradiation neuritis, chronic compression, and pain syndromes where an anatomic lesion is suspected.[5] Peripheral nerve imaging has the potential to dramatically change the diagnosis and treatment of peripheral nerve pathology and lead to an improved understanding of peripheral nerve pathophysiology.

Currently, MR imaging serves as a problem-solving tool when additional anatomic information is needed to clarify ambiguous electrodiagnostic and clinical examinations. MRN proved useful in the preoperative evaluation and planning of surgery in patients with peripheral nerve lesions and adjacent soft tissue and bone lesions.[6,7]

This study group consisted of 54 patients who underwent MRN in our institute during October 2012 to September 2014, a period of 24 months, show two age peaks between 30-39 and 60-69 years corresponding to 19%. 74% are males and 26% are females with male preponderance.

The study group consisted of 54 patients. Peripheral nerves are involved in only11 patients contributing to 20%. Most of the patients presented with cervical complaints. Brachial plexus is the most commonly involved nerve.

Axillary nerve is studied in 5 patients with complaints of pain and swelling in the shoulder. Involvement of axillary nerve is not observed in any of the patients contributing to 0%. C1-C7 nerve roots are studied in 12 patients with complaints of neck pain. Involvement of C1-C7 nerve roots are observed in two patients contributing to 16.6% and remaining ten patients does not show any nerve roots involvement. Brachial plexus are studied in 4 patients with complaints of neck swelling, pain and injury. Involvements of brachial plexus are observed in all the four patients contributing to 100%.

According to study conducted by Majid Chalian, MD., et.al.[8] 15 patients with final diagnosis of suprascapular neuropathy were recruited. The diagnosis was confirmed by electrodiagnostic studies , clinical and/or surgical follow-up examinations. 2 cases were excluded from the study. MRN depicted asymmetric enlargement and/or abnormal T2 hyperintensity of C5 nerve root (10/13 cases), C6 nerve root (10/13 cases), both C5 and C6 nerve roots (7/13 cases), upper trunk (11/13 cases) and SSN (11/13 cases), and other brachial plexus segments involvement (4/13 cases). MR findings of denervation changes in the ipsilateral supraspinatus and infraspinatus muscles were detected in 12/13 cases. In all seven cases where contrast-enhanced images were available, MRN demonstrated enhancement of the denervated muscles but did not provide any additional information regarding the nerve abnormality. None of the MRN studies revealed a mass lesion along the course of the SSN. Concluding that MRN is a valuable diagnostic tool in clinically suspected cases of suprascapular neuropathy, because it can directly demonstrate the nerve abnormality, as well as secondary muscle denervation changes.[9]

Dorso lumbar nerve roots are studied in 2 patients with complaints of paraparesis and paraplegia. Involvement of dorsal and lumbar nerve roots are observed in one patient contributing to 50%. Dorsal nerve roots are studies in 2 patients with complaints of pain. Involvement of dorsal nerve roots is not observed in any of the patients contributing to 0%.

Lumbar plexus are studied in 5 patients with complaints of low backache. Involvement of lumbar plexus is not observed in any of the patients contributing to 0%. Femoral nerve is studied in 9 patients with complaints of pain and swelling of hip. Involvement of femoral nerve is not observed any of the patients contributing to 0%.

According to Bowen, MD., et.al (10)24 healthy subjects (10 men, 14 women; mean age, 42.2 years; range, 24–69 years) underwent MRN study. The results showed nerve roots from L1 to S4, the spinal nerve ganglion, and the proximal branches of the LSP were identified (score of 1 or 2) in 48 (100%); the main branches of the lumbar plexus including the obturator nerves and the femoral and lateral femoral cutaneous nerves within the psoas major muscle were identified (score of 1 or 2) in 22 (92%), 2 (8%), and 16 (67%), respectively. The main branches of the sacral plexus including the sciatic nerves, the posterior femoral cutaneous nerve, and the gluteal nerves were identified (score of 1 or 2) in 24 (100%), 20 (83%), and 20 (83%), respectively.[11] Median nerve is studied in 2 patients with complaints of pain in forearm. Involvement of median nerve is observed in one patient contributing to 50%.

According to Guggenberger R, et.al,[12] 45 healthy volunteers (30 women, 15 men) and 15 patients (10 women, five men) were studied. Volunteers were divided into three age groups. Magnetic resonance (MR) neurography was performed in all study

participants. Fractional anisotropy (FA) and apparent diffusion coefficient (ADC) of the median nerve were determined at the levels of the distal radioulnar joint, pisiform bone, and hamate bone. Normative FA and ADC values were calculated for men and women, different age groups, and different anatomic locations. FA and ADC did not differ between men and women (P=.28 and P=.38, respectively). FA decreased and ADC increased when moving from proximal to distal locations (P<.001). FA decreased and ADC increased significantly with age (P<.001). There was a significant difference between healthy volunteers and patients with carpal tunnel syndrome (P<.001 for both FA and ADC). An FA threshold of 0.47 and an ADC threshold of 1.054×10(-3) mm2/sec might be used in the diagnosis of carpal tunnel syndrome.[13]

Radial nerve is studied in 2 patients with complaints of pain in the arm. Involvement of radial nerve is not observed in any of the patients contributing to 0%. Sciatic nerve is studied in 2 patients with complaints of swelling in the thigh. Involvement of sciatic nerve is observed in all the two patients contributing to 100%.

According to Filler et al,[14] prospectively evaluated 239 consecutive patients experiencing leg pain in the distribution of the sciatic nerve. Results of these imaging evaluations combined with those of physical examinations and medical history were consistent with piriformis syndrome.[5,15] The authors noted that when piriformis muscle asymmetry alone is used as a criterion to identify individuals with piriformis syndrome, criterion sensitivity and specificity are 46% and 64%, respectively. If unilateral sciatic nerve hyperintensity at the level of the sciatic notch is added as a criterion to identify individuals with piriformis syndrome, criteria sensitivity and specificity are 64% and 93%, respectively showing MRN is more specific. Tibial nerve is studied in 8 patients with complaints of pain, swelling and injury of knee. Involvement of tibial nerve is not observed in any of the patients contributing to 0%.

According to Majid Chalian, MD., et.al,[8] MRN of ten patients were studied. The MRN findings studied included presence and location of focal fibrosis, presence or absence of nerve abnormality, location of nerve abnormality, and presence of neuroma formation and regional muscle denervation. 9 of 10 MRN studies (90%) had findings of nerve reentrapment related to focal fibrosis. MRN had a sensitivity of 77% for posterior tibial nerve, 100% for medial plantar nerve, and 100% for lateral plantar nerve injury, and the overall accuracy was 86%. The sensitivity of MRN was 91% for the presence of focal fibrosis affecting the three nerves and 67% for neuroma detection. Regional muscle denervation was better evaluated on MRN studies than at surgery. Ulnar nerve is studied in 1 patient with complaints of elbow pain. Involvement of ulnar nerve is observed in that patient contributing to 100%.

Keen et al,[15] conducted a comparative trial, comparing MRN in patients referred for signs and symptoms of ulnar neuropathy at the elbow with MRN in normal volunteers to determine the utility of MRN.[6,11] The MRNs of 21 patients with ulnar neuropathy were reviewed retrospectively. MRN was performed prospectively on 10 normal volunteers. The MRNs included axial T1 and axial T2 fat-saturated and/or axial STIR sequences. The meanulnar nerve size in the symptomatic and normal groups was 0.12 and 0.06 cm2 (p<0.001). The mean relative signal intensity in the symptomatic and normal groups was 2.7 and 1.4 (p<0.01). When using a size of 0.08 cm2, sensitivity was 95% and specificity was 80%. The authors stated that MR neurography of the elbow, particularly when assessing the size of the ulnar nerve, can be a useful diagnostic test for evaluating for ulnar nerve dysfunction at the elbow.[14] To summarize Magnetic Resonance Neurography is accurate to image the normal fascicular structure of peripheral nerves and its distortion by mass lesions, trauma and demyelination, to identify abnormalities of various peripheral nerves and to evaluate the morphological changes in the muscles supplied by the affected nerves

CONCLUSION

MRN technique may be broadly categorized as T1, T2, T2 fat suppressed and/or STIR based sequences. T2 based imaging is currently performed and has many advantages such as good anatomic and pathologic imaging, wide availability and ease of protocol implementation. Good quality MRN examination include spin echo type contrast, thin sections (2-4 mm) T1W, T2W and Fat suppressed T2W/STIRMR images with slice thickness varying (3-4 mm) depending upon the field of view (FOV) and imaging time available, uniform and good fat suppression, high echo times (TE>60 ms) to minimize magic angle artifacts. The best sequence in distinguishing between normal and abnormal nerves is the STIR or T2 fat suppressed sequence. These sequences demonstrated the highest success in the assessment of specific diagnosis.

MR Neurography plays an important role in identifying different peripheral nerve pathologies by demonstrating size, continuity, course and signal intensity of the nerve along with perineural fat planes.

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