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Correlation of MR Neurography and Electrophysiological Findings in Traumatic Plexus and Peripheral Nerve Injuries: A Case Series

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Abstract

Background: Traumatic injuries to the plexus and peripheral nerves pose diagnostic challenges, particularly in differentiating transient conduction block from structural nerve damage. Magnetic resonance neurography (MRN) and electrodiagnostic studies (EMG/NCS) offer complementary insights, yet their correlation in clinical settings remains underexplored.

Aim of Study: To assess the agreement between MR neurography grading and combined electrodiagnostic findings in patients with traumatic peripheral neuropathies and plexopathies.

Patients and Methods: This descriptive case series included 24 patients with a history of trauma and clinical signs of neuropathy. All underwent MRN and EMG/NCS assessments. MRN findings were graded according to Sunderland's scale. Electrophysiological data were combined to classify neuropathic severity. Agreement between MRN grades and electrodiagnostic findings was evaluated using Cohen's kappa coefficient.

Results: MRN grades ranged from I to V, reflecting variable severity. Electrodiagnostic studies identified severe multiroot axonal neuropathy, focal entrapment, normal findings, and diffuse polyneuropathy. Perfect agreement was observed between MRN grading and combined electrophysiological findings ($\kappa = 1.00$). Higher MRN grades corresponded to more severe axonal involvement, while lower grades correlated with focal or mild abnormalities.

Conclusion: MR neurography grading demonstrates excellent concordance with electrophysiological assessments, supporting its utility as a complementary tool in the structural-functional evaluation of peripheral neuropathies. Larger studies are warranted to validate these findings and explore quantitative MRN metrics.

Key Words: *Magnetic Resonance Neurography – Electromyography – Nerve Conduction Studies – Traumatic Nerve Injury – Brachial Plexus – Sunderland Classification – Peripheral Neuropathy.*

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Introduction

PLEXUS and peripheral nerve injuries resulting from trauma present a diagnostic and therapeutic challenge, particularly in differentiating between transient conduction block and irreversible structural damage. While nerve conduction studies (NCS) and electromyography (EMG) provide valuable functional information, they can be limited in localization and may not reliably detect preganglionic or partial nerve injuries in the early stages **[1,2]**.

Magnetic Resonance Neurography (MRN) is an emerging imaging modality that provides high-resolution visualization of plexus and peripheral nerves, allowing the classification of injury severity according to anatomical disruption **[3-5]**. Sunderland's classification, which ranges from Grade I (neuropraxia) to Grade V (neurotmesis), is widely used to describe the extent of nerve damage **[6]**.

This case series aims to evaluate the correlation between MRN findings and electrophysiological results in patients with a traumatic history of nerve injury. By comparing both diagnostic modalities, we explore their agreement and complementarity in characterizing injury grade, guiding prognosis, and informing management.

Patients and Methods

Study population:

This study is a descriptive, observational case series conducted between April 2023 and December 2024. It included 24 patients (16 males and 8 females) with a history of trauma who presented with clinical symptoms consistent with radiculopathy or plexopathy. Ethical approval was obtained from the hospital's institutional review board, and all participants gave written informed consent prior to enrollment. The research was carried out in accordance with established ethical standards for clinical investigations.

All participants underwent both magnetic resonance neurography (MRN) and electrodiagnostic testing, including nerve conduction studies (NCS) and electromyography (EMG), as part of their diagnostic evaluation.

Inclusion criteria:

- Patients presenting with signs indicative of plexus or peripheral nerve involvement, such as weakness, altered sensation, paresthesia, or neuropathic pain.
- Documented traumatic etiology, including a clear history of injury, surgery, or fracture.
- Completion of both MR neurography and electrodiagnostic assessments (EMG/NCS).

Exclusion criteria:

- Presence of any contraindications to MRI (e.g., metal implants, pacemakers, severe claustrophobia).
- Patients who had incomplete diagnostic workup or missing data.

Clinical history:

Comprehensive clinical history was collected, including:

• Date and nature of the trauma.

• Time of onset of neurological symptoms.

• Any accompanying sensory or autonomic symptoms.

• Previous medical or surgical treatments related to the condition.

Electrophysiological assessment:

All participants underwent standard nerve conduction studies (NCS) and/or electromyography (EMG) using the Nihon Kohden Neuropak MEB-9200G/K EP/EMG System (Neuropak M1, version 08.1, Japan). Tests were performed with patients in the supine position.

Technical parameters included:

- Motor studies: Bandpass filter set between 10 Hz and 5 kHz.
- Sensory studies: Bandpass filter set between 20 Hz and 2 kHz.

Routine NCS assessments:

• Tailored to the patient's clinical presentation.

• Included motor studies of the median, ulnar, musculocutaneous, axillary, suprascapular, peroneal, posterior tibial, and femoral nerves.

• Sensory evaluations included the superficial peroneal, sural, radial, ulnar, and median nerves.

• Parameters such as latency, amplitude, waveform duration, and conduction velocity were measured.

• F-wave latencies were used to assess proximal nerve segments.

EMG Evaluation:

• Conducted using concentric needle electrodes at rest and during both minimal and maximal voluntary muscle contractions.

• Adjacent muscles were examined to help differentiate between single and multiple nerve injuries.

• Findings were analyzed for evidence of demyelination, axonal loss, conduction block, or signs of nerve regeneration.

MRI Neurography Examination:

All MR neurography studies were performed using a 3 Tesla Siemens MAGNETOM scanner (Netherlands), equipped with specialized surface coils (20-channel head/neck or anterior/posterior torso coils depending on the area being examined). Patients were positioned supine during scanning. Imaging protocols were customized based on clinical symptoms and the suspected nerve region involved (brachial plexus, lumbosacral plexus).

Imaging protocols and sequences:

Spinal Localization: Sagittal T2-weighted imaging of the spine was used to localize anatomy in the lumbosacral region. For thoracic-level evaluations, sagittal T2 images of the entire thoracic spinal cord were obtained to rule out central causes mimicking plexopathies.

3D Myelography: Fast 3D myelographic sequences with maximum intensity projection (MIP) reconstructions were utilized to identify indirect signs of nerve root avulsion, such as pseudomeningoceles.

Functional Imaging (DWIBS): A 2D diffusion-weighted imaging with background suppression (DWIBS) sequence was acquired in the axial plane (reformatted into coronal MIP). Parameters included: *b*-value of 700, TE = 70 ms, TR = 8258ms, echo train length = 47, inversion time = 220ms, and slice thickness = 2.5mm with no inter-slice gap. The LSS plexus was scanned in two overlapping slabs, and images were combined during post-processing.

Anatomical sequences:

Axial and coronal 2D T2-weighted and pre- and post-contrast T1-weighted mDIXON sequences were performed with a slice thickness of 2.5mm, TE = 80ms, TR = 3752ms, and echo train length = 22. The mDIXON technique enables simultaneous acquisition of fat-suppressed and non-fat-suppressed images, eliminating the need for multiple separate sequences.

LSS Plexus-Specific Sequence:

A 3D coronal PROSET (Principle of Selective Excitation Technique) sequence based on the MENSA (multi-echo steady-state acquisition) approach was used. This provided high-resolution anatomical detail with voxel dimensions of 0.99×1×2 mm and TE = 4.6ms. It helped reduce vascular artifacts and was especially valuable in detecting subtle compressive abnormalities, such as fibrous bands at the level of the sciatic notch.

Brachial Plexus-Specific Sequence:

Sagittal-coronal T1-weighted turbo spin echo (TSE) sequences with 2mm slice thickness were obtained in both full adduction and full abduction (arm raised) positions to assess for dynamic mechanical compression.

Image analysis:

Two experienced neuroradiologists, each with over a decade of expertise in peripheral nerve imaging, independently reviewed all MRN scans. Any differences in interpretation were resolved through consensus. Nerve abnormalities were classified according to Sunderland's grading system (Grades I–V) (Table 1) based on the following imaging features:

- Nerve discontinuity or abnormal thickening.
- Hyperintensity on T2-weighted/STIR images.
- Contrast enhancement patterns.
- Distortion of fascicular architecture.
- Presence of neuromas or fibrotic changes.

Table (1): Sunderland's classification of nerve injuries and corresponding MR neurography findings (6).

Sunderland Grade	Pathological Description	Clinical Features	MRN Findings
Grade I	- Neurapraxia – temporary conduction block	- Mild weakness, sensory loss; full recovery	- Normal nerve continuity; mild T2 hyperintensity, no swelling or disruption
Grade II	- Axonotmesis – axonal disruption, intact endoneurium	- Weakness, Wallerian degeneration; good prognosis	- Diffuse T2 hyperintensity, nerve thickening, fascicular enlargement, preserved outline
Grade III	- Disruption of axon + endoneurium	- Incomplete recovery; possible scarring	- Moderate nerve swelling, irregular margins, signal heterogeneity
Grade IV	- Disruption of axon, endoneurium, perineurium	- Severe deficits; poor spontaneous recovery	- Fusiform swelling, neuroma formation, signal heterogeneity, architectural distortion
Grade V	- Neurotmesis – complete transection	- Complete loss of function; surgical repair needed	- Discontinuity of nerve, retraction, fluid gap, possible surrounding edema

Statistical analysis:

Statistical analysis was conducted using SPSS version 26 (IBM Inc., Chicago, IL, USA).

Descriptive statistics were used to summarize patient demographics, clinical features, and findings from magnetic resonance neurography (MRN) and electroneurophysiological studies (nerve conduction studies/[NCS] and electromyography/[EMG]). Categorical variables were reported as absolute counts and percentages. MRN severity was graded on a five-point ordinal scale (Grade I to V) based on radiological features of nerve signal intensity, caliber, and fascicular architecture.

To assess the diagnostic agreement between MRN grading and electrodiagnostic findings (NCS/EMG combined), we used Cohen's kappa (κ) coefficient. This statistic evaluates the level of agreement beyond chance between two ordinal classification systems. Kappa values were interpreted using the Landis and Koch criteria: κ <0.20 (poor), 0.21–0.40 (fair), 0.41–0.60 (moderate), 0.61–0.80 (substantial), and >0.80 (almost perfect agreement).

Given the small sample size (n = 24), a qualitative cross-tabulation of MRN grades and corresponding electrodiagnostic categories was also performed to support interpretation. Statistical analyses were descriptive in nature and performed manually due to the limited cohort size, with no hypothesis testing conducted.

Results

Twenty-four patients were included in the study (16 males, 8 females), with a mean age of 34 years ±20.3 years (range: 15–75 years). Twelve patients (50%) presented with brachial plexus involvement, while the remaining twelve (50%) had lumbosacral or peripheral lower limb neuropathies. The onset of neuropathy was reported as acute in eight patients (33%), subacute in four (17%), chronic in four (17%), and unspecified in eight (33%).

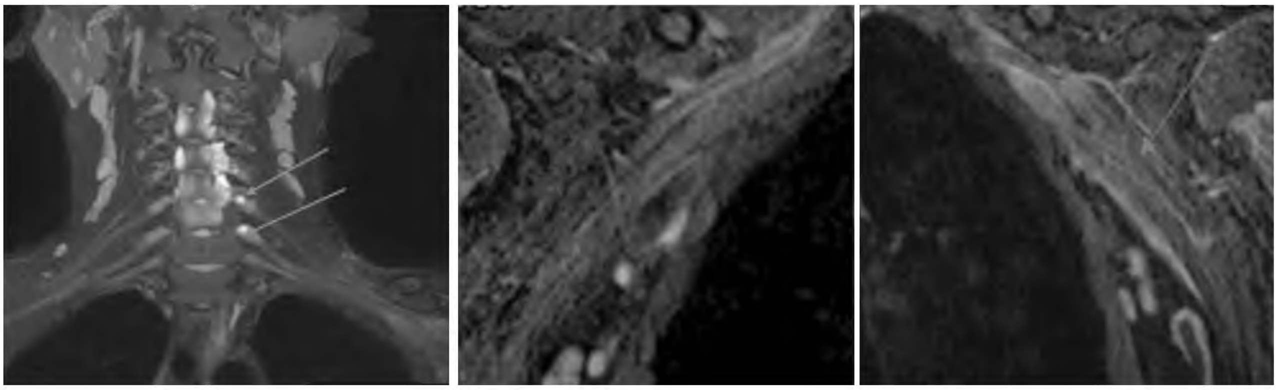
Electroneurophysiological and MR Neurography Findings:

Electroneurophysiological studies (NCS and/or EMG) were performed in all patients. The findings indicated:

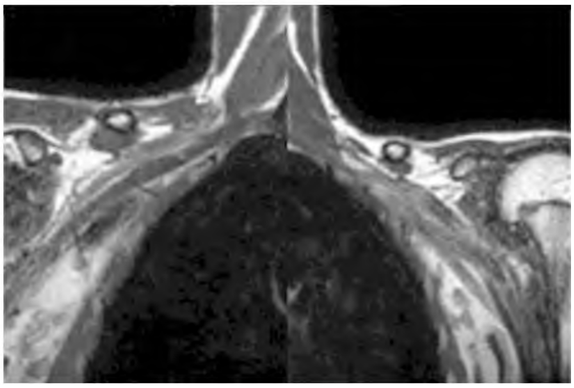
- Severe axonal multiroot involvement in 12 patients (50%)
- Focal entrapment neuropathy in 4 patients (17%).
- Normal findings in 4 patients (17%).
- Diffuse axonal polyneuropathy in 4 patients (17%).

MR neurography (MRN) was performed in all patients and graded using a standardized scale (Grade I to V). The distribution of MRN grades was as follows:

• Grade I: 8 patients (33%).
• Grade I–II (mixed): 4 patients (17%).
• Grade II: 4 patients (17%).
• Grade IV: 4 patients (17%).
• Grade V: 4 patients (17%) (Fig. 1).



(A) (B)



(C)

Fig. (1): A 15-year-old boy presented with history of left shoulder trauma two months ago.

MR neurography: (A) MIP reconstruction of coronal T2mDixon image showing avulsion and pseudo-meningeocele formation at the left C5 and C6 nerve roots Sunderland Grade V. (B) Coronal T2 mDixon images showing thickening of the distal trunks, divisions and cords of the left brachial plexus (blue arrow) compared to the right side. (C) Coronal T2W image showing atrophic changes of the left shoulder girdle muscles compared to the right side. EMG/NCS findings: Left upper trunk brachial plexus neuropathy with preservation of the middle.

Agreement Between MR Neurography and Electroneurophysiological Studies.

When combining EMG and NCS into a unified electrodiagnostic assessment, there was high concordance between the physiological severity of neuropathy and the MRN grade. Among all six patients:

Twelve patients with severe axonal neuropathy involving multiple roots demonstrated high MRN grades (IV, V, and I–II, respectively).

Eight patients with focal or no abnormalities on electrodiagnostic studieshad low MRN grades (Grade I).

Four patients with diffuse chronic axonal polyneuropathyshowed moderate MRN findings (Grade II).

The observed agreement between MRN and combined electroneurophysiological findings was 100%, with a Cohen's kappa coefficient of $\kappa = 1.00$, indicating perfect agreement and excellent concordance between MR neurography grading and electrodiagnostic assessment in this cohort. Higher MRN grades (IV–V) were consistently associated with severe axonal pathology and multiroot involvement, while lower MRN grades (I–II) corresponded to focal or mild findings on EMG and NCS.

Discussion

In this cohort of twenty–four patients with varying neuropathic presentations, our study showed perfect agreement ($\kappa = 1.00$) between MR neurography (MRN) grading and combined electroneurophysiological assessment (EMG and NCS). High-severity MRN grades (IV–V) consistently corresponded with severe axonal or multiroot involvement, intermediate grades with mixed findings, and low grades (I–II) with focal or minimal pathology, confirming the validity of MRN as a structural correlate to electrophysiologic status.

Our findings align with prior studies demonstrating strong electrodiagnostic–MRN concordance. For brachial plexopathies, Crim & Ingalls reported moderate MRN sensitivity (41–71%) but high specificity (98–100%) when EMG was used as a reference standard, with aninterobserver κ of 0.66–0.71 [7]. Similarly, for lumbosacral radiculopathy, MRN abnormalities significantly correlated with EMG/NCS evidence of denervation ($p<0.05$) [8].

Moreover, Su et al., found that quantitative MRN metrics (e.g., nerve size, T2 signal, FA, ADC) correlated well with electrophysiological parameters, highlighting MRN's potential to quantify demyelination and axonal injury [9]. Our study echoes this, albeit using a grading approach rather than quantitative parameters, but still demonstrates robust structural–functional correlation.

Additionally, in trigeminal nerve injury, MRN's grading showed 84% agreement with surgical findings, exceeding neurosensory testing performance (74%) [10]. This strengthens the notion that MRN can match or even outperform electrophysiology in assessing structural nerve damage. We demonstrated similar alignment between MRN and electrophysiologic severity, underscoring MRN's clinical value.

Finally, MRN's additive role in brachial plexus assessment especially when electrophysiology is inconclusive has been observed elsewhere [11]. In our cohort, MRN refined evaluation across all grades, supporting its adjunctive utility.

Several factors limit our study: Small sample size (n = 24) restricts generalizability and statistical power;the retrospective designintroduces sampling bias and heterogeneity in imaging timing; and qualitative grading may lack sensitivity compared with quantitative MRN metrics (e.g., FA, ADC). Additionally, timing differences between imaging and electrophysiological studies likely influenced findings, as denervation and morphological changes evolve over time.

Future research should involve larger, prospective cohorts with synchronized timing of MRN and electrodiagnosis. It would be beneficial to incorporate quantitative MRN techniques such as diffusion tensor imaging or T2 mapping to capture subtle structural changes. Comparative studies with high-resolution ultrasound, which has shown complementary utility in peripheral neuropathies, are also warranted [12]. Furthermore, longitudinal assessments could clarify how imaging and electrophysiologic changes evolve and predict clinical outcomes.

In conclusion, this study confirms a strong structural–functional agreement between MRN grading and combined electrodiagnostic findings in peripheral nerve and plexus disorders. MRN emerged as a reliable non-invasive modality that reflects physiological neuropathic severity, underscoring its role alongside EMG/NCS in diagnosis, prognostication, and management planning.

Acknowledgment:

Not applicable.

Declaration of conflicting interests:

The authors declare that they have no conflicts of interest.

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العلاقة بين نتائج الرنين المغناطيسي العصبي والدراسات الكهروفسيولوجية في إصابات الأعصاب الطرفية والضفيرة العصبية الناتجة عن الصدمات : سلسلة حالات

تُعد إصابات الأعصاب الطرفية والضفائر العصبية الناتجة عن الحوادث والتدخلات الجراحية من التحديات التشخيصية الصعبة، خاصةً فى التمييز بين الانقطاع الوظيفى المؤقت والتلف البنيوي الدائم فى العصب. في هذا البحث، تم دراسة العلاقة بين نتائج التصوير بالرنين المغناطيسى العصبى (MR Neurography) والدراسات الكهروفسيولوجية (تخطيط الأعصاب والعضلات) فى مجموعة من المرضى المصابين بإصابات عصبية ناجمة عن الصدمات.

شملت الدراسة ٢٤ مريضًا (١٦ ذكرًا و٨ إناثًا) لديهم أعراض سريرية تدل على إصابة عصبية، وجميعهم خضعوا لتقييم بالرنين المغناطيسي العصبى وتخطيط الأعصاب والعضلات. تم تصنيف نتائج التصوير بالرنين وفقًا لمقياس «ساندرلاند» لدرجات إصابة الأعصاب (من الدرجة الأولى حتى الخامسة). كما تم تحليل نتائج التخطيط الكهربى لتحديد شدة الإصابة العصبية.

أظهرت النتائج وجود تطابق تام بين درجات التصوير بالرنين المغناطيسى ونتائج الفحوص الكهروفسيولوجية، حيث بلغ معامل كابا (Cohen's Kappa) قيمة ١.٠٠، مما يشير إلى اتفاق كامل بين الطريقتين. وُجد أن الدرجات العليا من التصوير (الرابعة والخامسة) ارتبطت بإصابات شديدة متعددة الجذور، بينما الدرجات الدنيا (الأولى والثانية) كانت مصاحبة لإصابات بسيطة أو موضعية.

الاستنتاج: يُظهر التصوير بالرنين المغناطيسى العصبى توافقًا عاليًا مع التقييمات الكهروفسيولوجية فى حالات الإصابات العصبية الناتجة عن الصدمات، مما يجعله أداة فعالة ومكملة فى التشخيص والتخطيط العلاجى. توصى الدراسة بإجراء أبحاث مستقبلية على عينات أكبر مع تطبيق تقنيات كمّية متقدمة لتقييم الأعصاب.