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ELECTROPHYSIOLOGICAL LOCALIZATION AND PROGNOSTIC INDICATORS IN RADIAL NEUROPATHY PRESENTING AS WRIST DROP: A THREE-YEAR RETROSPECTIVE OBSERVATIONAL STUDY

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ABSTRACT

Background and Objective:

Radial neuropathy is a common cause of wrist drop, and accurate lesion localization is essential for appropriate management and prognostication. The objective of this study was to analyze electrophysiological localization patterns of radial nerve lesions presenting as wrist drop and to assess whether earlier referral for electrophysiological evaluation was associated with recovery outcomes.

Methods:

This retrospective observational study was conducted at Lady Reading Hospital Peshawar, a tertiary care setting, over a three-year period (January 2022–December 2024). Adult patients with wrist drop and electrophysiological confirmed radial neuropathy were included. Nerve conduction studies and needle electromyography were used to classify lesions as high radial nerve palsy, posterior interosseous nerve (PIN) syndrome, or radial tunnel syndrome. Functional recovery at ≥3 months was categorized as complete, partial, or none. Outcomes were compared between early (≤4 weeks) and delayed (>4 weeks) electrophysiological evaluation. Data was analyze using SPSS version 25.0.

Results:

Fifty-four patients were analyzed (mean age 42.3 ± 15.2 years; 70.4% male). High radial nerve palsy was the most common lesion (61.1%), followed by PIN syndrome (29.6%) and radial tunnel syndrome (9.3%). Compression was the leading etiology. Complete recovery was significantly more frequent in patients undergoing early electrophysiological evaluation compared with delayed assessment (76.0% vs. 44.8%; p = 0.03).

Conclusion:

Early EMG testing itself does not directly improve nerve recovery. Instead, earlier electrophysiological referral may facilitate timely diagnosis and management, which could contribute to improved functional outcomes.

Keywords: Radial Neuropathy, Nerve conduction studies, Electromyography, Prognosis, Wrist drop.

INTRODUCTION

Radial neuropathy is a common cause of wrist drop, a disabling condition characterized by inability to dorsiflex the wrist and extend the fingers.[1] The radial nerve's anatomical course, originating from the posterior cord of the brachial plexus and traversing the spiral groove of the humerus, predisposes it to injury at various levels.[2]

It is the third most prevalent focal mononeuropathy of the upper extremity, after median and ulnar neuropathies with motor deficits, particularly wrist drop as the prominent feature. Muscle weakness, especially wrist drop, is the primary clinical manifestation of most instances of radial neuropathy, and a comprehension of radial nerve architecture typically facilitates lesion localization. [2]

Clinically, the weak wrist-extensor posture can result from lesions at various levels of the radial nerve (axilla, spiral groove, forearm) or its branches, including

posterior interosseous nerve (PIN) and the radial tunnel. [3] Correct localization of the lesion is essential because management whether conservative, surgical decompression, or repair depends on both the level and severity of nerve injury .[4]

Etiologies of radial neuropathy are diverse and include external compression (e.g., prolonged pressure while sleeping "Saturday night palsy", trauma such as humeral shaft fractures, penetrating injuries, improper tourniquet application, and iatrogenic causes, including intramuscular injections or surgical interventions .[5,6]

Traditional clinical examination, while highly useful, has limitations in differentiating high radial nerve palsy from more distal branch entrapments such as PIN syndrome or radial tunnel syndrome. For example, sensory involvement and reflex changes may overlap between levels, making clinical localization imprecise. [2]

Electrophysiological studies, including nerve conduction studies (NCS) and electromyography (EMG), have proved themselves as critical tools in the diagnosis of radial neuropathy. These investigations provide objective assessments of motor and sensory nerve function, axonal loss versus demyelination, conduction block, and denervation.[7] They thereby allow accurate lesion localization, severity grading, and prognostication. For instance, in radial neuropathies, reduced compound motor action potential (CMAP) amplitude, slowed conduction velocity, or absent sensory nerve action potentials (SNAPs) support a proximal lesion, while preserved sensory potentials with distal motor involvement point to PIN or radial tunnel sites.[8]

High-resolution ultrasound and magnetic resonance neurography have become important adjuncts in atypical or refractory cases, offering anatomical insights into nerve entrapments and structural abnormalities .[9]

A pictorial review on radial nerve pathologies noted that the nerve's long and tortuous course in the upper limb, particularly in the spiral groove, predisposes it to injury from trauma, compression, or iatrogenic manipulations.[10] However, even with advanced imaging such as high-frequency ultrasound and MRI, electrophysiology remains the functional gold standard particularly in settings where imaging may not reliably reflect nerve function or may be unavailable.[11]

Despite the recognized value of electrophysiology, there remains a paucity of local data from Pakistan specifically examining radial nerve injury presenting as wrist drop and its electrophysiological localization patterns. An earlier Pakistani study of 119 wrist drop cases reported that 73.9% of lesions were at the mid-arm level and 70.6% were axonal, but did not provide detailed electrophysiological parameter breakdowns or link findings with lesion site and etiology in many tertiary-care Pakistan settings, radial neuropathy is often managed without detailed localization, and delays in electrophysiological referral may compromise outcome.[5]

Prognosis in radial neuropathy depends on several clinical and electrophysiological factors. Etiologic factors such as traumatic injury, compressive neuropathy, or iatrogenic injury have influence on recovery potential. In addition, electrophysiological parameters derived from nerve conduction studies and electromyography provide important prognostic information. Findings such as reduced compound muscle action potential (CMAP) amplitude, evidence of axonal degeneration, conduction block, and the presence of active denervation on needle electromyography are associated with varying degrees of functional recovery. Generally, demyelinating lesions with preserved CMAP amplitudes have a better prognosis compared with lesions showing significant axonal loss. Therefore, electrodiagnostic evaluation not only aids in lesion localization but also contributes to prognostic assessment of radial neuropathy.[12]

To address this gap, we conducted a retrospective study spanning a three-year clinical and electrophysiological experience of radial neuropathy presenting as wrist drop at a tertiary care hospital in Peshawar. The primary objective was to evaluate electrophysiological localization patterns of radial nerve lesions in adult patients with wrist drop and correlate these with clinical etiology and outcomes. Secondary objectives included assessing the association between early electrophysiological assessment and recovery, with the aim of providing useful clinical insights for neurologists, EMG technicians, and rehabilitation physicians in Pakistan.

METHODS

This retrospective observational study was conducted in the Department of Neurology, Lady Reading Hospital Peshawar, a tertiary care hospital over a three-year period from January 2022 to December 2024. Ethical approval was obtained from Institutional Board Review (Ref No

1024/LRH/MTI). Clinical and electrophysiological data were retrieved from the departmental neurophysiology laboratory database and patient medical records. Adult patients aged 18 years or older who presented with wrist drop and were electrophysiologically confirmed to have radial neuropathy were included. Patients with alternative causes of wrist drop, including cervical radiculopathy, stroke, motor neuron disease, brachial plexopathy, or functional neurological disorders, as well as cases with incomplete electrophysiological data or missing clinical documentation, were excluded.

Data were extracted using a structured proforma and included demographics (age, gender), side of involvement (right/left), duration of symptoms prior to EMG testing, clinical etiology (compression, trauma, iatrogenic, idiopathic), electrophysiological localization (high radial nerve palsy, posterior interosseous nerve [PIN] syndrome, radial tunnel syndrome), and management approach with clinical recovery status on follow-up. Nerve conduction studies (NCS) and electromyography (EMG) were performed using a standard NeMus EMG/NCS machine (EB Neuro, Italy), in accordance with the protocol recommended by Preston and Shapiro for EDX evaluation of a suspected radial nerve injury .[12]

The procedure was performed by an expert electro-physiologist and the results were interpreted by a consultant neurologist. Radial, Ulnar and Median nerves were tested during NCS. Motor conduction of the radial nerve was assessed by recording compound muscle action potentials (CMAPs) from the extensor indices and extensor digitorum, brachioradialis and triceps muscles were sampled during EMG, while superficial radial sensory responses were recorded from the dorsum of the hand using standard antidromic techniques. It was routinely performed as part of the assessment of suspected radial neuropathy. Needle EMG was conducted in radial nerve innervated muscles both proximal and distal to the suspected lesion.

Detailed quantitative electrophysiological parameters such as compound muscle action potential amplitudes (CMAP), conduction velocities, and specific EMG abnormalities for each muscle were not consistently available in the retrospective database. Therefore, electrodiagnostic findings were mainly used for lesion localization and diagnostic classification rather than detailed quantitative comparison across the groups.

Lesion localization was determined based on electrophysiological findings. High radial nerve palsy was diagnosed when there were abnormalities in radial motor responses with reduced CMAP amplitude or conduction block along with abnormal or absent radial sensory responses and EMG evidence of denervation in proximal radial-innervated muscles such as triceps or brachioradialis. Posterior interosseous nerve (PIN) syndrome was defined by reduced motor responses in PIN-innervated muscles with preserved radial sensory nerve action potentials and EMG abnormalities confined to distal extensor muscles. Radial tunnel syndrome was considered when nerve conduction studies were largely normal or showed minimal abnormalities, with EMG either normal or demonstrating subtle changes in PIN-innervated muscles in patients presenting primarily with pain.

Standard electrodiagnostic parameters were used while doing nerve conduction studies. Motor and sensory recordings were done using surface electrodes with filter settings typically set at 2 Hz–10 kHz for motor studies and 20 Hz–2 kHz for sensory studies. Sweep speed was maintained between 2–5 ms/division, and sensitivity was adjusted according to signal amplitude. Recovery was categorized as complete recovery when there was full restoration of wrist and finger extension, partial recovery when there was greater than 50% improvement in strength, and no recovery when persistent functional deficit was noted at three months or more follow-up. Early versus delayed diagnosis was defined by the timing of EMG testing as performed within four weeks or after four weeks of symptom onset, respectively. Data were then analyzed using SPSS version 25, with quantitative variables presented as mean ± standard deviation while categorical variables as frequencies and percentages. Associations between early testing, etiology, lesion level, and recovery were evaluated by using Fisher's exact test, and a p-value less than 0.05 was considered statistically significant. Patient identifiers were removed to make sure of the confidentiality. All procedures were carried out in accordance with the Declaration of Helsinki for research involving human subjects.

RESULTS

A total of 54 patients with electrophysiologically confirmed radial neuropathy presenting as wrist drop were included in the study. The majority were male (n=38; 70.4%), and the mean age was 42.3 ± 15.2 years. The right upper limb was involved in 31 patients

(57.4%). The mean duration between symptom onset and electrophysiological assessment was 19.6 ± 8.4 days. Patients were categorized according to timing of electrophysiological evaluation as early (≤4 weeks) or delayed (>4 weeks) after symptom onset. Among the study population, diabetes mellitus and hypertension were the most common underlying diseases.

The most common lesion level was high radial nerve palsy which accounts for 33 (61.1%), followed by PIN syndrome 16 (29.6%) and radial tunnel syndrome 5 (9.3%). Compression accounted for the largest proportion of cases overall, while trauma and iatrogenic injuries contributed substantially to high radial nerve palsy. Table 1 illustrates the etiologies of radial neuropathy in the study population.

Table 1: Etiologies of Radial Neuropathy

Lesion Level	Compression (%)	Trauma (%)	Iatrogenic (%)	Idiopathic (%)	Total (%)
High radial nerve palsy	13 (39.4%)	9 (27.3%)	7 (21.2%)	4 (12.1%)	33 (61.1)%
PIN syndrome	6 (37.5%)	4 (25.0%)	2 (12.5%)	4 (25.0%)	16 (29.6%)
Radial tunnel syndrome	2 (40%)	1 (20.0%)	1 (20.0%)	1 (20.0%)	5 (9.3%)

Electrodiagnostic features varied according to the anatomical localization of radial neuropathy. High radial nerve palsy showed abnormalities in both motor and sensory studies, whereas posterior interosseous nerve syndrome demonstrated preserved sensory responses with motor abnormalities limited to PIN-innervated muscles. Radial tunnel syndrome typically demonstrated normal nerve conduction studies with minimal or absent electromyographic abnormalities as shown in table 2.

Table 2: Electrodiagnostic findings according to lesion localization

Electrodiagnostic Feature	High Radial Nerve Palsy (n=33)	PIN Syndrome (n=16)	Radial Tunnel Syndrome (n=5)
Radial motor CMAP amplitude	Reduced in majority	Reduced in PIN-innervated muscles	Usually normal
Radial sensory SNAP	Reduced or absent	Normal	Normal
Motor conduction velocity	May be slowed across lesion	Usually normal	Normal
Needle EMG findings	Denervation in triceps, brachioradialis, and distal extensor muscles	Denervation in distal extensor muscles (EIP, EDC)	Normal or minimal abnormalities
Conduction block	May be present	Rare	Absent

CMAP = compound muscle action potential; SNAP = sensory nerve action potential; EMG = electromyography; PIN = posterior interosseous nerve; EIP= extensor indicis proprius; EDC= Extensor digitorum communis.

Table 3 presents the functional recovery outcomes in 54 patients with radial nerve palsy categorized by early (≤4 weeks from symptom onset) versus delayed (>4 weeks) electrophysiological evaluation. Complete recovery was significantly more frequent in the early EMG group compared with the delayed group (76.0% vs. 44.8%; OR 3.9, 95% CI 1.21–12.6; p = 0.03). No statistically significant differences were observed for partial or no recovery between groups. P-values were derived using Fisher's exact test.

Table 3: Recovery outcomes at ≥3-month follow-up stratified by timing of electrophysiological assessment					
Outcome	**Early EMG (≤4 wks) n (%)**	**Delayed EMG (>4 wks) n (%)**	**Total n (%)**	**Odds Ratio (95% CI)**	**p-value**
Complete recovery	19 (76.0%)	13 (44.8%)	32 (59.3%)	3.9 (1.21–12.6)	0.03*
Partial recovery	4 (16.0%)	10 (34.5%)	14 (25.9%)	–	0.29
No recovery	2 (8.0%)	6 (20.7%)	8 (14.8%)	–	0.41
Total	25 (100%)	29 (100%)	54	100%)	

Odds ratios and 95% CI are shown only for the primary outcome (complete recovery). ORs were not measured for nonsignificant secondary outcomes (partial or no recovery).

DISCUSSION

In this three-year series of adults presenting with wrist drop and electro physiologically confirmed radial neuropathy, high radial nerve palsy accounted for more than 60% of cases, followed by PIN syndrome (29.6%) and radial tunnel syndrome (9.3%). Compression neuropathy was the leading cause, most often related to sleep-associated postural pressure, and early electrophysiological testing was significantly associated with complete functional recovery. The poorer recovery in patients with posterior interosseous nerve (PIN) lesions in our study cohort is supported by previous studies in which more severe axonal damage, delayed diagnosis, and lack of sensory symptoms which frequently leads to late presentation.[13]

These findings reinforce the diagnostic and prognostic importance of timely neurophysiological assessment, particularly in resource-limited settings.

The predominance of proximal radial nerve involvement parallels prior reports identifying the spiral groove and upper arm as the most vulnerable anatomical segments.[1,14,15] Electrophysiological patterns in our cohort aligned with established lesion signatures: markedly reduced CMAP amplitudes and sensory involvement in high radial palsy, preserved SNAPs in PIN syndrome, and minimal needle EMG abnormalities in radial tunnel syndrome.[16,17] Similar localization trends have been documented in surgical and neurophysiology series from high-income countries, but electrophysiology-based breakdowns from South Asia remain scarce.[18]

The high proportion of compression neuropathy, highlights preventable mechanisms of nerve injury that are still under reported in Pakistan and other LMICs. Alcohol-associated compression neuropathy also called Saturday Night Palsy is well described in Western cohorts, but in this setting, sleep posture and exhaustion-related immobilization appear to be more relevant factors.[19] Equally notable is the frequency of iatrogenic injury nearly one in five cases most often after orthopedic procedures or upper-arm IM injection. Radial nerve palsy following humeral fracture fixation has been increasingly recognized worldwide, yet systematic surveillance in LMIC hospitals remains limited.[20]

Electrophysiology served as the decisive diagnostic tool in all cases and remains the most accessible modality in settings where ultrasound and MRI neurography are unavailable or unaffordable.[21] Although imaging can delineate focal enlargement or entrapment, EMG/NCS uniquely assesses functional integrity, axonal loss, and re innervation potential.[12,22,23] The strong association between early testing and complete recovery in our study is consistent with prior work showing that early CMAP amplitude measurement predicts functional outcome and guides splinting or surgical timing.[13] Delayed neurophysiological referral risks diagnostic uncertainty, unnecessary imaging, and missed opportunities for reversible decompression.

Early referral may facilitate timely identification of lesion localization and helps appropriate management. However, the timing of electro diagnostic testing itself does not directly affect nerve regeneration. Therefore, the

observed association should be interpreted as reflecting earlier clinical evaluation and intervention rather than a direct prognostic effect of electro diagnostic testing.

The relevance of these findings for LMIC healthcare systems is substantial. Wrist drop is clinically obvious, yet referral for electrophysiology is often delayed because of low awareness among non-neurologists and limited EMG availability outside tertiary centres. Establishing simple referral triggers such as automatic EMG request for new-onset wrist drop could reduce disability and cost. The preventable nature of most compression and iatrogenic cases also argues for targeted interventions, including patient education on limb posture, peri-operative nerve-sparing technique, and safer phlebotomy practice. A major strength of this study is its focus on electrophysiological localization rather than purely descriptive clinical categorization, performed in a tertiary referral center with a relatively large cohort from Pakistan.[24]

However, several limitations needed to be considered. As this is retrospective study so it can lead to selection bias, and three-month follow-up may underestimate the late motor recovery. Quantitative electrophysiological parameters like serial CMAP ratios or re-innervation indices were not systematically collected. Moreover, being a single-center study, these results may not fully reflect the total community burden of radial neuropathy in Pakistan.

Prospective studies in future should evaluate long-term outcomes, utilize imaging modalities such as ultrasound or MRI when needed, and evaluate the cost-effectiveness of early EMG referral in LMICs. The development of prognostic scoring systems integrating lesion level, extent of axonal loss, and time of testing could further refine further management strategies. There is also need of interventional studies focusing on education-based prevention, especially sleep posture and postoperative limb handling, are necessary.

In summary, radial neuropathy in this cohort most often evolved from preventable compression and mainly affected the nerve proximal to its bifurcation. Early electrophysiological assessment was strongly associated with favorable recovery, which supports its regular use in the early evaluation of wrist drop. Broader implementation of timely EMG/NCS and preventive strategies may help to reduce the disability burden from radial neuropathy in resource-limited settings.

CONCLUSION

Electrophysiological studies provide accurate localization and characterization of radial neuropathy presenting as wrist drop. Earlier referral was associated with higher rates of complete recovery, which likely reflects earlier clinical presentation and timely intervention rather than a direct therapeutic effect of electrodiagnostic testing. Adoption of timely neurophysiological evaluation and preventive measures for compression related injuries may improve outcomes in radial neuropathy in LMIC settings.

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Assad Ullah Khan: Concept, Design, Data collection, manuscript writing
Saad Ali: Data collection, manuscript writing
Muhammad Farooq; Data Analysis, Manuscript writing
Sadiq Ali Shah; data collection, data analysis, manuscript revision

All the authors have approved the final version to be published and agree to be accountable for all aspects of the work.