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# Role Of Ultrasound And Electrodiagnostic Study In The Assessment Of Traumatic Peripheral Nerve Injuries Of Upper Limbs

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***Abstract:***
***Background***: *peripheral nerve injury is a vital and potentially debilitating condition that affects the daily life of patients and their quality of life. Reaching the right diagnosis helps to find the optimal treatment which in turn leads to reduction of disabilities and, in many cases, regaining functionality.*
***Objectives***: *To evaluate the role of ultrasound and electrodiagnostic studies in assessing traumatic peripheral nerve injuries in upper limbs.*
***Patients and methods***: *Participants were (44) adult patients, with (40) men and (4) women; mean age (39.3± 10.2 years), with a total of (50) peripheral nerve injuries (duration of 3 months to 20 years). High-frequency US examinations and electro-physiologic studies were used to assess upper limb peripheral nerve injury.*
***Results***: *Partial nerve injury (axonotmesis) was diagnosed in 35 (70%) nerves, complete nerve injury (neurotmesis) in 2 (4%), normal nerve continuity was found in 12 (24%) with one case (2%) with foreign body detection. Ultrasound showed Sensitivity and Specificity of 92% and 90%, respectively, compared to EDX.*
***Conclusion***: *Nerve ultrasound demonstrates high sensitivity and specificity, indicating that it serves as a complementary tool to the gold standard electrodiagnostic studies. Ultrasound is a valuable tool for providing informative details, particularly assessing the morphology of nerve and evaluating its surrounding structures.*
***Key words***: *Peripheral nerve, Trauma, Ultrasound, Electrodiagnosis, nerve injury*

**Abbreviations:**
PNI peripheral nerve injury
TPNI Traumatic peripheral nerve injury
CSA Cross-sectional area
CMAPs Compound motor action potentials
EDX Electrodiagnostic studies
EMG Electromyography
MUAPs Motor unit action potentials
NCS Nerve conduction study
SNAPs Sensory nerve action potentials
TNL Traumatic nerve lesion

## INTRODUCTION:

Peripheral nervous system (PNS) trauma, though relatively uncommon, represents an important clinical issue because of its potential to cause severe sensorimotor dysfunction and chronic neurogenic pain. These injuries can significantly affect a patient's quality of life and functional capacity (1). The incidence of traumatic nerve injuries is approximately 2–3% of cases presenting to major trauma centers globally with more than 200,000 trauma-related nerve injuries annually reported in the United States alone. (2) Among civilians, blunt trauma is a commonly observed mechanism of injury, while during warfare penetrating injuries are more common. (3) Upper extremities are more commonly prone to peripheral nerve injury (PNI) than the lower extremities. PNIs result from varying degrees of force applied to the nerve. Medium- to high-energy force may cause a transection, contusion, stretch, and avulsion injuries to the involved nerve, whereas low-energy force may cause compressive neuropathies. (4) Among these, stretch injury is considered the most frequent type of injury in which the stretching force exceeds the elasticity of the nerve. Here, nerve continuity is usually preserved unless the injury is severe enough, causing complete nerve transection such as brachial plexus avulsion. The second most common type of injury is laceration injury caused by sharp objects like knives or blades. They sever the nerve partially or in more severe cases lead to complete nerve disruption. Compression injuries are the third most common type of PNI, when there is total loss of sensory and motor function despite the presence of intact nerve continuity. Because they are the most delicate and fragile structures, peripheral nerve fibers are more susceptible to damage. (5,6) A proper clinical evaluation of an injured nerve starts with a thorough history and electrodiagnostic testing (EDX) (7) which is considered the gold standard for the diagnosis nerve injuries. EDX includes nerve conduction studies (NCS) and electromyography (EMG) providing informative details about:

- The type of the damaged nerve fiber; whether sensory or motor
- The severity of the damage
- Whether the demyelination or axonal loss is the underlying pathophysiology
- The extent of axonal loss (8,9,10)

Although EDX provides valuable understandings for the damage in PNI cases, it has some limitations, (11,7) such as inability to distinguish between neuropraxic and complete nerve transection in the acute stage of the trauma; this leads to unsatisfying results that may lead to improper management, delayed surgical repair and poor outcomes. Electrodiagnostic studies often provide inconclusive results in the first few weeks following nerve trauma. (12,13) Ultrasound use in routine clinical practice is notably increasing and this is due to its safety, the possibility of dynamic imaging of peripheral nerves, providing a real time examination them along their anatomical course giving the precise location of the nerve lesion. Furthermore, because of the superficial anatomical course of the peripheral nerves, US became an ideal imaging modality in a way which is quick, painless, non-invasive and relatively cheap. (14) Peripheral nerves can be distinguished from other structures on ultrasound by key features. First, they have a hyperechoic rim due to presence of epineurium. Second, they exhibit less anisotropy than muscles and tendons, meaning tilting the transducer will markedly change the echointensity of these other structures when compared to nerves. Third, they are non-compressible with no pulsatile movement or Doppler flow, differentiating them from blood vessels. (14)

**Aims of study:**

To evaluate the role of ultrasound along with electrodiagnostic studies in assessing traumatic peripheral nerve injuries in upper limbs.

**Patients & Methods:**

Patients presented with clinical suspicion of traumatic peripheral nerve injuries were recruited from the neurophysiology clinic at **Ghazi Al-Hariri hospital** from **July 2024 to February 2025**. Inclusion criteria included referred patients with history of trauma and clinical features suggestive of nerve injury such as weakness, sensory deficit, or pain along the nerve course. Patients with radiculopathy, diabetes mellitus, pre-existing peripheral neuropathy, or refusal to participate were excluded. A through history was taken from all the patients, along with physical examination including motor strength assessment, sensory function testing and reflex examination. Informed consent has been taken from the participant, and ethical approval of the study was granted by the Ethical Committee of the College of Medicine / University of Baghdad.

**Electrodiagnostic Study:**

The electrodiagnostic studies (NCS and EMG) were performed using Natus 2019 Ireland. In NCS evaluating peripheral nerves of upper limbs typically consists of assessing both sensory and motor components of median, ulnar, and radial nerves.Patient was seated or lying comfortably with arm relaxed, and the skin was prepared with alcohol or any abrasive gel to reduce impedance. Hand should be warm as cold extremities slow conduction. The electrodes were then placed at the appropriate sites. (15, 16)

For EMG, the same preparation as NCS was applied. The patient was seated or lying comfortably and the procedure was explained to them, including the insertion of a thin needle into the muscle. The skin was cleaned by alcohol before the procedure. The examination was performed for the muscles supplied by the injured nerve. It is done during two phases: resting muscle and during voluntary contraction of the muscle, evaluating spontaneous activity and MUAP analysis, respectively. (16)

**Ultrasound:**

Ultrasonography was performed for all patients using Philips IU22 and Philips HD11XE (USA) systems, with a linear transducer of 10-18 MHz. The depth, focus, gain, and frequency were adjusted according to the structure being examined. The patient was seated with elbow flexed and supported, or in a laying position depending on the nerve being examined. A generous amount of gel was applied and both longitudinal, and transverse sections were taken, ensuring the probe is perpendicular on the underlying structure. A comparison with the contralateral healthy limb was also performed. (16)

**Statistical analysis:** were performed by using SPSS software version 26.0 (SPSS, Chicago). Continuous data were presented using descriptive statistics as mean and standard deviation. Categorical variables are presented as frequencies with percentages. Paired study design for diagnostic test was used to measure sensitivity, specificity, positive and negative predictive value as well as the accuracy of US examination were calculated using a 2 × 2 contingency table. Any value of $p < 0.05$ was considered significant. Cochran Q test was used to assess differences in proportions across related samples.

**RESULTS:**

A total of 44 patients with 50 nerve injuries met the inclusion criteria for the study in which males represented 40 cases (90.90%) and females 4 cases (9.09%).
The mean age was 39.3± 10.2 years. Some patients had more than one trauma and more than one injured nerve. Twenty-four (48%) were injured on the right side and 26 (52%) were in the left side. Thirty-nine (78%) patients had laceration injury, 11 (22%) had traction injury. As shown in Table 1
Table 1: Demographic and clinical data among studied patients.

| | | | |
|---|---|---|---|
| Gender | Male | 40 | 90.9% |
| | Female | 4 | 9% |
| Side | Right | 24 | 48% |
| | Left | 26 | 52% |
| Mechanism of injury | Laceration | 39 | 78% |
| | Traction | 11 | 22% |
| Duration of injury | <1 year | 14 | 28% |
| | 1-5 years | 19 | 38% |
| | >5 years | 17 | 34% |

NCS of median, ulnar and radial nerves showed varying degree of axonal loss, where compound muscle action potentials (CMAPs) were reduced in 54% of nerves, absent in 8%, and normal in 38% and sensory nerve action potentials (SNAPs) were reduced in 30%, absent in 36%, and preserved in 34%. Regarding EMG, only 26 (52%) had abnormal EMG findings, while 24 (48%) showed normal motor unit action potentials (MUAPs) morphology and duration, with no spontaneous activity during the resting phase. As shown in table 2

Table 2: Electrodiagnostic findings in patients under study.

| Parameter name | | Number of nerves | Percentage |
|---|---|---|---|
| CMAP | Reduced | 27 | 54% |
| | Absent | 4 | 8% |
| | Normal | 19 | 38% |
| SNAP | Reduced | 15 | 30% |
| | Absent | 18 | 36% |
| | Normal | 17 | 34% |
| Degenerative potentials | Present | 10 | 20% |
| | Absent | 40 | 80% |
| MUAPs | Normal | 30 | 60% |
| | Neurogenic MUAP | 20 | 40% |

*SNAP Sensory nerve action potential
*CMAP Compound motor action potential
*MUAP Motor unit action potential

In Ultrasonography, 38 cases (76%) were abnormal and 12 (24%) had normal nerve appearance. Nerve discontinuity was the most frequent noted abnormality. Neuroma was found in 11 cases (22%). As shown in table 3

Table 3: Ultrasound Findings

| Ultrasound Findings | Number | percentage |
|---|---|---|
| Partial nerve injury (axonotmesis) | 35 | 70% |
| Complete nerve injury (neurotmesis) | 2 | 4% |
| Normal nerve appearance | 12 | 24% |
| Others (foreign body, scar, fibrosis) | 1 | 2% |

Ultrasonography demonstrated a sensitivity of 92%, specificity of 90%, positive predictive value (PPV) of 97%, negative predictive value (NPV) of 75%, and an overall diagnostic accuracy of 76%. As shown in table 4.

Table 4: Diagnostic indices of ultrasound in traumatized nerves detection.

| Statistic | Value (%) |
|---|---|
| Sensitivity | 92% |
| Specificity | 90% |
| Positive predictive value | 97% |
| Negative predictive value | 75% |

**DISCUSSION:**

Trauma is one of the most common causes of PNI in the general population and the most common in young people, with incidence estimated between 1.46% and 2.8%, and a higher frequency observed in upper extremities. (17) The impact of PNI extends beyond physical disability, often leading to chronic neuropathic pain, long-term reliance on pain killers and reduced quality of life. These outcomes are especially significant given that PNIs primarily affect individuals of working age, thereby contributing to socioeconomic burdens (7). In this context, high-resolution ultrasound (US) has emerged as valuable adjunctive modality as it is safe, time-effective, non-invasive, and affordable imaging modality that enables assessing the entire nerve course in real-time, without pain or radiation. (8,10) . In the current study, we assessed the diagnostic utility of ultrasound combined with electrodiagnostic studies (EDX) in patient with traumatic peripheral nerve injuries in upper limbs. It is a cross-sectional study includes 44 patients with 50 nerve injuries, of these, 40 (90.90%) were male and 4 (9.09%) were female with a mean age of 39.3 ± 10.2 years. These demographic findings are consistent with the evidence in literature from Magnéli and Axenhus in 2024 which reports higher incidences of peripheral nerve injuries among men compared to women across all age groups. (18). The most frequent etiology of injury in this study was the trauma by missiles, accounting for 40% of cases, followed by motor vehicle accidents at 18%. In contrast, in a study by Aman et al. (2022), who identified motor vehicle accidents as the primary mechanism in 7% of traumatic injuries after evaluation of a total of 110,667 patients treated at their trauma center. (19). In our study, the most commonly injured nerve was ulnar, which was injured in 20 cases (40%), consistent with previous studies such as Elfayoumy et al. (2020) Kouyoumdjian et al., (2017) who also reported that the most commonly injured nerve was the ulnar nerve, in isolation or combined. (20,21) In our dataset, six cases were combined injuries, of which, four involved both the ulnar and median nerves in the same trauma. However, Jung et al. (2024) reported that radial nerve injury, associated with humeral fractures, was the largest subgroup in a study of Korean soldiers. (22) Electrophysiological assessments in our study showed partial axonal loss (axonotmesis) in 42% of nerves, complete axonal loss (neurotmesis) in 22%, and normal nerve conduction in 36%. We followed in this classification the studies by Padua et al. (2013) and Elfayoumy et al. (2020) as they classified their results according to the degree of axonal loss. (20,14) Upon combining EMG examination, we detected denervation potentials in the form of fibrillation potentials and positive sharp waves at rest in the affected muscles of the injured nerves in 10 cases (20%). Additionally, 20 cases (40%) showed abnormal neurogenic or absent MUAPs. This can be explained by collateral sprouting following incomplete axonal loss. (20). Ultrasound findings revealed partial nerve discontinuity in 70% of nerves, complete discontinuity in 4%, and intact nerve continuity in 24%. Neuroma formation was identified in 22% of cases. These results are in agreement with the classification

proposed by Padua et al. (2013), who emphasized ultrasound's utility in detecting nerve continuity, defining etiology, and identifying multi-focal damage. (23)
In our study, ultrasound showed a sensitivity of 92%, specificity of 90%, positive predictive value (PPV) of 97%, negative predictive value (NPV) of 75%. These values are slightly lower than those reported by Youssef et al. (2021), who found a sensitivity of 95.7%, specificity of 100%, and accuracy of 96.1%. (24) The discrepancy may reflect differences in sample size.

## CONCLUSION

Nerve ultrasound demonstrates high sensitivity and specificity indicating that it serves as a complementary tool to the gold standard electrodiagnostic studies. Ultrasound is a valuable tool for providing informative details, particularly assessing the morphology of nerve and evaluating its surrounding structures.

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