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Role of Ultrasonography in Evaluation of Peripheral Nerve Lesions in Upper Limb

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Abstract:

Background: Peripheral nerve injuries in the upper limb can lead to significant challenges, leading to substantial disability for cases globally. Early and accurate diagnosis is essential for effective treatment and better outcomes. High-Resolution Ultrasonography (US) has rapidly gained acceptance as a first-line modality in the evaluation of peripheral nerves. This study aimed to assess the role of ultrasound in evaluation of upper limb peripheral nerve lesions. **Methods:** This cross-sectional study was conducted on 38 cases with peripheral nerve lesions in upper limbs. This study was carried out on cases referred from neurology & rheumatology department to the radiology department in Benha University Hospitals & from private centers. Ultrasound scanning was performed on GE Logiq E9 using wide band linear transducer with active-matrix array technology of bandwidth: 5 – 15 MHz. **Results:** Majority of the examined muscles exhibited increased echogenicity (86.8%), indicating potential pathological changes. Additionally, 73.68% of cases showed reduced muscle girth. The presence of fibrosis was noted in 65.79% of cases, while vascular involvement was significantly lower at 18.42%. The finding of muscle injury in 42.11% of cases. The ultrasound findings revealed that the majority of nerves assessed showed discontinuity (52.6%), indicating significant injury. The presence of fibrosis changes in 26.3% of the cases from prior injuries. The diagnostic indices demonstrate the exceptional sensitivity and accuracy of ultrasound, indicating that it is a reliable tool for evaluating peripheral nerve lesions. **Conclusion:** Use of ultrasound offers a promising avenue for enhancing diagnostic accuracy and treatment planning of Peripheral Nerve Lesions in Upper Limb and aids in optimizing the management of peripheral nerve injuries and improving case outcomes.

Keywords: Peripheral Nerve Lesions; Upper Limb; Ultrasonography; Nerve injury.

Introduction

Peripheral nerve lesions (PNLs) are frequently encountered and can arise from various causes such as trauma, compression, or systemic conditions. The clinical impact varies with the specific nerve affected and the extent of injury [1].

Peripheral nerve injuries pose major clinical challenges and are a significant cause of disability worldwide. They commonly result from motor vehicle accidents, falls, workplace or household trauma, and penetrating injuries [2].

Traditional diagnostics rely on clinical and electrophysiological (EP) assessments, which help determine the functional state of nerves and classify damage as axonal or demyelinating. However, EP studies lack insight into the morphological features and etiology of the lesion [3].

Clinical presentation of PNLs is diverse, necessitating a thorough evaluation, including history-taking, physical examination, and appropriate testing for precise diagnosis and management [4].

High-resolution ultrasonography (US) has become a frontline imaging modality for peripheral nerves. Recent improvements in scanners and high-frequency probes now offer resolution comparable to, or better than, magnetic resonance imaging (MRI) [5].

Ultrasound (US) offers a reliable, painless alternative for assessing peripheral nerves. Its growing role in clinical practice stems from its cost-effectiveness and efficiency in evaluating long nerve segments. The dynamic and real-time capabilities of US, coupled with a limited number of contraindications, make it an appealing diagnostic tool. Recent advancements in high-frequency transducers and post-processing techniques have further enhanced the utility of US in this field[6].

Peripheral nerve US typically starts with transverse imaging at well-known anatomical landmarks (e.g., the median nerve in the carpal tunnel or the ulnar nerve in the cubital sulcus). Once optimal imaging is achieved, the nerve is tracked both proximally and distally, including areas of suspected pathology[7].

Color-coded sonography (color or power Doppler) enhances US by enabling evaluation of perineural and intraneural vascularity. This is especially beneficial in detecting inflammatory neuropathies, nerve tumors, and compressive lesions. It also aids in nerve localization, particularly where nerves run alongside blood vessels—such as the radial nerve near the profunda brachii artery [8].

Utilizing US for lesion localization in the peripheral nervous system can improve diagnostic precision and guide more targeted therapeutic interventions [3].

This study investigated the utility of ultrasound in assessing upper limb PNLs.

Subjects and methods:

Cases:

This Cross-sectional study included 38 cases with peripheral nerve lesions in upper limbs. Cases report pain, weakness, numbness, hypoesthesia or paresthesia that are not related to a known bone or vascular injury. This study was conducted at neurology & rheumatology department to the radiology department in Benha University Hospitals & from private centers, during the period from January 2023 to December 2024.

Informed written consent was secured from all participants following a thorough explanation of the study's objectives. To ensure participant anonymity, each individual was assigned a unique confidential identification code. The study protocol was reviewed and approved by the Research Ethics Committee (MD 18-3-2018) of the Faculty of Medicine, Benha University.

Inclusion criteria were cases of any age group who presented with clinical suspicion of PNLs in the upper limbs were included. These cases reported symptoms such as pain, weakness, numbness, hypoesthesia, or paresthesia not attributed to a known bone or vascular injury. Additionally, cases with superficial soft tissue masses associated with motor or sensory deficits were also included**.**

Exclusion criteria were Cases with a history of previous upper limb surgery were excluded from the study.

Methods:

All studied cases were subjected to the following: Detailed history taking, including [Personal history; name, age, gender and body mass index (BMI), Present history: course of the disease and duration, Past history of any medical condition or previous hospital admission and Family history of similar condition]. **Full clinical examination: General examination including [**General comment on case conscious and mental state, Jaundice or pallor, Vital signs: pulse, blood pressure, capillary filling time, respiratory rate and temperature]. **Routine laboratory investigations [**complete blood count (Hb, WBCs, Platelets), random blood sugar, kidney function tests and liver function tests]. **High-resolution ultrasound evaluation** using a superficial wide-band linear transducer (5–15 MHz).

Equipment:

Ultrasound scanning was performed using the GE Logiq E9 machine, equipped with a wide-band linear transducer utilizing active-matrix array technology, with a bandwidth of 5–15 MHz.

Examination technique:

The examination began at a known anatomical landmark near the target nerve. Once the nerve was identified in the short axis, it was traced both cranially and caudally to assess for any contour or structural abnormalities. During dynamic assessment, normal peripheral nerves exhibited a sliding movement over adjacent muscles and tendons. Any alteration in movement or deformity in contour during this process suggested underlying pathology.

To enhance nerve visibility, techniques such as movement of surrounding tissues, rocking or toggling the transducer, and adjusting the angle to improve contrast between the nerve and adjacent structures were employed. When a diseased site was identified, the focus was directed toward that specific segment, and the transducer was rotated to obtain a long-axis view for detailed evaluation.

Nerve measurements include: Cross-sectional area, swelling ratio and Flattening ratio.

Risks and Ethical Considerations

All expected risks that could arise during the course of the research were explained clearly to the participants and promptly reported to the ethical committee. Provisions to protect the privacy and confidentiality of participants were strictly followed, including assigning a unique code for each participant and storing their contact information securely. Study results were used solely for research purposes, and case names were omitted from any images or data used in documentation or presentation.

Statistical analysis

"The dataset was processed and analyzed using SPSS software (version 25, released in 2017 by SPSS Inc., Chicago, IL, USA). To depict numerical variables, either means with standard deviations or medians with ranges were used, based on distribution patterns. The distribution of the data was scrutinized for normality through the Kolmogorov-Smirnov and Shapiro-Wilk tests. Categorical variables were expressed as proportions to capture their relative frequencies.

Results:

The study included a total of 38 cases, with a higher representation of males (60%) compared to females (40%). The predominant age group was 15-30 years (40%), indicating that younger individuals are more frequently affected by peripheral nerve lesions. The right side was more commonly involved (60%) in injuries. (**Table 1)**

The majority of injuries were due to cut and crush wounds, each accounting for 28.95% of cases with the median nerve being the most frequently injured (55.3%). (**Table 2)**

Majority of the examined muscles exhibited increased echogenicity (86.8%), indicating potential pathological changes. Additionally, 73.68% of cases showed reduced muscle girth. (**Table 3)**

The presence of fibrosis was noted in 65.79% of cases, while vascular involvement was significantly lower at 18.42%. The finding of muscle injury in 42.11% of cases. (**Table 4)**

The ultrasound findings revealed that the majority of nerves assessed showed discontinuity (52.6%), indicating significant injury. The presence of fibrosis changes in 26.3% of the cases from prior injuries. (**Table 5, Figure 1, Figure 2)**

The diagnostic indices demonstrate the exceptional sensitivity and accuracy of ultrasound, indicating that it is a reliable tool for evaluating peripheral nerve lesions. (**Table 6).**

Cases:

CASE 1: 44-year-old male met with gradual weakness and pain. US showed Ulnar nerve injury neuroma. (**Figure 3, Figure 4)**

CASE 2: 45-years-old female with history of numbness & tingling in the thumb and fingers. After complete evaluation, US showed thickened median nerve at carpal tunnel. (**Figure 5, Figure 6)**

Table 1: Case Demographics

Demographic Factor	Count	Percentage (%)
Total Cases	38	100
Male	23	60
Female	15	40
Age Group		
< 15 years	8	20
15-30 years	15	40
30-50 years	10	27
> 50 years	5	13
Affected Side		
Right	23	60
Left	15	40

Table 2: Clinical Characteristics of Trauma

Mode of Injury	Count	Percentage (%)
Cut wound	11	28.95
Crush	12	31.58
Traction	6	15.79
Compression	9	23.68
Site		
Arm	17	44.74
Forearm	10	26.32
Hand	11	28.95
Nerve		
Median	21	55.26
Ulnar	10	26.32
Radial	7	18.42

Table 3: Ultrasound Findings Regarding Supplied Muscles

Finding	Count	Percentage (%)
Echogenicity		
Normal	5	13.16
Increased	33	86.84
Muscle Girth		
Normal	10	26.32
Reduced	28	73.68

Table 4: Associated Ultrasound Findings

Finding	Count	Percentage (%)
Fibrosis		
Absent	13	34.21
Present	25	65.79
Vascular injury		
Absent	31	81.58
Present	7	18.42
Orthopedic injury		
Absent	25	65.79
Present	13	34.21
Muscle Injury		
Absent	22	57.89
Present	16	42.11

Table 5: Shape and Continuity of the Examined Nerves by Ultrasound

Shape of Nerve	Count	Percentage (%)
Fibrosis	12	26.32
Neuroma	9	18.42
Increased CSA	17	39.47
Continuity		
Continuous	18	47.37
Discontinuous	20	52.63

Table 6: Diagnostic Indices of Ultrasound Compared to final diagnosis

Statistic	Value (%)	95% CI
Sensitivity	90	85.18–100.00
Specificity	89	78.88–99.89
Positive Predictive Value	92	77.15–99.37
Negative Predictive Value	87	
Accuracy	93	88.71–99.95

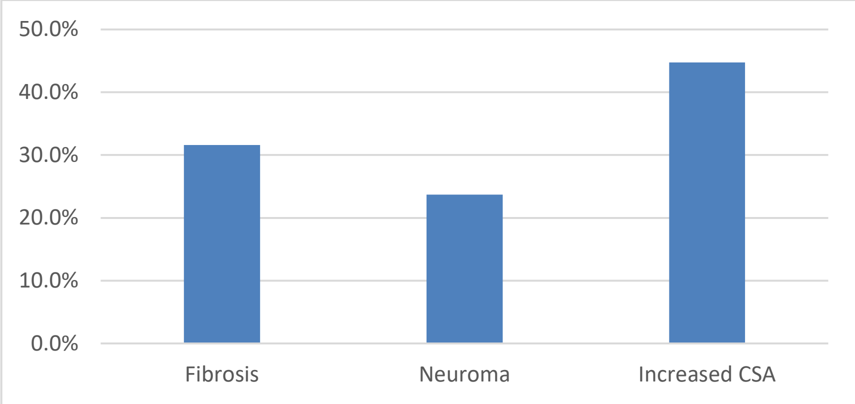

Figure 1: Shape of the Examined Nerves by Ultrasound

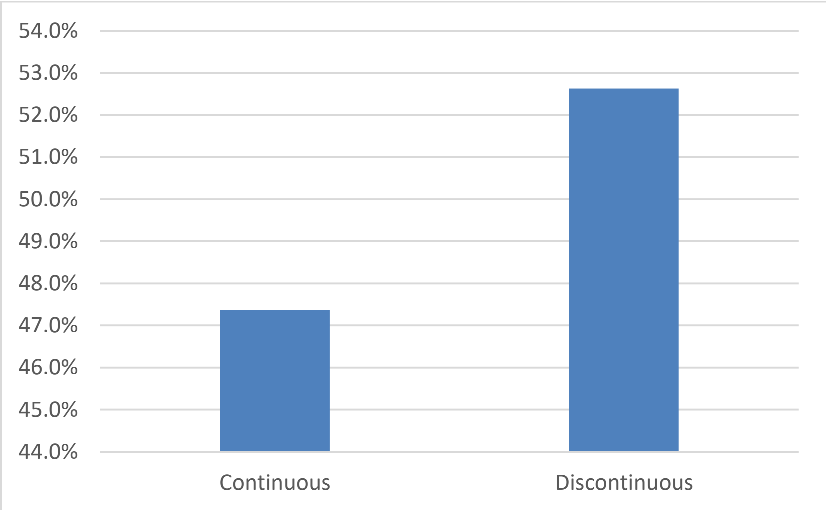

Figure 2: Continuity of the Examined Nerves by Ultrasound

Figure 3: Small mass related to ulnar nerve sheath.

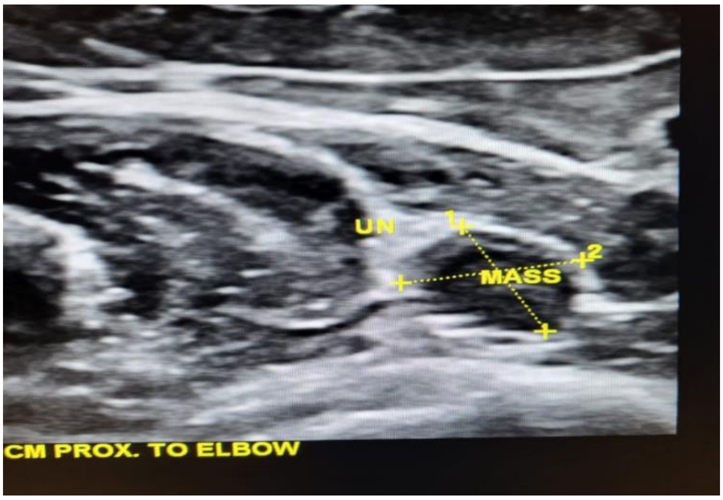

Figure 4: Well defined hypoechoic mass related to ulnar nerve sheath.

Figure 5: Thickened median nerve at carpal tunnel.

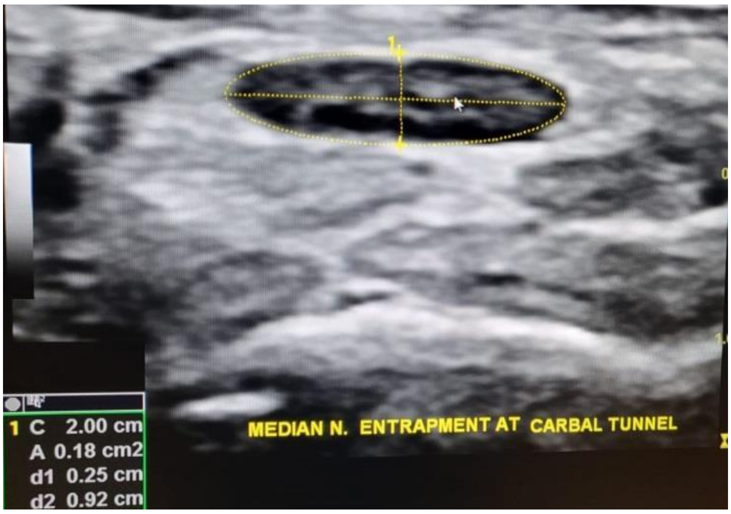

Figure 6: Increase median nerve circumferential thickness at carpal tunnel.

Discussion:

PNLs are a common condition that can result from various causes, including trauma, compression, and systemic diseases. The severity and symptoms of peripheral nerve lesions vary widely, depending on the nerves involved and the extent of the damage[9].

Ultrasound (US) offers a reliable, painless alternative for assessing peripheral nerves. Its growing role in clinical practice stems from its cost-effectiveness and efficiency in evaluating long nerve segments[10].

The study included a total of 38 cases, with a higher representation of males (60%) compared to females (40%). The predominant age group was 15-30 years (40%), indicating that younger individuals are more frequently affected by peripheral nerve lesions. The right side was more commonly involved (60%) in injuries.

Our study reported that the majority of injuries were due to cut and crush wounds, each accounting for 28.95% of cases with the median nerve being the most frequently injured (55.3%).

While Ferrante and colleagues., noted that the radial nerve is often the most frequently injured in the upper limbs, whereas our results indicated that the median nerve was most commonly affected (56.3%), followed by the ulnar (25%) and radial (18.8%) nerves[11].

In the present study, a majority of the examined muscles exhibited increased echogenicity (86.8%), indicating potential pathological changes. Additionally, 73.68% of cases showed reduced muscle girth. The presence of fibrosis was noted in 65.79% of cases, while vascular involvement was significantly lower at 18.42%. The finding of muscle injury in 42.11% of cases. The electrophysiological studies reveal a predominance of moderate (47.4%) and severe (21.1%) injuries. The ultrasound findings revealed that the majority of nerves assessed showed discontinuity (52.6%), indicating significant injury. The presence of fibrosis changes in 26.3% of the cases from prior injuries.

The present findings are supported by those of Şahin and colleagues., who investigated 50 cases of traumatic nerve injury at the wrist level and reported comparable results, with 75–79% of cases exhibiting decreased or absent CMAPs. This phenomenon may be attributed to the complexity of hand function, which necessitates the coordinated activation of multiple muscle groups. Consequently, EMG evaluations based on a single muscle may not adequately capture the overall functional status of the hand [12].

Similarly, Campbell and Robinson observed that denervation potentials typically manifest within 10–14 days in muscles proximal to the injury site, and within 3–4 weeks in distal muscles. The detection of these potentials is indicative of even minimal axonal damage, highlighting the sensitivity of EMG in the early identification of nerve injuries [13]14].

In the present study, diagnostic indices indicated a high sensitivity and accuracy for US in the evaluation of peripheral nerve lesions, affirming its clinical reliability. However, inter-study variability in diagnostic performance has been reported. For instance, Toia and colleagues. documented a lower diagnostic accuracy of 72.2%. In comparison, the sensitivity and specificity of US in the current study were 91% and 89%, respectively, whereas Padua and colleagues. reported a sensitivity of 71.35% [15], [16].

The classification system proposed by Koenig and colleagues. for sonographic nerve injury assessment identified distinct patterns, including normal architecture, epineural and intraneural fibrosis, partial and complete neuromas, and nerve transection [17]. Furthermore, Extremite and colleagues. demonstrated the utility of US in characterizing the nature of nerve injuries, as well as in detecting nerve stumps, embedded foreign bodies, and post-traumatic scar tissue [18]. Consistent with these findings, our data revealed neuroma formation in 21.9% of cases and an increase in cross-sectional area (CSA) in 34.4% of injured nerves.

Additionally, Bonala and colleagues., emphasized the role of US in surgical planning, particularly in cases presenting with neuromas, retained foreign material, or complications following fractures. Their findings underscored the advantages of ultrasound in guiding targeted surgical approaches and reducing the need for extensive exploratory procedures due to its capacity for precise localization and assessment of nerve damage [19]

Nonetheless, the current study is subject to certain limitations, including a relatively small sample size and incomplete postoperative follow-up data. Future investigations should aim to validate these findings through studies involving larger case cohorts and longitudinal designs, to better elucidate the role of ultrasound in the comprehensive management of traumatic peripheral nerve injuries

Conclusion:

From our findings we can conclude that use of ultrasound offers a promising avenue for enhancing diagnostic accuracy and treatment planning of Peripheral Nerve Lesions in Upper Limb and aids in optimizing the management of peripheral nerve injuries and improving case outcomes.

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