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ORIGINAL ARTICLE

THE VALUE OF ULTRASOUND IN PREOPERATIVE DIAGNOSIS OF TRAUMATIC NERVE INJURIES IN FOREARM AND HAND

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ABSTRACT

Background: This study aimed to detect the role of ultrasound (US) in preoperative diagnosis of traumatic nerve injuries in the forearm and hand and correlation with operative findings. **Methods:** Thirty patients (30) with thirty one (31) traumatic median, ulnar and radial nerve injuries in forearm and hand were evaluated by ultrasound. All patients underwent surgical exploration and the sonographic findings were compared with the surgical data. **Results:** Neuroma in-continuity was the most common US finding found in fourteen (14) injured nerves (45.2%). Followed by complete tear found in seven (7) injured nerves (22.6%). Incomplete tear is the least common findings found only in two (2) injured nerves (6.5%) The preoperative US findings in our study had agreed with intra-operative data in twenty nine (29) out of thirty one (31) injured nerves (93.5%). **Conclusion:** Ultrasonography provides an economical and accurate imaging modality that can be utilized in diagnosis, assessment and treatment planning of traumatic peripheral nerve injuries.

Keywords: Ultrasonography (US), positive predictive value (PPV), negative predictive value (NPV).

INTRODUCTION

Traumatic injury of peripheral nerves is a worldwide problem that occurs from a variety of causes and their prevalence is 2.8% among patients who had a traumatic injury [1].

Electrophysiological studies are useful in detecting the severity and location of nerve injury, however they cannot detect the structural causes of denervation. Magnetic resonance imaging can be used in evaluation of peripheral nerves lesions; but it is cost effective and has limited availability [2].

Over the last decade, high frequency ultrasonography of peripheral nerves has progressed technically, and multiple studies have confirmed that ultrasound is highly sensitive and specific in diagnosis of peripheral nerve lesions rivaling the efficacy of electrophysiologic studies [3].

Ultrasound has been shown to be an efficient, noninvasive, low-cost method of imaging and better accepted by the patients than MRI in traumatic peripheral nerve pathologies [4].It represents a powerful tool in enabling proper planning for treatment, preventing unnecessary surgery where conservative management is sufficient and thus enhancing overall outcomes with patients with traumatic nerve injuries of forearm and hand [5].

Critical information to be gathered from ultrasound includes the following: whether the nerve remains in continuity; length of the gap, if present; presence of a focal neuroma and its location & size; additional areas of nerve injury, like tandem lesions;

degree of adjoining scar tissue; detection of foreign bodies and the status of adjacent tissues such as tendons, blood vessels and bones [6].

This work aimed to detect the role of Ultrasound in preoperative diagnosis of traumatic nerve injuries in the forearm and hand.

METHODS

This prospective study was carried out during the period from April 2018 to September 2019. Written informed consent was obtained from all participants and the study was approved by the research ethical committee of Faculty of Medicine, Zagazig University. The work has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for studies involving humans.

The study included thirty participants (22 males and 8 females; aged 9 to 61 years; mean age was 37 ±13.7 years).

Inclusion criteria included; 1- patients who sustained trauma to the forearm and hand who were clinically suspected to have nerve injury. 2- Patients underwent surgical exploration.

Exclusion criteria included patients not underwent surgery.

The study was approved by the institutional review board of our hospital and an informed consent obtained from all patients.

All patients were examined with GE LOGIQ E9 ultrasound machine using ML6-15-D broad-spectrum linear matrix array transducer. All ultrasound examinations were done by one radiologist who had 5 years experience in musculoskeletal ultrasound.

Technique of examination:

Patient was seated in comfortable position facing the radiologist or lay in supine position for examination according to patient's general condition.

At the forearm: The elbow was supported and placed in flexed position and forearm extended.

At the hand: The wrist was supported and placed in slightly hyperextended position.

A generous amount of gel was important for good contact between the transducer and skin surface.

Sonographic identification of the nerves was done using a known anatomical landmark. Once detected, the nerve was kept in the center of the US image in its short axis and then followed proximally and distally. US examination was then appropriately focused on the region of interest using transverse and longitudinal scanning planes.

The suspected injured nerve was examined for; 1- Location of the nerve injury, 2- Degree of nerve injury: partial or complete transaction, 3- Amount of nerve retraction and the gap after complete nerve transaction, 4- Nerve thickening, 5- Bony fragments compressing the nerve in close vicinity to bone fracture site, 6- Proximal terminal neuroma: appears as concentric enlargement at the terminal end of a transected nerve with homogeneous texture and hypoechoic echogenicity and 7- Neuroma incontiunity: the continuity of the nerve is preserved and appears as nodular shaped broadening of the nerve contour.

Statistical analysis

The collected data were tabulated and analyzed the statistical package for social sciences (SPSS) for windows version 18.0 software package (SPSS Inc., Chicago, IL).

RESULTS

This study included 30 patients with clinically suspected traumatic median, ulnar or radial nerve injury in forearm and hand.

The most common clinical presentation in our patients was tingling and numbness which noted in 23 cases (76.7%). Some patients complained from more than one complain.

Nerve injury by sharp objects (in 16 patients 53.4%) and lacerations (in 9 patients 30%) were the most common types of nerve injury, while gunshot and iatrogenic nerve injury were the least common types of trauma encountered only in one patient (3.3%) for each [table 1].

Median nerve was the most common injured nerve in our patients detected in 17 cases (56.7%), followed by the ulnar nerve injury (in 10 patients 33.3%), then radial nerve injury in 2 patients (6.7%) and combined median and ulnar nerve injuries were found in 1 patient (3.3%) [table 2]. So we had total 31 injured nerves.

Nerve injury at the wrist was the most common affected site seen in 19 cases (61.3%) "the most frequently injured nerve at the wrist was the median nerve (15 cases 48.4%)", while middle 1/3 of forearm was the least common site detected only in 1 case (3.2%) involving the radial nerve [table 3].

18 nerves (58.06%) were injured in the right side while 13 nerves (41.94 %) were injured in left side.

Neuroma in-continuity was the most prevalent finding by US, it was found in 14 injured nerves (45.2%). Followed by complete tear in 7 injured nerves (22.6%), terminal neuroma and focal thickening (each in 5 injured verves 16%). Incomplete tear is the least common findings found only in 2 injured nerves (6.5%) [table 4].

We found foreign body impaction in 3 cases, one is at the upper third of forearm (related to radial nerve) and the other two are above the wrist joint (related to median nerve).

Associated injuries were found in 10 cases (33.3%), 4 cases had associated tendon injuries, 4 cases had bone injuries and 2 cases had vascular injuries.

All patients underwent surgical exploration for repair and the sonographic findings were compared with the surgical data.

We had two cases (6.5%) out of the 31 injured nerves referred to surgery misdiagnosed, one case was diagnosed as neuroma secondary to partial nerve injury on US but surgery showed swollen nerve with thickness circumferential scar. And the other case diagnosed on US as complete nerve injury with loss of continuity but surgery revealed incomplete tear and some fascicles were preserved and continuous.

The sensitivity, specificity, accuracy, PPV and NPV of US in detecting neuroma in-continuity and local thickening were 100%, 94.4 %, 96.7%,92.8%,100% and 83.3 % , 100%, 90%, 100%, 96% respectively. In cases of complete tear and incomplete tear; the sensitivity, specificity, accuracy, PPV and NPV of ultrasound was 100%, 96%, 90.9% ,85.7%, 100% and 66.7%, 100%, 85.7% ,100%, 96.5% respectively. The Sensitivity, specificity, PPV, NPV and accuracy of US in diagnosing terminal neuroma were 100% for each [table 5].

Table 1. Causative agents of trauma among our patients

		Frequency	Percent
Type of trauma	Sharp object	16	53.4
	Laceration	9	30
	Blunt trauma	3	10
	Gunshot	1	3.3
	Iatrogenic	1	3.3

Table 2. The affected nerve in the examined patients

Injured nerve	Frequency of patients	Percent
Median nerve only	17	56.7
Ulnar nerve only	10	33.3
Radial nerve only	2	6.7
Combined nerve (median & ulnar nerves)	1	3.3
Total	30	100

Table 3. level of nerves injury detected in our patients

Level of injury	**Frequency**	**Percent**
Upper 1\3 forearm	6	19.3
Radial nerve	2	6.4
Ulnar nerve	3	9.7
Median nerve	1	3.2
Middle 1\3 forearm	1	3.2
Ulnar nerve	1	3.2
Lower 1\3 forearm	5	16.1
Ulnar nerve	3	9.7
Median nerve	2	6.4
Wrist	19	61.3
Ulnar Nerve	4	12.9
Median Nerve	15	48.4
Total injured nerves	31	100

Table 4. Ultrasonographic diagnosis in our patients

Us finding	Frequency	Percent
Neuroma incontinuity	14	45.2
Proximal terminal neuroma	5	16
Complete tear	7	22.6
Local thickening	5	16
Incomplete tear	2	6.5

Table 5. diagnostic performance of high frequency US in diagnosis of traumatic nerve injury

Diagnosis	**US diagnosis**	**Surgery diagnosis**	**Sensitivity**	**Specificity**	**PPV**	**NPV**	**Accuracy**
Neuroma in-continuity	14	13	100	94.4	92.8	100	96.7
Local thickening	5	6	83.3	100	100	96	90
Complete tear	7	6	100	96	85.7	100	90.9
Incomplete tear	2	3	66.7	100	100	96.5	85.7
Terminal neuroma	5	5	100	100	100	100	100

Table 6. Clinical presentation in 30 patients.

Clinical presentation	No of patient	Percent
Tingling and numbness	23	76.7
Pain	16	53.3
Weakness or wasting	9	30
Swelling	4	13.3

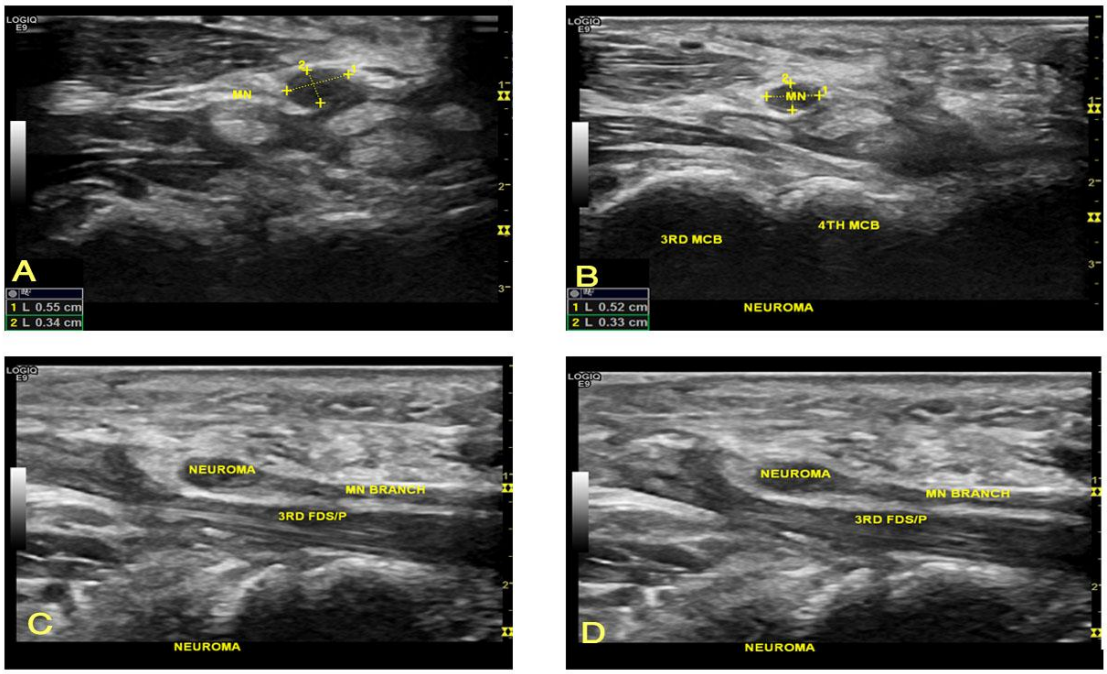

Figure 1. Median nerve neuroma within the hand.
Male patient, aged 56 years old, complains from cut wound in the right hand palm.
A & B: Transverse US image of the median nerve in the hand, showing median nerve neuroma with surrounding adhesions.
C & D: longitudinal US images show well defined soft tissue mass lesion along course of the median nerve in the hand in front of the flexor digitorum tendon of the 3rd finger, with no evident nerve tear.

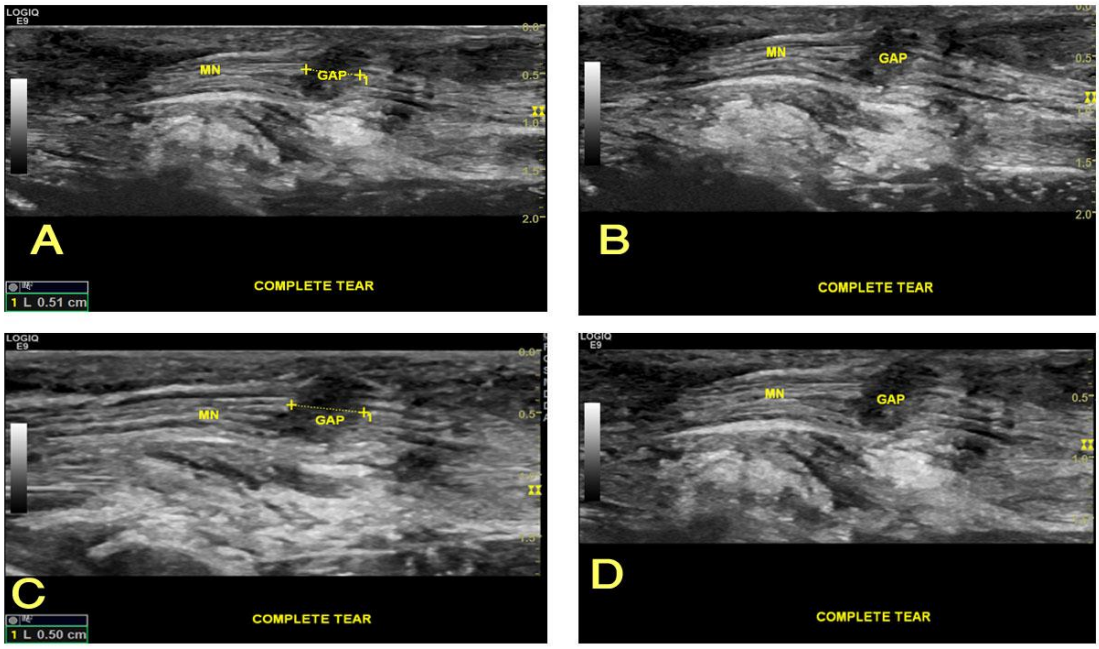

Figure 2. Full thickness tear of median nerve within forearm.
Male patient, aged 40 years old with cut wound at right forearm complaining from burning sensation, tingling and numbness at forearm and hand.
A, B, C & D: Loss of continuity of median nerve with a gap measuring 5mm denoting full thickness tear.

DISCUSSION

Traumatic peripheral nerve injuries (TPNI) are progressively perceived nowadays in clinical practice, because of improved trauma services [7]**.** It results in multiple pathologies and may involve single or multiple nerve units [4]**.**

TPNI in the upper limb significantly impact individuals' function and ability to return to work [8]**.**

Electrodiagnosis in some cases has a limited ability to detect the accurate site as well as severity of nerve injuries, particularly in the immediate post-injury period because certain electrodiagnostic changes take time to occur [9].

Sonography is an adequate, cost-effective, widely available noninvasive imaging modality for evaluating peripheral nerve disorders particularly in traumatic lesions. Careful examination using precise scanning technique and perfect knowledge of the anatomic relationships of the nerves to the surrounding structures provides an accurate information to the clinician for choosing the appropriate treatment [5].

In addition to accurate localization of the site of nerve injury, Ultrasonography also indicates whether the nerve is partially or completely dissected, if the nerve is displaced or encased by surrounding scar or fibrous tissue [10]**.** It may be used as a first-line imaging modality in patients with suspected peripheral nerve lesions before further treatment is administered as it not only asses the pathologic changes in nerve but also assess changes in the adjacent tissue [11].

In our study, 30 patients who sustained trauma to the forearm and the hand and clinically suspected to have

median, ulnar or radial nerve injury were examined by US.

In the study of Lee et al., [12] ultrasonography was able to accurately recognize the site of nerve injury in 6 patients with peripheral nerve trauma.

In agreement with the previous study, we correctly detected the location of nerve injury by US. Nerve injury at the wrist was the most common affected site; detected in 19 cases (61.3%), while middle 1\3 of forearm was the least common site detected only in 1 case (3.2%). The most frequently injured nerve in the wrist was the median nerve (84.4%).

Afsal et al., [11] found that, the most frequently injured nerve was median nerve, followed by ulnar nerve, then radial nerve. This findings was significantly proved in our study where median nerve was the most common injured nerve (18 injured nerves "17 single involvement & 1 combined with ulnar nerve") followed by the ulnar nerve (11 injured nerves "10 single involvement & 1 combined with median nerve") then radial nerve (2 injured nerves).

According to Campbell [13] and Kouyoumdjian [14], combined lesions most commonly involved the ulnar and median nerves. This was in agreement with our study as we had combined median and ulnar nerve injuries in 1 patient.

In the study of Afsal et al., [11], 6 patients suffered from trauma of the upper limb were examined by US. They found that the most common sonographic feature was nerve thickening, which was noted in all patients while partial discontinuity in the epineurium detected in 2 cases and complete discontinuity in 1 case, suggestive of complete nerve transaction. Neuroma was diagnosed in 2 injured nerves, one was a side neuroma and the other was an end neuroma.

Neuroma is a non-neoplastic mass results from random proliferation of schwann cells, axons and fibroblasts that admixed together to form a neuroma.

In our study, neuroma in-continuity was the most prevalent US findings diagnosed in 14 injured nerves (45.2%). Followed by complete tear diagnosed in 7 injured nerves (22.6%), proximal neuroma and nerve thickening each in 5 injured nerves (16%). Incomplete tear was the least common findings found only in two injured nerve (6.5%).

Incomplete tear appeared as loss of fascicles but no loss of continuity, while complete tear appeared as loss of fascicles and loss of continuity.

Neuroma appeared as a hypoechoic irregular mass within the nerve at the location of trauma and shows no evidence of internal vascularity. The sonographic appearance of traumatic neuroma in our study was similar to that described in previous studies [15]

Chen et al, [15] presented a case who complain of consistent numbness over the fingers and hand after cutting the wrist and subsequent median nerve repair. Electrodiagnostic testing was normal, however high-resolution ultrasound demonstrated a focal hypoechoic swelling in the median nerve consistent with a neuroma and that was confirmed at surgery. They concluded that high-resolution ultrasound might be superior to electrodiagnostic studies in the diagnosis of post traumatic neuroma.

Zeidenberg et al, [6] stated that US can provide information about the status of adjacent tissues such as tendons, blood vessels and bone. This proved in our study as we detected 10 cases with associated tissue injuries (4 cases with tendon injury, 4 cases with bone fractures, and 2 cases with vessel injury)

US is playing an important role in detection and localization of foreign bodies. They appeared on US as localized

hyperechoic foci with surrounding hypoechoic area due to granulation tissue and edema. Posterior acoustic shadowing or comet-tail artifact may be present depending on the type of material [16] &[17]. That was achieved in our study as we detected foreign body in 3 cases, appeared on US as hyperechoic foci, 2 with posterior acoustic shadowing and one with surrounding hypoechoic halo.

Cartwright et al, [9] showed that high-resolution ultrasound was able to identify transected nerves in the upper extremity with 89% sensitivity and 95% specificity.

In our study, the sensitivity, specificity, PPV, NPV and accuracy of US in diagnosing terminal neuroma were 100%. US had 100% sensitivity, 94.4% specificity and 96.7% accuracy in detecting neuroma in-continuity and 83.3 %, 100% and 90% sensitivity, specificity and accuracy respectively in detecting local thickening. In cases of complete tear and incomplete tear; the sensitivity, specificity, and accuracy of US were 100%, 96%, 90.9 and 66.7%, 100%, 85,7% respectively.

In the study of Zhu et al, [5] 202 patients with a history of trauma were included. The accuracy of classification by using US was 93.2%. There were 8 cases misclassified by US, in which minimal scar tissue was seen and surgery revealed nerve degeneration.

Toros et al, [18] evaluated 26 patients with peripheral nerve lesions in the upper limb. US demonstrated loss of continuity, stump neuroma, and partial laceration of a nerve. They reported 100 % agreement between US finding and intraoperative findings.

The preoperative US findings in our study had agreed with intra operative data in 29 out of 31 injured nerves (93.5%). We had two cases (6.5%) out of the 31 cases with misdiagnosis, one case was misdiagnosed as neuroma on US but surgery showed traumatic neuropathy and swollen nerve. The other case on US misdiagnosed as complete tear but surgery revealed incomplete tear and some fascicles were continuous.

CONCLUSION

We concluded that ultrasonography provides an economical and accurate imaging modality utilized in the pre operative diagnosis, assessment and treatment planning of traumatic peripheral nerve lesions.

Conflict of Interest: Nothing to declare.
Financial Disclosures: Nothing to declare.

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