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ORIGINAL ARTICLE

Ultrasonography as a diagnostic modality in cases of peripheral nerve injuries: Is it worth?

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ABSTRACT

Background: There are many etiological causes of peripheral nerve injury as obstetric traction trauma, crushing accidental nerve injury and penetrating injury by sharp or blunt objects. Between all polytraumatic injuries, traumatic peripheral nerve ones constitute at least 2-3%.Ultrasonography (US) especially, the high resolution one is a non invasive easily applicable radiation free diagnostic imaging tool capable of drawing the morphological data of the peripheral nerves and their surrounding structures. Recent and continuous advances in the ultrasonography technology and resolution result in accepted anatomical image of most of the peripheral nerves up to the fascicular level.

Aim of the work: We are aiming for studying the applicability and accuracy of the ultrasonography as a diagnostic modality in cases of peripheral nerve injures and how much the preoperative US imaging data of the nerve correlated with the intra-operative one.

Methods: Prospective study conducted in Department of Neurosurgery Zagazig University Hospitals. It included 15 cases (20 nerves) of post traumatic peripheral nerve injury, between January 2018 and June 2019.

Results: 15 patients, 9 males and 6 female. Age ranging from 10 to 65 years, right side affected in 12 nerves(60%) and 8(40%) nerves was at the left side ,isolated nerve injury was present in 10(67%) patients and two nerve injuries in 5(33%) patients. The success of preoperative nerve ultrasonography in localizing the lesions of the nerves was 90%, to descript the injury and its architecture was 85% and foreign body detection was 75%.

Conclusion: Ultrasonongraphy of the peripheral nerves is considered a complementary diagnostic modality for electro diagnostic studies for proper evaluation of the peripheral nerve injury as regard to the nerve location, course, proximal and distal ends, continuity and the surrounding tissues.

Keywords: Ultrasonography; pre-operative; peripheral nerve injuries**.**

INTRODUCTION

There are many etiological causes of peripheral nerve injury as obstetric traction trauma, crushing accidental nerve injury and penetrating injury by sharp or blunt objects [1, 2]. .Between all polytraumatic injuries, there is at least 2-3% traumatic peripheral nerve injuries[2,3,4]Traumatic nerve injury classification started early by **Seddon** in his study 1943,and he classified the injury simply into 3 types (neuropraxia, axonotemesis and neurotemesis), followed by **Sunder** classification in 1951who classified the injury into 5 grade system which updated recently into 6 grade system[5,6].

Diagnostic workup of peripheral nerve injury includes the history (including type, direction of the trauma and other associated injury), detailed neurological examination and electro-diagnostic studies (nerve conduction studies and electromyography).Although the electro-diagnostic studies (EDS) are considered the gold

standard diagnostic tools in cases of nerve injury, but it fails to give a data about the type of injury, gap distance, and neuroma or associated perilesional fibrotic scar. The idea of using US in cases of nerve affection started initially in cases of infiltrating thyroid or parathyroid lesions by **Solbiati et al** ., for evaluation the recurrent laryngeal nerve injury[7].

Excluding morbid obese patients, Nearly, all main nerves of upper, lower limbs and supraclavicular brachial plexus, even also the smaller nerves as superficial radial nerves can be clearly visualized by US, but due to the of clavicle and the depth of tissues ,the infraclavicular and infrapectoral brachial plexus are difficult to be clearly visualized. Sometimes the visulisation of sciatic and tibial nerves is difficult especially in obese patients, but in thin patients even the small sensory branches can be seen and evaluated as sural and lateral femoral cutaneous nerves[8,9]. Sometimes the colour coded US able to show the epineurial vasa nervorum of some nerves as median nerve at the distal forearm[8,9,10].

The cranial nerves like the accessory and vagal nerves can be visualized regularly. For the differentiation between the healthy nerve and the pathological one ,We need to know the US criteria of the normal peripheral nerve ,the normal healthy nerve are cable like structure which appear on transverse sections as round or an oval hyperechoic structures and surrounded by an echogenic zone of the epineurium and the perineural fatty tissue. Histologically, the rounded hypoechoic areas correspond o the nerve fascicles, and the interfascicular epineurium seen as echogenic septa[8,9,10].

Computerized Tomography (CT) and Magnetic Resonance Imaging (MRI) can also outline peripheral nerves. MRI is considered superior on CT in this area and has potentially better resolution than ultrasound. However, ultrasonography is faster, cost effective, easily applicable and radiation-free image technique [11].

By longitudinal scans the amputation neuroma seen as a hypoechoic bulbous mass where the nerve ends. If the nerve is partially transected, the intact parts of the nerve and its interfascicular epineurium can be seen. This type of lesion is very difficult to diagnose with clinical and electrophysiological methods especially within 3 months of the trauma. Neuroma-in-continuity is seen as fusiform hypoechoic thickened nerve with extincted nerve echotexture Thus, US can facilitate the therapeutic decisions with proper method (neurorrhaphy, nerve grafting or neurolysis). Postoperative complications such as abnormal scarring and dehiscence of the nerve sutures can be diagnosed too [12].

Other advantages of US are it is portable ,able of continuous scanning without skipped sections, gives a more dynamic study and real time imaging, furthermore it can be used on claustrophobic patients and it facilitated the surgical planning in cases with neuroma, foreign bodies and post fracture complication. But the US is an operator dependent technique and it needs a long learning curve and these are the main problems[13]. US was particularly useful in cases with atypical clinical and neurophysiological characteristics, multifocal damage or inaccessible lesions for electro diagnostic studies [14].

METHODS

Prospective study conducted in Departement of Neurosurgey, Zagazig University Hospitals. It included 15 cases (20 nerves) of post traumatic peripheral nerve injury in upper and lower limbs between January 2018 and June 2019. Informed written consents were obtained from the included patients and approval from the Zagazig University review board (IRB) was taken. The study was done according to The Code of Ethics of the World Medical Association (Declaration of Helsinki) for studies involving humans. Routine preoperative laboratory investigation and x-ray done (if suspected fracture).Before using the ultrasonography, we roughly determined the site of injury by neurological examination, nerve conduction studies and skin indents. Pre-operative Ultrasonography for all patients done by the second author using superficial probe US machine (Philips HD,11XE,12MHZ),the examination started with enough distance proximal and distal to the site of injury (about 10 cm).Injured nerve and surrounding structures(bone ,muscle, tendons, vessels) were examined and identified in perpendicular and transverse plane. Detailed data about the injured nerve were obtained as the continuity, shape, caliber, neuroma, proximal and distal stump, integrity and architecture. Images were saved and printed on paper for comparison with intra operative findings. A written consent was obtained; review the results of NCV carefully in cases of delayed intervention, one gram third generation cephalosporine given one hour before surgery. Patients were positioned in supine or prone position according to the injured nerve, the procedure done under general anesthesia, proximal tourniquet applied at 200 mmHg, the wound explored, any foreign body removed and proper intra-operative evaluation of the injured nerve and surrounding tissues has done by using magnifying 5.5xloupe.nerve evaluation includes; identification

of the neuroma, detection the type of injury and measuring the distance between the proximal and distal stump for proper grafting. The adhesolysis started with excision of the associated neuroma and nerve repair was done with grafting from sural nerve cable or simple end to end anastomosis according to the length of the defect.

Statistical analysis: All data were collected and analyzed using SPSS Version 19.0 (SPSS Inc., Chicago, IL, USA).

RESULTS

In the current prospective study as shown in Table (1) 15 patients involved with 20 nerves affection.9 patients were males(60%), 6 patients were female(40%). Twelve (12) nerves have been injured in the RT side (60%) and the Lt side was involved in (8) nerves (40%). The mean age was 30.20± 14.67 years (minimum age was 12 years and maximum was 56 years).The most affected age group was between 15-30 years (40% of the cases).Isolated nerve injury has been reported in 66.7% of cases and two nerve injuries was noticed in 5 patients (33,3%).the most common cause of injury was RTA(40%),followed by knife and sharp objects in (27%).

Compared to the intra-operative data as reported in table(2), the US succeeded to localize the stump neuroma of the injured nerve in 91.7%, detects the gap between the proximal and distal stump in 86.7% and identified the foreign bodies in 75% of the cases.

For more accuracy, the gaps between the proximal and distal ends of the injured nerve have been measured by US and intra-operatively as reported in table(3) , figure (1&2) and there was a positive correlation (correlation coefficient was 0.699).

Table (1): Demographic data age, sex, affected side, number of the affected nerves, and the causes of injury.

	No	%
Total number	15patients (20 nerves)	100
sex		
Male	9 patients	60%
Female	6 Patients	40%
Age		
< 15	3 patients	20%
15-30	6 patients	40%
30-50	4patients	27%
>50	2patients	13%
Affected side		
Right	12	60%
Left	8	40%
Isolated Nerve injury	10 patients	66.7%
Median	4	
Ulnar	2	
Radial	3	
Sciatic nerve	1	
Two nerve injuries	5patients(10nerves)	33.3%
ulnar nerve and median nerve	Three(3) patients	
median nerve and radial nerve	One(1) patient	
ulnar nerve and common peroneal nerve	One (1)patient	
Cause of the injury		
RTA	6patients	40%
Knife	4	27%
Gunshot	2	13 %
others	3	20%

Between 20 nerves affected, 9 patients were males and 6 patients were females. The most common cause was RTA, Isolated nerve injury in 10 patients and two nerves injury were in 5 patients.

Table (2): Preoperative ultrasonographic data of peripheral nerves in relation to the Intraoperative findings

	Ultrasonographic data	Intraoperative findings	percentage
Localization of injury	18	20	90%
Description of injury	17	20	85%
FB detection	3	4	75%
Stump Neuroma	11	12	91.7%
Excessive scar	6	7	85.7%
Gap between proximal and distal stump	13	15	86.7%
Nerve continuity	4	5	90%

US detected the precise location of the injury in 90% of cases, nerve stump neuroma in 91.7%, and FB detection in 75%.

Table (3): Gap between the proximal and distal stumps (13 nerves)

US reported distance mm	Intra-operative distance mm
5	8
17	11
16	19
13	9
16	18
15	17
9	11
10	7
15	18
10	12
11	9
12	11
14	17

There was a positive correlation between the data of US and inta-operative ones, Correlation coefficient is 0.699 (positive correlation).

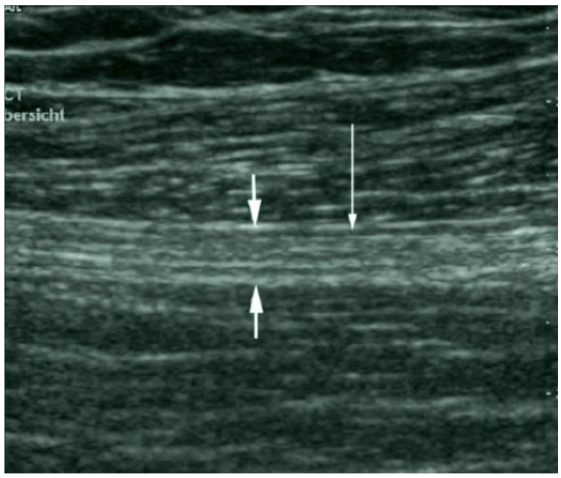

Fig (1): Longitudinal US image of normal nerve revealed hypoechoic linear fascicles with intervening echogenic interfascicular perineurium .

Fig (2):Pre-operative US of the median nerve neuroma at the wrist (defect of 0.7cm)

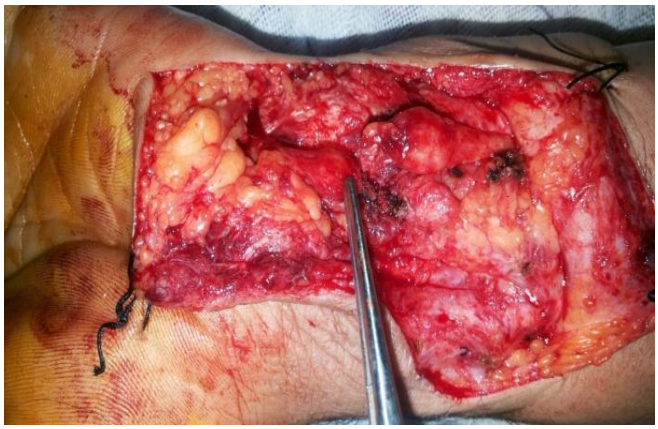

Fig (3) Intra operative photo shows the gap after excision of median neuroma

Fig(4):High resolution sonography long axis shows the 8mm partial tear(the black defect), distance between the black arrows is the entire thickness of the nerve.

Fig (5): Intraoperative photo shows the swollen radial Nerve with partial tear

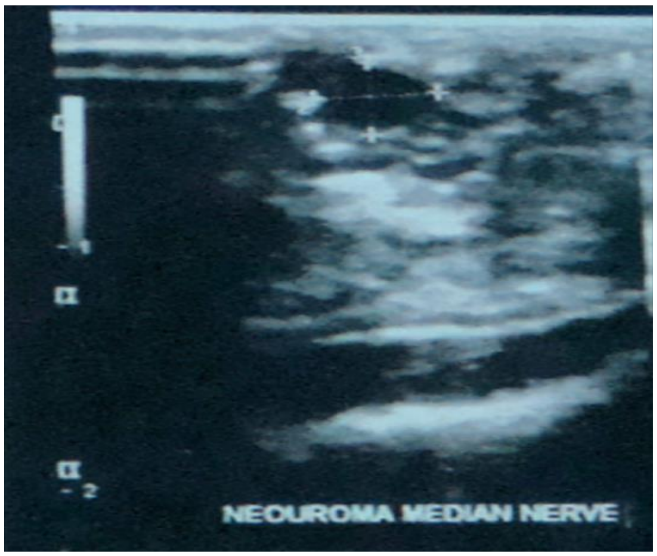

Fig (6): Pre-operative US of the median nerve neuroma at the wrist (defect of 1.3cm)

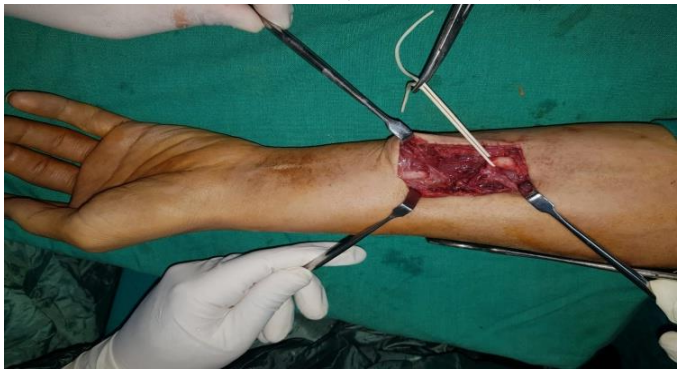

Fig (7) An intra-operative photo of the same median nerve, the defect is bigger than which seen in US(1.9cm).

DISCUSSION

The approach to deal with the peripheral nerve injury is controversial ,Some surgeons prefer to operate later after at least 3 weeks to compare the data of electro -diagnostic studies with the US data, others advocate early to deal with the injury as early as possible with no need to wait to confirm the injury by NCV whenever the data from the pre-operative US was clear especially in cases which associated with other injuries (tendon, vascular ,bone injury[15].The early approach gave us the chance to manage other associated injuries

(tendons, vascular, fracture),avoid the perilesional scar, evacuation of associated hematoma, removal of foreign bodies, missiles and traumatic necrotic tissue. For the cases we choose the delayed intervention inspite of the NCV data are limited, the data of US examination is very important especially in terms of continuity of the nerve, presence of neuroma, distance between the two stumps for proper graft size and amount of the scar. Knowledge of regional anatomy and topography is very important for proper sonographic assessment of peripheral nerves, anatomical landmarks are useful and once identified at any site, continuous tracing of the nerves in proximal and distal directions done. Although all main nerves are found easily and visualized clearly according to these landmarks, knowledge about the entire courses of different nerves and important surrounding structures is helpful for more accurate assessment, especially for smaller or less commonly imaged nerves and in cases of anatomic variations. Although, It is known the MRI is one of the most sensitive and accurate radiological modalities, **Zaidman et al** .have reported that US has a higher sensitivity and equal specificity as compared to MRI, and also detects multifocal nerve lesions than MRI, they stated that the US is the preferred choice modality in evaluating the surgical anatomy of the peripheral nerve lesions in US accessible regions [16]

In spite the NCV data are limited, giving us information only about the degree of injury (is it complete or not), the Ultrasonographic examination of the nerves gives us a valuable data about; type of injury, architecture, continuation, proximal and distal stumps, associated neuroma, perilesional scar, other associated injuries,

When comparing the results of our study to the study **Zhu et al**[17],which discussed the value of ultrasonography for determing the type of traumatic peripheral nerve injury, they classified the severity of injury of peripheral nerves into seven types by using the preoperative US and then compared their results with the intraoperative data ,they found the US was accurate in 93.2% of cases and this proportional to the results of our study which ranging from (75% to 91.7%), although ultrasound did not detect abnormal findings in some patients (6%) and resulted in rare misclassification of severity (6.8%)[17]. In comparison to the study which has done by **Cokluk et al.,** our results was in the same range of the localization accuracy (83.3%) but lower in neuroma and FB detection to (100%) due to the failure of preoperative US to detect the presence of perilesional scars and small pieces of glass as foreign bodies in some cases in our study which cannot detected by preoperative US[15]. **Caterwright et al**., in their cadaveric study, US detected nerve transection in 89% sensitivity and 95% specificity[18]. **Lee et al**, in his retrospective study using high –resolution US in preoperative and intraoperative management of peripheral nerve lesions concluded that, the US demonstrated 100% success rate of correct lesion diagnosis and location and in 58% of cases [19]. US provided right diagnosis when other radiological and electrodiagnostic studies were inconclusive or inadequate [19]. Our results are considered relatively better in comparison to the results of **Toia et al.,** in their retrospective study which stated that the contributive role of US to NCV in preoperative evaluation differed according to the cause and it was (72.2%) in cases of traumatic neuropathy. they concluded that the US findings were negative (nonconfirming with respect to nerve conduction studies) in only 10.1% of patients with different types of nerve lesions [20]. In our study when comparing the gap distance between the proximal and distal stumps which reported by the preoperative US and the intraoperative findings as in figures (1&2), there was a difference but it was insignificant, In some cases the US was over or underestimating the distance but the intraoperative expoloration discovered the real distance, lack of accuracy in detecting gap length precisely may be due to presence of perineural scar and other associated injuries. When comparing the results of US gap distance and intraoperative one, the correlation coefficient was (0.699) which means a positive correlation and our results proved the use of US examination of the injured peripheral nerve is very important modality in proper evaluation and for effective (early &delayed)repair, and it is valuable for visualizing features of traumatic nerve injuries, such as discontinuity of the nerve, neuroma, bone callus, bone fragments, foreign bodies, and scar tissue. Ultrasonography allows differentiating the complete nerve injury that requires surgical therapy as observed in figures(1&2) from partial nerve injury as shown in figures(3&4) and the degree of stump dehiscence determines the surgical procedure (neurorrhaphy in the case of a small defect, nerve transplant in the case of greater dehiscence).

Conclusion: Ultrasonongraphy of the peripheral nerves is considered a complementary diagnostic modality added to electrodiagnostic studies for proper evaluation of the peripheral nerve injury and it is a good alternative in cases of early posttraumatic nerve repair. It gives a valuable data as regard to the nerve location, course, proximal and distal ends, continuity and the surrounding

tissues. With continuous advancement of US technology, our hope in the future, the US could give more details about the anatomical or physiological data, the degree of degeneration in partial injury and degree of post operative regeneration.

Limitations: the number of cases is limited; we need to apply this modality in a large number of patients with different types of injuries especially brachial plexus and nerve injuries in lower limbs.

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