Pre-Operative Ultrasonography in Post-Traumatic Chronic Peripheral Neuropathy of the Upper Limb: Is It Accurate?

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ABSTRACT

High-resolution ultrasonography is a noninvasive, readily applicable imaging modality, capable of depicting real-time static and dynamic morphological information concerning the peripheral nerves and their surrounding tissues. Continuous progress in ultrasonographic technology results in highly improved spatial and contrast resolution. Therefore, nerve imaging is possible to a fascicular level, and most peripheral nerves can now be depicted along their entire anatomical course.

Patients and Methods: This study was conducted in Faculty of Medicine, Zagazig University, as a collaborative work between Plastic Surgery Unit, General Surgery Department and Radiology Department. It included 76 patients with injury of one or more of the peripheral nerves of the upper limb.

In this study, we were concerned about the accuracy of US as a preoperative diagnostic tool in patients with peripheral nerve injuries. So, a comparison between the preoperative US findings of upper limb peripheral nerve injuries and the intraoperative findings found was made.

Results: The diagnostic accuracy of pre-operative US in detecting structural lesions of nerves was found to be 100%. Also, diagnostic accuracy of US in diagnosing the type of lesion and its extent varied between 81.4 and 86.8%.

Conclusion: Ultrasonography is suggested to be a precious complementary tool for assessing peripheral nerve lesions with respect to their exact location, course, continuity, and extent in chronic traumatic nerve lesions in the upper limb.

Key Words: US – Post-traumatic – Peripheral neuropathy – Upper limb.

INTRODUCTION

Peripheral nerve injury can occur due to different etiologies. Obstetrical trauma (traction), penetrating (sharp or blunt objects e.g. knives, glasses and missiles) and crushing injuries of limbs are frequent causes of peripheral nerve injuries [1].

Traumatic peripheral nerve injuries range mostly between 2 to 3% of all trauma cases as mentioned by many authors [2-4]. A study by Seddon, 1943 led to clinical identification and classification of such injuries into a three-graded system (neuropraxia, axonotmesis and neurotmesis). This was later adapted into a five grade system by Sunderland, 1951 and recently has been updated to include a sixth grade; in which a combination of any of the five degrees of injury can be present together [5-8].

The current approach for diagnosing peripheral nerve pathology, in such cases, involves history, physical and neurological examination and electro-diagnostic tests (nerve conduction and electromyography). Electro-diagnostic tests have been defined as the gold standard in the diagnosis, localization and description of a nerve lesion. However, these tests might not be able to give clear information about the type of injury, visualization of nerve stumps, diagnosing the presence or absence of a neuroma and evaluation of excessive peri-lesional scar tissue formation for orientation and planning of surgical intervention [9].

The concept of utilizing ultrasonography (US) to evaluate peripheral nerves dates back to Solbiati et al., 1985; who evaluated this modality to assess the recurrent laryngeal nerve and to diagnose its associated palsy, particularly in cases of infiltrating thyroid or parathyroid pathologies [10].

In normal-weight people, all major nerves of the extremities, e.g. the median, ulnar, radial, sciatic, tibial and peroneal nerves, can be visualized in their entire course at the extremities. Even smaller nerves, e.g. the posterior interosseus and the superficial radial nerves, are regularly displayed. The spinal nerves C4-C8 and the supraclavicular...
brachial plexus can also be visualized, but especially the inferior trunk and the fascicles are not constantly imaged in good quality. The visualization of the infraclavicular and infrapeitoral brachial plexus is restricted by the clavicle and the depth of the structures. Cranial nerves like the vagal and accessory nerves, can be visualized regularly. Particularly in obese patients, the examination of the sciatic nerve in the thigh and tibial nerve at the proximal lower leg is difficult or even impossible. In lean people, however, even small sensory nerves, such as the saphenous, sural and superficial peroneal nerve as well as the lateral femoral cutaneous nerve can be assessed [11].

Another study conducted by Fornage et al., 1988 had helped in the differentiation between normal versus pathological conditions of peripheral nerves using US. The healthy nerves are cable-like structures that appear on transverse sections as round to oval hyperechoic structures (Fig. 1). They are surrounded by an echogenic rim representing the epineurium and the perineurial fatty tissue. US echo pattern (echotexture) is called “honeycomb-shaped”. The rounded hypoechoic areas correspond histologically to the nerve fascicles, and the echogenic septa to the interfascicular epineurium. With color coded US the epineurial vasa nervorum can be displayed in some nerves (e.g. median nerve at the distal forearm). Meanwhile, the pathological conditions ranged from masses to inflammatory conditions and linked to hypo-echoic areas with distal sound enhancement as well as thickening of the nerve [12-14].

Other imaging modalities, such as 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 greater resolution than ultrasound. However, ultrasonography currently has the advantages of being a faster, more cost effective and radiation-free image processing technique. It also offers portability, continuous scanning with no skipped sections, superior spatial resolution for a more dynamic study and real-time imaging. Furthermore it can be used on claustrophobic patients. But of course, still the US is an operator dependent machine which also requires a long learning curve [15,16].

In this study, we were concerned about the accuracy of US as a preoperative diagnostic tool in patients with peripheral nerve injuries. So, a comparison between the preoperative US findings of upper limb peripheral nerve injuries and the intraoperative findings found was made.

PATIENTS AND METHODS

This study was conducted in Faculty of Medicine, Zagazig University, as a collaborative work between Plastic Surgery Unit, General Surgery Department and Radiology Department. It included 76 patients with injury of one or more of the peripheral nerves of the upper limb.

Demographic data of patients are plotted in Table (1). Most of patients were males in the age of activity (12-50 years). Of course, the dominant hand (right hand) was much affected than the left one. Patients with injuries behind or above the clavicle were excluded from this study. This is because of the technical difficulties in visualization of the infra-clavicular and infra-pectoral parts of the brachial plexus which is restricted by the clavicle and the depth and complexity of the examined structures.

Preoperative evaluation for all patients using superficial probe US machine (Philips HD, 11 XE, 12 MHz) was done. Length of nerve deficit, type and size of neuroma and any other associated injury were all reported (Table 2). The majority of our patients showed combined type of injuries. So, we operated upon 76 cases with 112 injured nerves with associated 44 vascular injuries and 53 cut tendons as diagnosed by US, preoperatively. Those with bone fractures (12 cases) were identified by history taking and also by radiological evaluation using plain digital X-ray.

Patients in this study underwent basic routine investigations like total blood count, serum urea and creatinine. A written consent was also obtained for every patient. Surgery was done under general anesthesia and whenever possible, exploration was done under tourniquet control. Surgical chemoprophylaxis (third generation cephalosporin, Cefotaxime sodium, 100mg/Kg/day) was started one hour before surgery and continued for the next two days postoperatively in a divided IV doses.

With the help of a 4X magnifying loupe, wound exploration, identification of the injured structures, measuring and photographing the nerve lesion were done. Thereafter, adhesolysis, neuroma excision and nerve repair were done either by direct end-to-end neuro-anastomosis or sural nerve cable grafting according to the length of the nerve defect. Associated tendon and vascular injuries were also managed accordingly.
RESULTS

In this study, 76 patients were explored for having peripheral nerve injury. Upon exploration, confirmation of the previously gained data using preoperative superficial probe US was done (Table 3). As a whole, the intra-operative findings correlated well with the preoperative US data as regards the number of injured structures. The overall injured structures (112 nerves, 44 vessels and 53 tendons) were found to be as diagnosed preoperatively by ultrasonography. So, accuracy of US in diagnosing structural injury is found to be 100%.

On looking to the fine intra-operative details, some differences were found between what was found on exploration and the preoperative US findings (Tables 2,3). For patients with ulnar nerve injury, there was one patient diagnosed preoperatively as having fusiform neuroma and found intra-operatively to have a saccular one (side neuroma). Out of the twelve cases with neuroma size <1cm, nine were found to be truly <1cm. Also, out of the twenty six cases with neuroma size between 1 and 5cm, twenty two cases were correct. The remaining four were found to have a nerve gap greater than 5cm and were added to the last group. This yielded a diagnostic accuracy of about 81.4% (Fig. 2:A-D).

Patients with median nerve injury; two patients were diagnosed preoperatively to have fusiform neuroma and found intra-operatively to have a saccular one. Between the ten cases with neuroma size <1cm, eight were found to be truly <1cm. Out of the twenty five cases with neuroma size between 1 and 5cm, twenty two cases were correct. The remaining three were found to have a nerve gap greater than 5cm and were added to the last group. Diagnostic accuracy in this group of patients was almost 86.8% (Fig. 3:A-D).

Those with injury to the radial nerve showed similar findings. A second patient was added to the saccular neuroma group. One out of the two patients in the group of neuroma <1cm was found to have his neuroma bigger. Lastly, one case only was added to the last group with a defect >5cm. So, diagnostic accuracy here was about 82.4% (Fig. 4:A-C).

Patients with digital nerve injury were found to have similar pre-operative and intra-operative findings except for two cases that were having their neuromas bigger than detected pre-operatively. This gave a diagnostic accuracy of 85.7% (Fig. 5:A-D).

| Table (1): Demographic and preoperative data of patients in the current study. |
|-----------------|-------|-----|
| 1- Age:         | No.   | %   |
| < 12 years      | 6     | 7.9 |
| 12-30 years     | 32    | 42.1|
| 30-50 years     | 31    | 40.8|
| > 50 years      | 7     | 9.2 |
| 2- Sex:         |       |     |
| O               | 57    | 75  |
| F               | 19    | 25  |
| 3- Affected side: |       |     |
| Right           | 58    | 76.3|
| Left            | 18    | 23.7|
| 4- Level of injury: |       |     |
| Above elbow     | 21    | 27.63|
| Below elbow     | 23    | 30.26|
| Above the wrist | 24    | 31.58|
| In the hand     | 8     | 10.53|
| 5- Affected nerve: |       |     |
| Ulnar           | 43/112| 38.4|
| Median          | 38/112| 33.9|
| Radial          | 17/112| 15.2|
| Digital         | 14/112| 12.5|

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<th>Table (2): Findings found by preoperative US.</th>
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<td>Type of Neuroma: Fusiform Saccular</td>
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<td>Ulnar nerve</td>
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<td>Median nerve</td>
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Associated injuries:
- Vascular injury: 44
- Tendon injury: 53

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<th>Table (3): Intra-operative findings.</th>
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Associated injuries:
- Vascular injury: 44
- Tendon injury: 53
Fig. (1-A): Longitudinal USG image of normal nerve depicting hypoechoic linear fascicles with intervening echogenic interfascicularperineurium i.e. “bundle of straws” appearance [1].

Fig. (1-B): Axial USG image of normal nerve showing rounded hypoechoic areas separated by hyperechoic septae, giving a “honeycomb” appearance [1].

Fig. (2-A): Pre-operative US of ulnar nerve neuroma above the elbow (defect of 3cm, longitudinal view).

Fig. (2-B): An intraoperative photo of the same ulnar nerve showing that the neuroma is nearly of the same size seen by US (almost 3cm).

Fig. (2-C): Neuroma excised.

Fig. (2-D): Four cables of sural nerve grafts used to reconstruct the ulnar nerve defect (almost 3cm in length).
Fig. (3-A): Pre-operative US of the median nerve neuroma at the wrist (defect of 0.7 cm). On left side is an axial view while on the right side is a longitudinal one.

Fig. (3-B): An intraoperative photo of the same median nerve showing that the neuroma is slightly bigger than seen by US (almost 1 cm).

Fig. (3-C): Neuroma excised.

Fig. (3-D): Primary micro-epineurial repair done using 8/0 proline suture.

Fig. (4-A): Pre-operative US longitudinal view of the radial nerve just above the elbow with a thickened epineurium and empty trunk.

Fig. (4-B): An intraoperative photo showing that only thick adhesions around the nerve were present and intraoperative nerve stimulation was strongly positive.
DISCUSSION

Neurological examination and electro–diagnostic tests are known to be the gold standards in the diagnosis of peripheral nerve lesions and making decisions about the selection of the best treatment modality. The limitations of these methods for assessing the location and type of peripheral nerve injury have led to exploration of alternative techniques, such as imaging. With the advent of higher resolution imaging techniques and better image reconstruction, the ability to identify and map peripheral nerves in both the upper and lower extremities is now well described [17].
High-resolution ultrasonography is a noninvasive, readily applicable imaging modality, capable of depicting real-time static and dynamic morphological information concerning the peripheral nerves and their surrounding tissues. Continuous progress in ultrasonographic technology results in highly improved spatial and contrast resolution. Therefore, nerve imaging is possible to a fascicular level and most peripheral nerves can now be depicted along their entire anatomical course [1].

In a study done by Cokluk et al. [9] who addressed their experience in pre-surgical ultrasound in cases of peripheral nerve injury. Although the number of patients in their series was small (only 14 cases), they were able to conclude that ultrasound-assisted neuro-examination is a useful diagnostic method in the precise localization of the injured site, the type of injury, the position of stumps, and the diagnosis of a neuroma.

In another work done by Cartwright et al., [3] they revealed that high-resolution ultrasound was able to identify transected nerves in the upper extremity with 89% sensitivity and 95% specificity in the ten fresh cadaver study they conducted with a diagnostic accuracy of about 89.5%. These results correlate well with the results in the current study. As in this study, diagnostic accuracy for the detailed description of the lesions ranged between 81.4 and 86.8. Of course the number of the examined nerves in that study was much less than that in the current one and this may be the reason for the little difference in the final outcome.

In another recent study made by Zhu et al., [18] in which they assessed the value of ultrasound for determining the type of traumatic peripheral nerve injury, the diagnostic accuracy of ultrasound reached 93.2%. This figure is also close to that present in the current work. Ultrasound did not detect abnormal findings in some patients (6%) and resulted in rare misclassification of injury severity (6.8%), and this is in contrast to our study which yielded 100% diagnostic accuracy in the view of injury detection. It is worth to mention that they included 117 cases in their series which is almost double the number of cases in the current study. But, despite that, they considered the technique to be of value in preoperative assessment of such cases [19].

Conclusion:

In patients with post traumatic chronic peripheral nerve lesions of the upper limb, addition of ultrasonography to the preoperative diagnostic work-up provides a lot of information about the localization and the cause of impaired nerve function. This is considered as very helpful for deciding upon surgical intervention. Ultrasonography allows precise localization of the site of nerve injury, whether a nerve is completely transected or partially dissected and whether the nerve is displaced or even encased by surrounding scar formation or by a fibrous or bony callus after bone fracture. Furthermore, ultrasonography may identify the distance of nerve retraction after complete nerve transection.

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