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The Role of Ultrasound in Pre-Operative Assessment of Nerve Pathologies; Correlation with Intra-Operative Findings

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Abstract

Background: Peripheral nerves are the seat of different types of pathologies that might be attributed to trauma, inflammation, tumors which can be benign or malignant, vascular malformations of the accompanying vessels.

Aim of Study: The aim of this research was to investigate the significance of the US in the diagnosis of various nerve diseases in patients scheduled to undergo surgical management of their nerve conditions. And to correlate the ultrasound details with the intra-operative findings.

Patients and Methods: All patients were submitted to a comprehensive history and clinical examination, and a total of 27 different nerve diseases were considered for inclusion in our final study. All US exams were done with the patients either seated or lying supine (or occasionally lateral decubitus) to access the target nerve. We looked for evidence of nerve continuity, possible cause of entrapment, presence or absence of fibrosis, distortion, or neuroma formation.

Results: Ultrasonography greatly helped the surgeon plan his incision and intraoperative management which significantly reduced the operation time and effort.

Conclusions: Ultrasound is sensitive tool in assessing the variable nerve pathologies and in aiding their surgical management if done routinely preoperatively.

Key Words: *Ultrasonography – Peripheral nerves – Surgical repair.*

Introduction

PERIPHERAL neuropathy may affect either the upper or lower limbs, and traumatic traumas are a typical cause. Most peripheral nerve injuries (46 percent) occur in men and are caused by motor vehicle accidents.

The radial nerve is the most often injured nerve in the upper extremities, afterwards the median and ulnar nerves. The sciatic nerve, followed by the peroneal and tibial nerves, is the most often injured nerve in the lower extremities **[1].**

Other common causes of peripheral neuropathies also include entrapment neuropathies due to variable etiologies that cause compression of the nerves in their anatomically known fibro-osseous tunnels or by a nearby pathology, Carpal tunnel syndrome, caused by median nerve compression in the carpal tunnel, is the most frequent form of entrapment neuropathy **[2].**

The diagnosis of such diseases can be done via thorough history taking, clinical examination, nerve conduction studies, imaging modalities such as magnetic resonance imaging and ultrasonography, the availability of the ultrasonography and the low cost along with the non-invasiveness make it a perfect tool for diagnosing such conditions, though it has limitations being operator dependent which might require some experience, and it is sometimes difficult to identify and to localize the very small branches of the peripheral nerves **[3].**

The treatment of traumatic nerve injuries relies greatly on the continuity of the injured nerve, and in cases of neuroma formation on the availability of the distal end while the treatment of entrapment neuropathies starts with conservative management using anti-inflammatory medications and the surgical management resorted to only in the cases not responding to conservative management and/or deteriorating. It includes removal of the cause of entrapment if there is one and it may include nerve transposition as in cubital tunnel syndrome **[4].**

The purpose of this research was to investigate the United Us' contribution to the diagnosis of various nerve diseases in patients scheduled to undergo surgical management of their nerve conditions. And

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List of Abbreviations:
CSA: Cross-sectional area.

to correlate the ultrasound details with the intra-operative findings **[5]**.

Patients and Methods

Patients having a known history of peripheral nerve diseases participated in this cross-sectional investigation of 27 nerves. Their backgrounds include neurosurgical training at Cairo University's EL Kasr Al Ainy facilities with cases examined in between May 2022 into November 2022. Informed consent was given by all participants. Male and female participants aged 8 to 55 were included in the analysis. All of their symptoms fit the clinical profile of peripheral nerve damage. Patients with polyneuropathies, renal or hepatic problems, radiculopathy, or diabetes mellitus were not included. Taking part in this research is entirely voluntary. The participants in this study have been given further information about the research's goals and methods. A complete medical history and physical examination was performed on each patient. Patients were questioned on two topics: The clinical course of their symptoms (improvement, worsening, or remaining stable) and the history of any prior surgical intervention.

Sonographic assessment:For clinical and other neurophysiologic outcomes, the sonographer was kept in the dark. The research used a Toshiba Aplio 500 equipped with a 7-14 MHz linear probe. All US exams were done with the patients either seated or lying supine (or occasionally lateral decubitus) to access the target nerve. We looked for evidence of nerve continuity, possible cause of entrapment, presence or absence of fibrosis, distortion, or neuroma formation. And in cases of neuroma formation, the availability of the distal end was assessed.

The intraoperative findings: The surgical exploration was carried out in the neurosurgery department operative ward, at the site marked preoperatively by the sonographer, the surgeon was required to inform the sonographer about the operative findings to be correlated with the US findings as regards the exact site of nerve pathology, nerve continuity, swelling or edema of the nerve, presence of neuromas and if so the availability of the distal end, any retained foreign bodies and the cause of entrapment if identified, also intraoperative images of the nerve pathologies were obtained.

Ethical approval: Patients were provided comprehensive trial information and the research was authorized by the Cairo University Ethics Board. All research participants provided written informed permission. All procedures used in this study have been performed in compliance with the principles outlined in the World Medical Association's Declaration of Helsinki on the ethical treatment of human subjects in medical research.

Statistical analysis: SPSS version 28 (IBM Corp., Armonk, NY, USA) was used to input and code the collected data. Quantitative data was summarized using mean, standard deviation, median, minimum, and maximum, while categorical data was described with frequency (count) and relative frequency (%).

Results

A total of 27 variable nerve pathologies were eligible for inclusion in our final analysis, we included 16 (59.3%) males, and 11 (40.7%) females. They had a mean age 33.3 ± 15.5 years old. Table (1).

The pathology was traumatic neuroma in 15 patients (55.6 %) and entrapment in 12 patients (44.4%), no tumor patients were included in the study. 16 cases were on the right side (59.3%) and 11 on the left (40.7%). The pathology was at the level of forearm in 12 patients, followed by leg in 5 patients, gluteal region in 4 patients, 2 patients at the level of neck and similarly at the level of the arm with 2 in the iliac regions. The included nerve was mainly ulnar nerve in 9 (33.30%) cases, median in 5 (18.50%) cases, sciatic in 4 (14.80%) cases and the sural nerve in 2 cases (7.4%), the common peroneal nerve in 2 cases (7.4 %), brachial plexus in 2 cases (7.4%), and the tibial nerve in one case (3.7%) and the ilioinguinal nerves bilaterally in one patient (7.4%). Table (2).

Table (1): Demographics of the included patients.

	Mean	Standard Deviation	Median	Minimum	Maximum
Age	33.33	15.58	32.00	8.00	55.00

Table (2): Clinical characters of nerve pathology.

		Count	%
Pathology	Trauma	15	55.6
	Entrapment	12	44.4
Side	Right	16	59.3
	Left	11	40.7
Site	Arm	2	7.4
	Forearm	12	44.40
	Gluteal	4	14.80
	Leg	5	18.50
	Neck	2	7.40
Nerve	Ilioinguinal	2	7.40
	median	5	18.5
	ulnar	9	33.30
	Sciatic (pyriformis syndrome)	4	14.80
	Common peroneal	2	7.40
	Sural nerve	2	7.40
	Tibial nerve (tarsal tunnel)	1	3.70
	Brachial plexus (thoracic outlet syndrome, upper trunk injury)	2	7.40
	Ilioinguinal nerve	2	7.40

Ultrasound findings showed that nerve was normal as regards the CSA and echogenicity in 8 (29.62%) patients, showed neuroma in continuity in 10 (37.03%) patients, nerve discontinuation in 2 (7.40%) patients and 7 (25.92%) showed an increase of CSA of the injured nerve. Table (3).

Table (3): The ultrasound findings included in the study and the availability of nerve conduction study in the included patients.

		Count	%
Nerve conduction	Not-done	17	62.96
	Abnormal	10	37.03
US findings details	Normal	8	29.62
	Neuroma	10	37.03
	Discontinuous	2	7.40
	Swollen	7	25.92
US findings	Normal	8	29.62
	Abnormal	19	70.37

The ultrasound showed associated fibrosis in 6 patients (22.2%), vascular injury in 1 patient (3.7%), and orthopedic injury in 4 patients (14.8%), muscle injury in 5 patients (18.5%), increased muscle echogenicity and reduced muscle girth in 13 patients (48.14%). Table (4), Figs. (1,2).

Table (4): The presence of associated fibrosis, muscle, orthopedic and vascular injuries, change of the muscle echogenicity and girth in the included patients.

		Count	%
Fibrosis	Absent	21	77.8
	Present	6	22.2
Vascular	Absent	26	96.3
	Present	1	3.7
Orthopedic	Absent	23	85.2
	Present	4	14.8
Muscle injury	Absent	22	81.5
	Present	5	18.5
Supplied muscles (echogenicity)	Normal	14	51.85
	Increased	13	48.14
Supplied muscles (girth)	Normal	14	51.85
	Reduced	16	48.14

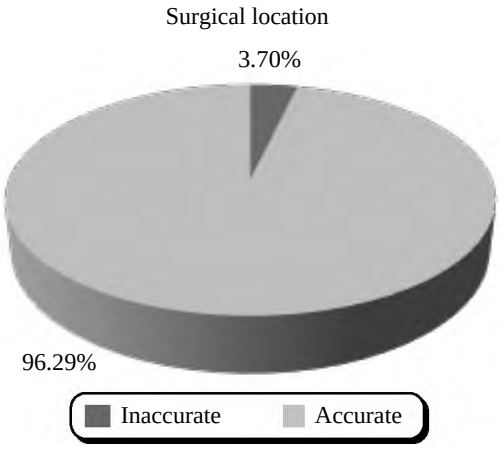

Fig. (1): The accuracy of the preoperative ultrasound pathology localization as compared to the intraoperative.

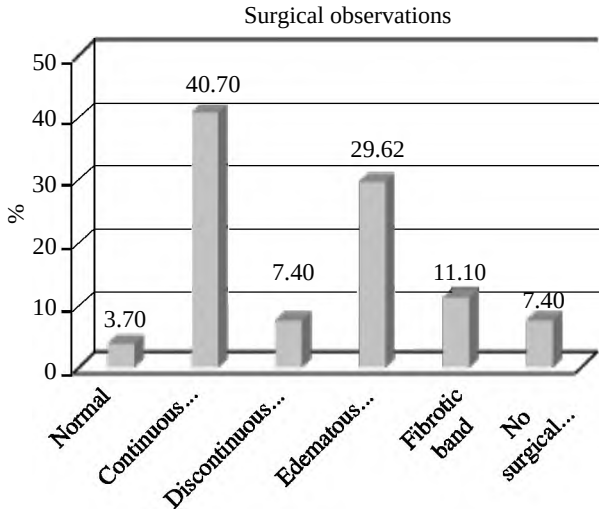

Fig. (2): The intraoperative findings among the included patients.

A 10 -year- old male patient with retraction injury to the left arm & neck, the patient has weakness in the shoulder movement & elbow flexion denoting upper trunk injury (Erb's palsy).

US findings: Ultrasound of the left brachial plexus was done in the left posterior triangle of the neck to visualize the brachial plexus trunks as they descend in between the scalene muscles. It revealed thickening and edematous changes of the upper trunk as well altered echogenicity of the overlying scalene muscles which was suggestive of a muscular hematoma. Figs. (3,4).

Intra-operative findings: Triple transfer was performed to restore shoulder abduction and elbow flexion after supraclavicular exposure of the brachial plexus showed thickness and edema of the upper trunk of the brachial plexus. Suprascapular nerve spinal accessory, The Oberlin transfer involves rerouting the nerves that supply the long head of the triceps, the anterior division of the axillary nerve, and the biceps branch of the musculocutaneous nerve. Fig. (5).

A 55-year-old female patient presenting with numbness and tingling along the antero-medial aspect of the right forearm and medial aspect of the palm & little finger of several months duration. No history of trauma or operative interventions. Nerve conduction studies suggested entrapment of the ulnar nerve at the level of the elbow. The surgical plan was to expose the ulnar nerve at the elbow in the cubital tunnel.

US findings: Thickening of the ulnar nerve and decreased echogenicity within the cubital tunnel. Increased echogenicity and reduced girth of the supplied muscles. (Figs. 6,7,8).

Examination of the nerve within the Guyon's canal revealed average CSA and echogenicity.

Intra-operative findings:

Exposure of the ulnar nerve was done in the cubital tunnel.

It revealed markedly increased thickness of the ulnar nerve behind the medial epicondyle with an overlying constricting band between the 2 heads of flexor carpi ulnaris.

Fig. (3): B mode image, transverse axis, in the left posterior triangle of the neck showing interruption of the scalene muscles' continuity with intermuscular relatively iso/ hyperechoic lesion suggestive of hematoma (arrow).

Fig. (4): B mode image, transverse axis, in the left posterior triangle of the neck showing thickening and decreased echogenicity of the brachial plexus upper trunk, arrow inicated measured area.

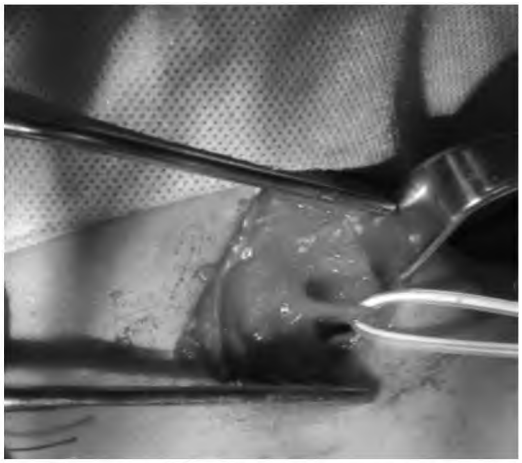

Fig. (5): Left brachial plexus trunks are exposed intraoperatively, revealing swelling and thickening in the upper plexus.

Fig. (6): B mode image, longitudinal axis showing marked change of the ulnar nerve thickness and decrease of the echogenicity (arrow), D: Distal.

Fig. (7): B mode image, transverse axis behind the medial epicondyle showing marked increase in the ulnar nerve CSA (A) and decrease of the echogenicity as well as loss of the characteristic fascicular appearance, ME: Medial epicondyle.

Fig. (8): B mode image, transverse axis showing decrease in the hypothenar muscle girth and increased echogenicity.

Fig. (9): Intraoperative image; exposure of the ulnar nerve behind the medial epicondyle revealed marked thickening of the ulnar nerve (black arrow) and an overlying constricting band (yellow arrow).

Discussion

Peripheral nerves maybe attributed to trauma, inflammation, tumors which can be benign or malignant, vascular malformations of the accompanying vessels and they might possibly result in serious neurological disabilities. A common cause of peripheral neuropathies is traumatic injuries of the peripheral nerves that may result in a wide scope of nerve affection ranging from complete transection to axonal injury or sometimes chronic sequel as neuroma formation **[6].**

In the current study we evaluated the role of ultrasound in assessing the variable peripheral nerve pathologies mostly of entrapment and traumatic causes as regards presumed etiology, and confirmation of neuronal origin, accurate localization and determination of the extent as well as helping the surgeon planning the best planes for making incisions, and the accuracy of the ultrasound findings were correlated with the intraoperative findings regarding the location, characterization of the peripheral nerves, presence of associated injuries, we conducted a cross section study on 27 nerves in patients with history of acute and chronic neurological symptoms, we included 16 (59.3%) males, and 11 (40.7%) females. They had a mean age 33.3±15.5 years old.

Ultrasound findings showed that nerve was normal as regards the CSA and echogenicity in 8 (29.62%) patients, showed neuroma in continuity in 10 (37.03%) patients, nerve discontinuation in 2 (7.40%) patients and 7 (25.92%) showed an increase of CSA of the injured nerve.

The ultrasound showed associated fibrosis in 6 patients (22.2%), vascular injury in 1 patient (3.7%), and orthopedic injury in 4 patients (14.8%), muscle injury in 5 patients (18.5%), increased muscle echogenicity and reduced muscle girth in 13 patients (48.14%).

The intraoperative findings included accurate localization of the nerve pathology in 26 cases (96.29%), inaccurate localization in 1 case (3.7%) continuous peripheral nerve in 11 patients (40.7%), discontinuous peripheral nerve in 2 patients (7.4%), edematous nerve in 8 patients (29.62%) and fibrotic bands in 3 patients (11.10%).

Lee conducted a retrospective analysis of 13 patients undergoing ultrasonographic evaluation and surgical treatment of nerve lesions at their institution (nerve entrapment [5], trauma [6], and tumor [2]). Ultrasonography was used for diagnostic (12 of 13 cases) and intraoperative management (6 of 13 cases) **[7].**

The authors examined the initial impact of ultrasonography on clinical management. Ultrasonography was an effective imaging modality that augmented electrophysiological and other neuroimaging studies. The modality provided immediate visualization of a sutured peroneal nerve after a basal cell excision, prompting urgent surgical exploration. Ultrasonography was used intraoperatively in 2 cases to identify postoperative neuromas after mastectomy, facilitating focused excision **[8].**

Ultrasonography correctly diagnosed an inflamed lymph node in a patient in whom MR imaging studies had detected a schwannoma, and the modality correctly diagnosed a tendinopathy in another patient referred for ulnar neuropathy.

Ultrasonography was used in 6 patients to guide the surgical approach and to aid in intraoperative

localization; it was invaluable in localizing the proximal segment of a radial nerve sectioned by a humerus fracture. In all cases, ultrasonography demonstrated the correct lesion diagnosis and location (100%); in 7 (58%) of 12 cases, ultrasonography provided the correct diagnosis when other imaging and electrophysiological studies were inconclusive or inadequate [8].

Another study conducted by Toia F., et al., [11] The authors analyzed the use of ultrasound in 119 entrapment, tumoral, posttraumatic, or postsurgical nerve injuries of limbs evaluated in 108 patients during 2013 and 2014.

All patients were candidates for surgery, Ultrasound was used to explore the nerve fascicular echotexture, continuity, and surrounding tissues. The maximum cross-sectional area (CSA) and the presence of epineurial hyper echogenicity or intraneural hyper- or hypo echogenicity, anatomical anomalies, dynamic nerve dislocations, or compressions were recorded [9].

Ultrasonography confirmed electrodiagnostic findings in 36.1% of cases and showed a contributive role in the diagnosis and surgical planning in 53.8% of all cases; the findings were negative ("non-confirming") in only 10.1% of the patients. In 16% of cases, ultrasound was not only contributive, but had a key diagnostic role in the presence of doubtful electrodiagnostic findings. The contributive role differed according to etiology, being higher for tumors (100%) and for posttraumatic or postsurgical neuropathies (72.2%) than for entrapment neuropathies (43.8%) [10].

They concluded that Ultrasound is a powerful, noninvasive tool for the examination of peripheral nerve injuries, and can guide diagnosis and surgical strategy for focal peripheral nerve injuries. It allows direct visualization of the cause and extent of nerve lesions and finds its place between electrodiagnostic tests and exploratory surgery. It can provide invaluable information, such as the presence and extent of a mass, scar compression, or neuromas. The authors recommend it as a complement to routine clinical and neurophysiological evaluation and as the first-line imaging modality for masses of suspected nerve origin [11].

Conclusions:

Ultrasound greatly helps the evaluation of the variable peripheral nerve pathologies; due to several etiologies; trauma, entrapment and tumors as regards confirmation of the diagnosis, detection of possible cause, exclusion of associated vascular, muscular injuries, planning the surgical management, preoperative wire localization, prediction of the outcome of surgical management (especially in traumatic neuroma cases by assessing the availability of the distal end, any long term changes of the supplied muscles).

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دور الموجات فوق الصوتية فى تشخيص اسباب امراض الاعصاب قبل التدخل الجراحى لدراسة مدى توافقه مع الملاحظات الجراحية

يمكن أن تكون الأعصاب الطرفيه سببًا للإعاقات العصبية بسبب الصدمة أو الأورام أو الانغلاق. يمكن أن يؤدي ضغط أو انقطاع استمرارية الأعصاب الطرفية إلى إعاقة دائمة إذا تُركت دون علاج و قد يؤدى إلى تدهورجوده الحياة إلى حد ما فى بعض الحالات.

الهدف من العمل هو تقييم دور الموجات فوق الصوتيه فى تقييم أنواع مختلفة من أمراض الأعصاب لدى المرضى المقرر خضوعهم لاجراءات جراحية لحالاتهم العصبية. للمساعدة فى تخطيط علاجها جراحيا وربط تفاصيل الموجات فوق الصوتية بالنتائج أثناء الجراحة.

فى الدراسه الحاليه قمنا بفحص ٢٧ حالة من أمراض الأعصاب المختلفه فى المرضى الذين لديهم تاريخ من الأعراض العصبية الحادة والمزمنة الذين تتراوح أعمارهم بين ٨ و ٥٥ عامًا تم اخذ التاريخ المرضى والفحص البدنى، وتم المقارنة مع الجانب الاخر.

لقد اكتشفنا تطابقًا رائعًا بين البيانات التى قدمتها الموجات فوق الصوتية والنتائج أثناء العملية، وتم استنتاج أن الفحص الروتيني بالموجات فوق الصوتية قبل الجراحة للأعصاب الطرفية ذات الأهمية والذى يتوفر بسهولة، ومنخفض التكلفة يمكن أن يحسن بشكل كبير العلاج الجراحى عن طريق تحديد دقيق لمكان الخلل بالعصب الطرفى، وتقليل وقت الإجراء الجراحى وتحسين نتائج الجراحة.