Investigation of the Correlation Between Ultrasound Findings and Median Nerve Tear Repair Outcomes

Abstract

Introduction: Median nerve injury has an incidence of approximately 2.8% among trauma patients. Electromyographic tests cannot provide clear information regarding the type of injury, imaging of the severed nerve, presence or absence of neuroma, or assessment of scar tissue formation around the lesion, which are essential for surgical intervention planning. Ultrasound is a reliable, inexpensive, useful, and quickly accessible diagnostic method at the patient's bedside.

Materials and Methods: In this descriptive-analytical study, patients with symptoms of acute median nerve injury and tear due to penetrating trauma, admitted to an orthopedic teaching department over one year, were included. Patients with congenital neurological disorders, diabetes, other systemic diseases, previous wrist nerve surgeries, or cervical discopathies were excluded. Patients underwent clinical examination, electromyographic tests, and ultrasound follow-ups three months post nerve repair.

Results: Over one year, 21 patients, including 12 men and 9 women aged between 20 to 55, with median nerve repairs were retrospectively included in the study. The average thickness of the repaired nerve at the proximal site was 2.58 ± 0.51 mm and 2.51 ± 0.61 mm at the distal site. The average thickness of the repaired nerve at the proximal injury site was significantly higher in males. Clinically, 12 cases (57.1%) showed complete recovery, and 9 cases (42.9%) showed partial recovery three months post-surgery. Ultrasound analysis indicated that the volume of neuroma formed at the repair site was less in patients with complete recovery compared to those with partial recovery. The neuroma volume at the repair site was lower in patients with electromyographic evidence of nerve regeneration compared to those with severe axonal injury, but no significant correlation was found. Additionally, patients with injuries at the carpal tunnel entry had complete recovery post-surgery, although no significant relationship was observed.

Conclusion: Ultrasound can be used as a low-cost, non-invasive method for assessing peripheral nerve injury treatment outcomes and follow-ups post-repair.

Keywords: Ultrasonography, Median Nerve, Neuroma, Peripheral Nerve Injuries

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Introduction

Median nerve injuries can arise from various causes, including puncture wounds, fractures, crush injuries, and cuts by sharp objects like knives, glass, or bullets. Overall, the prevalence of median nerve injuries in trauma patients is 2.8%. Proper diagnosis of such injuries involves taking a detailed medical history, conducting a thorough physical examination, and performing nerve conduction velocity tests and electromyography. Electrodiagnostic tests, considered the gold standard for diagnosing median nerve injuries, can accurately locate the nerve lesion(1). These tests answer critical questions, such as whether nerve conduction is present in the injured nerve, which indicates that some nerve fibers remain intact. In contrast, the absence of nerve conduction confirms complete degenerative nerve injury. Electrodiagnosis can distinguish between low-grade injuries, where the axon remains intact (neurapraxia according to Seddon classification), and high-grade injuries involving axon and sheath destruction (axonotmesis and neurotmesis)(2). However, electrodiagnostic tests do not provide clear information about the type of injury, visualization of a severed nerve, the presence or absence of neuromas, or the assessment of scar tissue around the lesion to guide surgical intervention. Therefore, a reliable, cost-effective, and quickly accessible diagnostic method at the bedside is needed(1). Significant advancements have been made in imagin techniques for peripheral

nerve evaluation, such as Magnetic Resonance Interferometry (MRI). Although MRI is superior for assessing soft tissue injuries, it cannot visualize small nerves or the extent of severed nerves[3].

Currently, physicians have found that using ultrasound for diagnosing median nerve injuries offers numerous benefits, including cost-effectiveness, rapid diagnosis, the ability to examine long sections of the nerve, minimal contraindications, portability, non-invasiveness, and providing information that cannot be obtained through electrophysiological or other tests. Additionally, surgeons can use ultrasound to diagnose and evaluate nerve injuries pre- and post-operatively due to trauma, neoplasia, infection, or crush injuries[4].

In Iran, extensive studies on this subject have not yet been conducted. Worldwide, the first study was conducted in 2003 by Siegfried and colleagues, who indicated that ultrasound has high potential for monitoring patients undergoing peripheral nerve repair[5]. This study aims to evaluate the repair of the median nerve post-surgery and the capability of ultrasound in diagnosing nerve regeneration. A neuroma is an excessive growth of nerve cell axons, potentially a benign tumor, but often resulting from peripheral nerve injuries. Following trauma and nerve rupture, localized nerve growth at the rupture site can form a lump known as a neuroma.

A case report from Taiwan by Wang and colleagues evaluated the use of pre-operative ultrasound on a 22-year-old patient with a left-hand median nerve injury. The patient had sustained a left-hand injury from a sharp object seven years prior. Examination revealed numbness in the first, second, and third fingers. Electrophysiological tests also reported a median nerve injury. After hospitalization, ultrasound with a Philips HDI 5000 device using a 7-12 MHz linear probe showed a gap between the two ends of the median nerve at the injury site and the formation of a neuroma. Exploratory surgery confirmed the separation of the median nerve and neuroma formation at the root of the severed nerve. This case demonstrated that pre-operative ultrasound provides valuable information for identifying injury type and planning surgical interventions[1].

In 2009, Toros and colleagues conducted a prospective study in Izmir, Turkey, to evaluate the value of ultrasound in diagnosing peripheral nerve injuries, including the area and extent of injury in patients with clinical evidence of peripheral nerve lesions. They performed high-resolution ultrasound on 26 patients with upper limb peripheral nerve injuries using a Siemens Sonoline-Siena scanner with a 7-9 MHz adjustable transducer by a single radiologist. The ultrasound was conducted at the injury site and at least 10 cm above and below it. High-resolution ultrasound effectively visualized the injured nerves in all patients, providing detailed information about the injury's cause and anatomical location. The researchers concluded that surgeons must be aware of the injury type, anatomical location, and presence or absence of neuroma before planning treatment. Ultrasound enables accurate patient follow-up[2,3].

A prospective study in China in 2014 by Manluo and colleagues assessed the role of ultrasound in diagnosing peripheral nerve injuries and post-operative follow-up on 34 patients injured in the 2008 earthquake. These patients underwent clinical examinations and electrophysiological tests by orthopedic specialists, revealing muscle weakness, numbness, and pain at the injury site. Ultrasound with a 7-13 MHz linear probe connected to a MyLab90 system was performed before surgery to accurately locate the nerve injury and post-operatively at the surgical scar site and 10 cm above and below it. Ultrasound failed to identify only one of the 59 nerve injuries. Additionally, ultrasound evaluated nerve repair and the presence of epineurium and perineurium. The study concluded that ultrasound is a valuable method for initial and secondary evaluation of patients with peripheral nerve injuries pre- and post-operatively[3].

In a 2003 prospective study in Austria, Siegfried and colleagues examined the potential of ultrasound for monitoring and evaluating patients undergoing nerve repair surgery after peripheral nerve injuries. They assessed 19 patients who directly underwent nerve repair surgery following peripheral nerve injuries. All patients showed clinical symptoms consistent with electrophysiological tests indicating nerve dysfunction. They evaluated 26 injured nerves. Ultrasound was performed using an HDI 5000 device with a 10-15 MHz broadband linear probe. The nerve was identified around the surgical scar and approximately 10 cm above and below it. Special attention was given to determine epineural and epineurium connections across the nerve suture site. Ultrasound identified neuroma formation in 13 nerves, 11 of which were post-secondary surgery. The results showed that the size and location of neuromas matched the ultrasound findings. Thus, ultrasound proved useful for obtaining information about the exact location of repaired nerves[5].

In 2013, a retrospective study compared the diagnostic results of ultrasound and MRI for

assessing peripheral nerve injuries by Zeidman and colleagues in Washington. They evaluated 53 patients with clinically diagnosed peripheral nerve injuries using both MRI and ultrasound. The final diagnosis was confirmed by clinical examinations and exploratory surgery. All ultrasounds were conducted by a single radiologist using a Philips HDI xe device with IU22 ultrasound system and 5-12 L or 5-17 L linear probes. MRI was performed with a multi-level, multi-stage protocol with intravenous contrast injection. Statistics showed that ultrasound detected nerve lesions more accurately than MRI, with a diagnostic accuracy of 93% compared to MRI's 70%. Ultrasound better identified the lesion pathology. Multicentric lesions were detected in six cases by ultrasound and one case by both ultrasound and MRI. The study ultimately confirmed the value of ultrasound in assessing and diagnosing nerve lesions[6].

Method

In this descriptive-analytical study, patients with signs of acute median nerve injury due to penetrating trauma, admitted to the orthopedic department of Imam Khomeini Hospital in Urmia over one year from January 20, 2019, to January 20, 2020 were included. Inclusion criteria were the absence of congenital nerve disorders, age between 18 and 65, no diabetes or other systemic diseases that could increase the likelihood of neuropathy, no prior surgeries on wrist nerves, no wrist deformities, and no cervical discopathy. All eligible patients were selected and underwent clinical examination and electrophysiological tests three months after admission.

Electromyography (EMG) was performed using needle electrodes at the injury site. These needle electrodes were inserted into the muscle at the injury site, and the muscle's response was recorded on a monitor after stimulation. Electrophysiological data analyzed included the amplitude composition of action potentials recorded from the electrodes during EMG. According to the recorded reports, an action potential amplitude of 10% or more indicates a good prognosis. All EMG tests were conducted by an experienced physician who was unaware of the clinical examination results and were performed before the ultrasound.

Ultrasound was performed using a Supersonic Ultimate device with an 18-5 SL linear probe connected to an ultrasound system. Patients were positioned according to the injury site, with special attention given to stabilizing the injured limb using supportive pillows. Gel was applied to the injured area to facilitate probe movement and increase accuracy. The ultrasound was conducted at the injury site and at least 10 cm above and below it. The shape, echo pattern, diameter, and volume of the neuroma, as well as the overall integrity of the nerve and nerve bundles, perineurium, epineurium, and surrounding tissues of the median nerve, were examined.

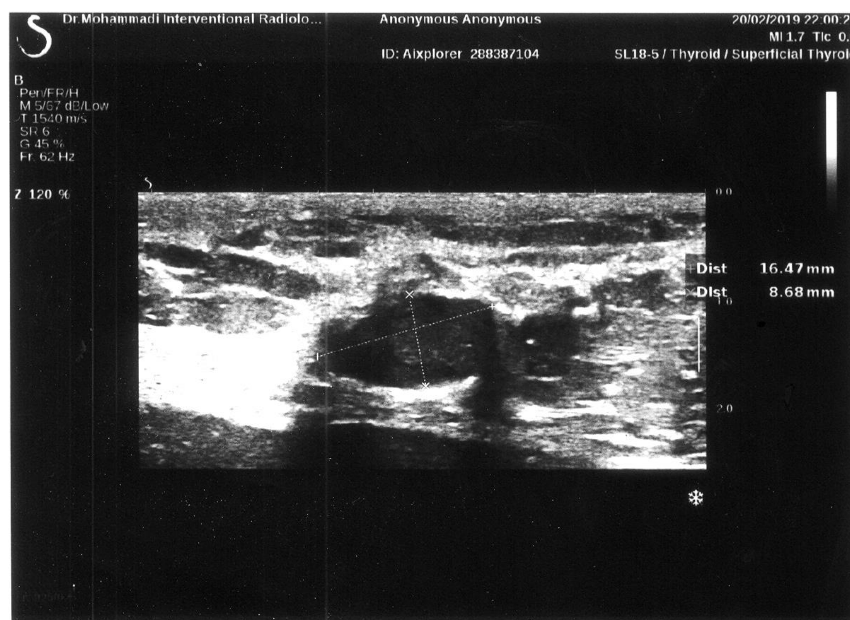


Figure 1. Transverse ultrasonography shows a bizarre shape hypodense nodule at repaired site of Median nerve after surgical repair of previous trauma

Chart 1: Tickness of Neuroma at Repair Site, 3 Months Post-Surgery, Based on Recovery Level

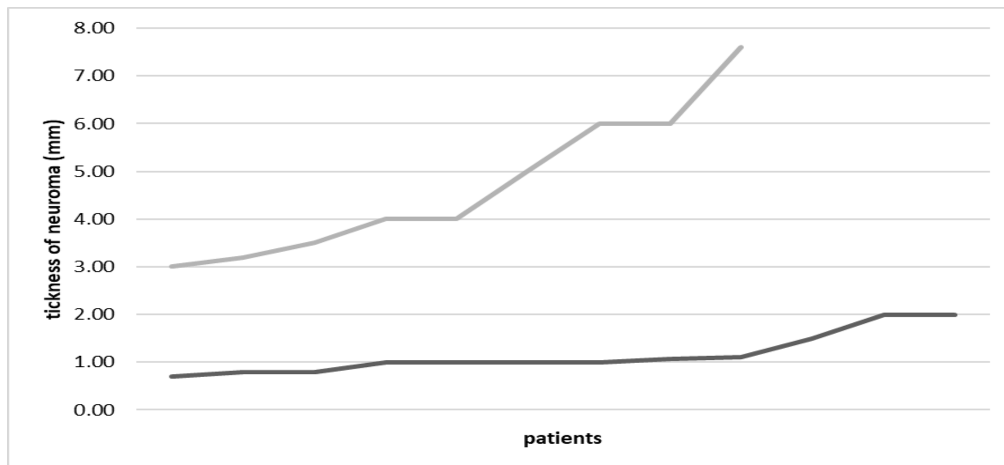
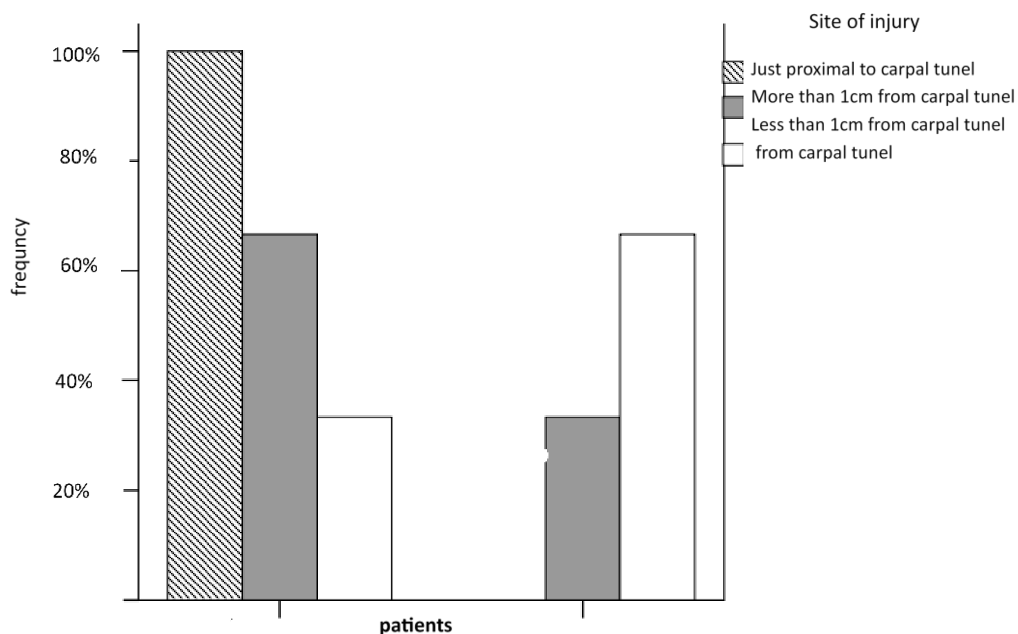


Chart 2: Frequency of Patients Based on Injury site



All ultrasounds were performed by an experienced sonographer who was unaware of the clinical examination results and electrodiagnostic tests. All surgical repairs were conducted by a specialist under loupe guidance using 07 nylon sutures, and the rehabilitation program was uniform and identical for all patients. The average volume and diameter of the repaired nerve were compared with the findings of the nerve conduction study using the Pearson test

Results

In this retrospective study, 21 eligible patients with median nerve trauma who had undergone nerve injury repair due to trauma at Imam Khomeini Hospital in Urmia from January 20, 2019, to January 20, 2020, were selected and included in the study. All patients were between 20 to 55 years old and had no prior history of underlying diseases. The mean age of all patients was 31.47 ± 8.68 years. Of these, 12 cases (57.1%) were male, and 9 cases (42.9%) were female.

The average thickness of the repaired nerve at the proximal end in all patients was 2.58 ± 0.51 mm, and at the distal end, it was 2.51 ± 0.61 mm. The mean thickness of the repaired nerve at the proximal end to the injury site was significantly higher in males. Out of the total patients, based on clinical examinations, 12 patients (57.1%) had full recovery and 9 patients (42.9%) had partial recovery three

1: Average thickness of the median nerve at proximal and distal sites relative to the injury, 3 months post-surgery by gender							
		Mean	**Standard Deviation**	**Median**	**Min**	**Max**	**p-value**
Proximal	Male	2.78	0.53	2.80	1.99	3.70	0.041
	Female	2.32	0.35	2.30	1.90	2.90	
	Total	2.58	0.51	2.57	1.90	3.70	
Distal	Male	2.66	0.61	2.50	1.90	3.90	0.188
	Female	2.30	0.57	2.18	1.60	3.50	
	Total	2.51	0.61	2.30	1.60	3.90	

Table 2. Average volume of neuroma at the repair site 3 months / post-surgery by degree of recovery						
	Mean	**Standard Deviation**	**Median**	**Min**	**Max**	**p-value**
Full Recovery	1.16	0.43	1	0.70	2	p<0.001
Partial Recovery	4.70	1.55	4	۳	7.60	
Total	2.67	2.07	2	0.70	7.60	

Table 3. Average volume of neuroma at the repair site 3 months post-surgery by electromyography results						
	Mean	**Std. deviation**	**Median**	**Min**	**Max**	**p-value**
Nerve Regeneration	1.81	1.67	1.07	0.70	6	0.507
Severe Axonal Damage	3.63	2.12	3.35	١	7.60	
Total	2.67	2.07	2	0.70	7.60	

Table 4. Frequency of Patients by Injury Location and Residual Complications Post-Surgery								
		Full Recovery		**Partial Recovery**		**Total**		**p-value**
		Frequency	%	Frequency	%	Frequency	%.	
Injury Location	Carpal Tunnel Entrance	3	100%	0	0	3	100%	0.097
	More than 1 cm above	6	66.7%	3	33.3%	9	100%	
	Less than 1 cm below	3	33.3%	6	66.7%	9	100%	
Residual Complications	Sensory Disturbance	0	0	9	100%	9	100%	p<0.001
	No Complications	12	100%	0	0	12	100%	

months after surgery. According to the analysis conducted, the volume of neuroma formed at the repair site was significantly lower in patients with full recovery compared to those with partial recovery.
According to the results, the volume of neuroma formed at the repair site was significantly lower in cases with electromyography results indicating nerve regeneration compared to patients with severe axonal damage, although no statistically significant relationship was found. All patients with injuries at the entrance of the carpal tunnel had full recovery post-surgery due to the protective factor of the tunnel for the median nerve, but no significant relationship was observed.

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Discussion

The median nerve is a mixed nerve with a very important role in hand function. Its nerve branches include C5, C6, C7, C8, and T1. This nerve is responsible for the abduction of the thumb, wrist flexion, finger flexion, and sensation of the major lateral part of the palm. Median nerve injuries occur through various mechanisms and can be injured at different points along its path in the upper limb.

In this study, 57.1% of the total patients achieved full recovery three months after reparative surgery without any complications, while the remaining patients experienced partial recovery with sensory disturbances. Ultrasound was successfully used in all patients to accurately examine the injury site, nerve thickness, and neuroma volume.

Common injuries to the median nerve include anterior shoulder dislocation, elbow dislocation, humerus fractures, mid-shaft radius fractures, knife wounds, prolonged application of a tourniquet, and frequent use of crutches. However, these injuries are rarely isolated and are often associated with radial or ulnar neuropathies.

High-resolution ultrasound is an important tool in the diagnosis, management, and follow-up of nerve injuries, with high sensitivity and specificity. In a review study conducted by Al-Aqeel and Al-Shomaili, the recovery results following the repair of peripheral nerve injuries in patients monitored by ultrasound were close to the reported statistics in previous studies.

In Siegfried's study, the location and size of the neuroma diagnosed at the injury site were confirmed with secondary surgery in 11 out of 13 cases, suggesting that this diagnostic method can be crucial in decision-making for subsequent therapeutic actions.

Additionally, in a study by Manlu and colleagues in China, which aimed to assess the role of ultrasound in diagnosing peripheral nerve injury and follow-up after surgical repair in 34 individuals, ultrasound failed to identify only one of the 59 nerve injuries. This study reported the use of ultrasound as a valuable method for initial evaluation in the management of peripheral nerve injuries.

Conclusion

Ultrasound can be used as a low-cost and non-invasive method for examining peripheral nerve injuries and follow-up after reparative surgery.

Recommendations: It is recommended that a study with a larger sample size be conducted. Additionally, the use of ultrasound as a diagnostic method should be explored for other types of injuries and in other peripheral nerves. Concerning patient recovery rates, other factors influencing recovery after repair—such as age, time of patient presentation, time of intervention, duration from presentation to surgery, and nature of the injury—should be investigated.

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