INTRAOPERATIVE ULTRASOUND FOR RESECTION MARGIN PLANNING IN POST-TRAUMATIC MEDIAN NERVE NEUROMA: A CLINICAL CASE AND EARLY OUTCOMES

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Abstract

Post-traumatic neuromas are a common complication of peripheral nerve injuries, often resulting in chronic pain, as well as sensory and motor dysfunction. The ulnar and median nerves are most frequently affected. The high incidence of neuroma formation and its significant impact on patients' quality of life highlight the importance of effective surgical management. Intraoperative ultrasound is increasingly being utilized in neuroma surgery, offering real-time visualization of nerve pathology, although its routine use remains limited. This paper presents a clinical case of a 27-year-old patient with a recurrent post-traumatic neuroma of the left median nerve. The patient had undergone multiple previous surgeries, including primary neurorrhaphy and revision neurolysis. Due to persistent neuropathic symptoms, a revision surgery was performed with the use of intraoperative ultrasound, which enabled accurate identification of the neuroma, evaluation of lesion extent, and precise delineation of resection margins. Early postoperative outcomes demonstrated reduced pain, decreased swelling, stabilization of neurological function, and no recurrence on follow-up ultrasound. This case illustrates the potential of intraoperative ultrasound as a safe and effective tool that can improve surgical precision and reduce the risk of neuroma recurrence.

Introduction

Peripheral nerve injuries are a common type of neurological disorder. One possible result of these injuries is post-traumatic neuromas (PTNs). These are benign growths that form when nerve regeneration is disrupted. These neuromas are made up of growing Schwann cells, connective tissue, and tangled axons. This shows a problem in how neurogenesis should work. PTNs can form anywhere in the body after nerve damage. This damage may come from surgery, injury, or long-term inflammation. A main cause of disease is the failure of healing processes. This can happen from poor surgical repairs or ongoing irritation from fibrosis and inflammation.

As a result, non-functional nerve structures form, causing pain syndrome.[1]

From a morphofunctional view, post-traumatic neuromas fall into three types: neuromas-in-continuity, where the nerve keeps its anatomical continuity; terminal neuromas, which happen after a complete nerve rupture; neuromas that are wrapped in scar tissue. It's important to tell apart secondary neuroma-like growths from real nerve tumors. For example, neurofibromatosis can cause these secondary formations. In contrast, true tumors include acoustic schwannoma and Morton's neuroma.[2,3]. According to various sources, the incidence of PTNs ranges from 1% to 10%, though in most cases they lack overt clinical manifestations.[4,5] The most important types are symptomatic forms. This is especially true for those that affect the major nerves in the upper limb. Median nerve neuroma is the second most common type. Ulnar nerve neuroma is the first. This ranking is due to the nerve's position and its risk during trauma or surgeries. The main clinical signs are localized pain, stiffness, heightened sensitivity, and nerve pain. These often have a specific trigger zone.[6,7]

Given the key sensorimotor role of the median nerve, post-traumatic neuromas in this location represent a clinically significant issue requiring accurate diagnosis and timely surgical intervention. The initial stage involves clinical assessment with identification of trigger points and sensorimotor deficits, followed by electroneuromyography to determine the extent of axonal damage. For visualization, MRI, CT, and especially ultrasound are widely used, the latter being highly sensitive to structural and thickness changes in the nerve. [2,8] Ultrasound is actively used not only for diagnosis and nerve blocks but also for preoperative planning.[9] A significant contribution to the development of this technique was made *by Fornage*, who was the first to systematize data on the ultrasound anatomy of peripheral nerves, while *Gofeld et al.* confirmed its reliability on anatomical specimens.[10] Although imaging techniques are common, studies on intraoperative ultrasound for peripheral nerve reconstruction have emerged only since 2010.[11] This method allows for accurate localization of problem areas. It also offers real-time surgical control and lowers the risk of trauma during surgery. This makes it very important for today's traumatology and reconstructive neurosurgery.

Material and methods

The study was conducted at JSC «National Center of Neurosurgery» in the city of Astana during 2020–2025.

Ethical approval: The study was conducted in accordance with the Declaration of Helsinki and the principles of Good Clinical Practice. Written informed consent for the surgical intervention and participation in the study was obtained from the patient. The project underwent ethical review and was approved by the local ethics committee of the National Center for Neurosurgery JSC, Astana, Kazakhstan (Meeting №5, Extract №1 from the minutes of the Bioethics Committee meeting dated September 05, 2025), ensuring protection of the participant's rights and safety.

Case presentation

A 27-year-old man arrived at the National Center for Neurosurgery. He reported pain in his left hand that felt both shooting and aching. He also mentioned numbness in his first three fingers (digits I-III). The patient had a wrist injury on the left side five years ago. Since then, they have felt numbness and less sensation in their first three fingers. Their finger flexion is limited, and skin peeling occurs near the injury site. An initial surgery - wound closure - was performed, but no improvement was noted. One month later, a second surgery was carried out: neurorrhaphy of the left median nerve.

In the postoperative period, the patient continued to experience paresthesia and neuropathic pain. Ultrasound examination revealed scar-compression neuropathy of the median nerve. Three years later, they did an electroneuromyography (ENMG) test. It showed nerve damage in the carpal tunnel, both axonal and demyelinating. One year after that, ultrasound imaging of the soft tissues in the scar area of the left wrist revealed destructive changes. MRI of the median nerve confirmed the presence of a neuroma, and a third surgery - neurolysis of the left median nerve - was performed.

The patient kept reporting pain in the left hand and numbness in fingers I-III. This situation led to a referral to our clinic.

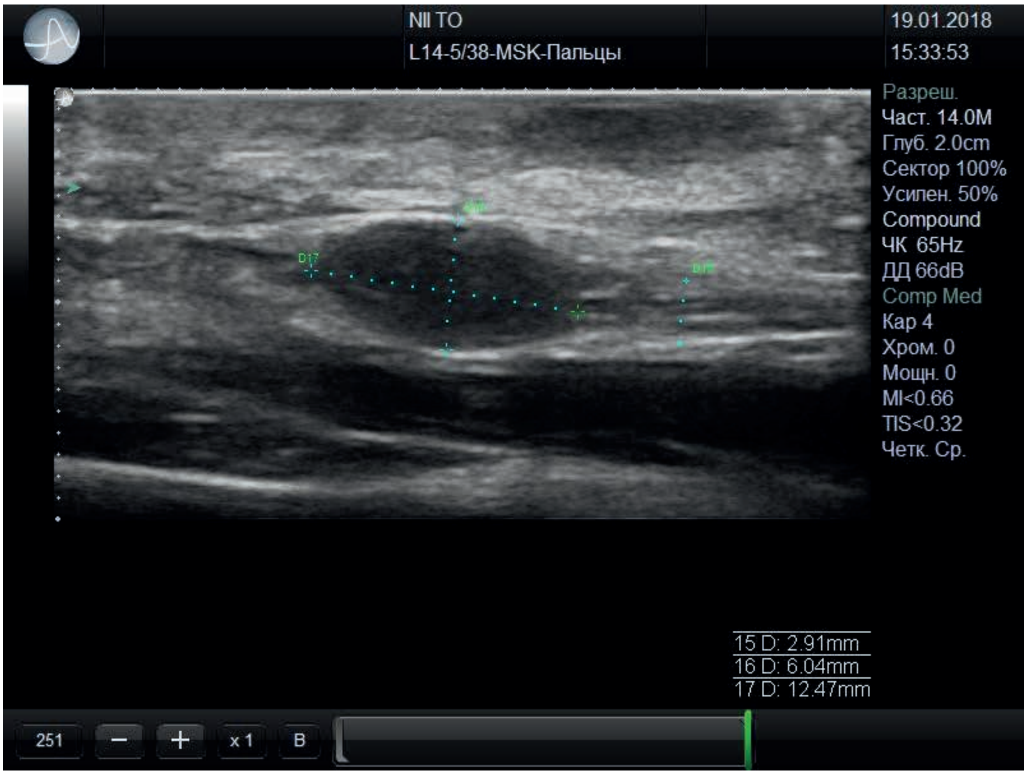

Figure 1. Ultrasound examination of the median nerve performed in the longitudinal (sagittal) view An oval, hyperechoic lesion with well-defined margins and a homogeneous internal structure is visualized along the course of the nerve. The lesion measures 7.7 × 4.5 mm. It is intraneural, associated with a thickened segment of the nerve proximally and thinning of the nerve distally to the pathological focus (which may indicate traction changes). The normal fascicular architecture of the nerve is disrupted, and the surrounding soft tissues show signs of perineural fibrosis without significant edema or vascular pathology. The imaging findings are consistent with a post-traumatic neuroma of the median nerve.

On admission, the exam showed weakness in both shallow and deep finger flexors of the left hand. The flexor pollicis brevis for fingers I-III was especially affected. Muscle strength in these groups was assessed as 2/5 on the MRC scale - active movements were only possible with gravity eliminated. Decreased muscle tone and moderate thenar hypotrophy were noted. The sensory exam found loss of feeling in the area served by the median nerve. This includes the palmar surfaces of fingers I-III and the dorsal surfaces of the index and middle fingers' tips. The palm experienced hypesthesia. There was allodynia and localized hyperesthesia around the surgery scar too. Tinel's sign: positive. Phalen's test: positive. Froment's sign: negative. Pinch test: positive. Durkan's test: positive.

ENMG confirms demyelination and axonopathy in the carpal tunnel region. Ultrasound reveals changes in the scar tissue (Figure 1). MRI then shows a solid mass lesion, pointing to a possible neuroma.

Due to the ongoing pain and sensorimotor problems, we did a full differential diagnosis before deciding on surgery. Past treatments didn't provide lasting improvements. We needed to rule out several conditions. These included scar-compression neuropathy, recurrent carpal tunnel syndrome, neuropathy from systemic diseases, and true nerve tissue tumors. A detailed diagnostic process confirmed that the median nerve has a post-traumatic neuroma. This included clinical neurological tests, ENMG, MRI, and high-frequency ultrasound.

A clear, solid lesion was found where surgeries happened before. There was damage to the nerve's structure and notable changes around the nerve. The clinical picture also supported the need for surgery. Due to the risk of more neurological issues and ongoing pain, we decided to remove the neuroma using microsurgery. We also performed neurolysis with the help of intraoperative ultrasound. This method marked the edges of the lesion clearly. It also reduced damage to healthy nerves. This created a good setup for later reconstruction using guiding epineural sutures.

The procedure included: microsurgical neurolysis of the median nerve, excision of the neuroma, and placing guiding epineural sutures. Intraoperative ultrasound guided these steps (see Figure 2).

Surgical procedure

The surgeon made a straight cut on the palm side of the forearm. This cut followed the line of the carpal tunnel and the earlier scar. Dense, keloid scar tissue was encountered, extensively adhered to the expected course of the median nerve. The surgery had to be adjusted because of severe fibrosis and trouble finding neural structures. So, the exposure was extended both up and down. We saw intact parts of the median nerve with a clear fascicular structure past the dense adhesions.

Upon nerve dissection, it was noted that the nerve trunk anatomically consisted of two bundles. A solid, dense, dull-gray neuroma measuring 5 cm in length was identified, causing nerve deformation. We used a high-frequency intraoperative ultrasound probe (10-18 MHz) to navigate along the nerve path. According to criteria described in the literature,[12] the resection zone was defined by the following ultrasound features: sharp increase in nerve diameter > 2.5× proximal to the neuroma; loss of fibrillar signal in both transverse and longitudinal planes; edge asymmetry; hypoechoic solid lesion with a hyperechoic rim.

After ultrasound-guided navigation, the boundaries for the planned nerve resection were defined based on the intraneural appearance of the peripheral nerve.

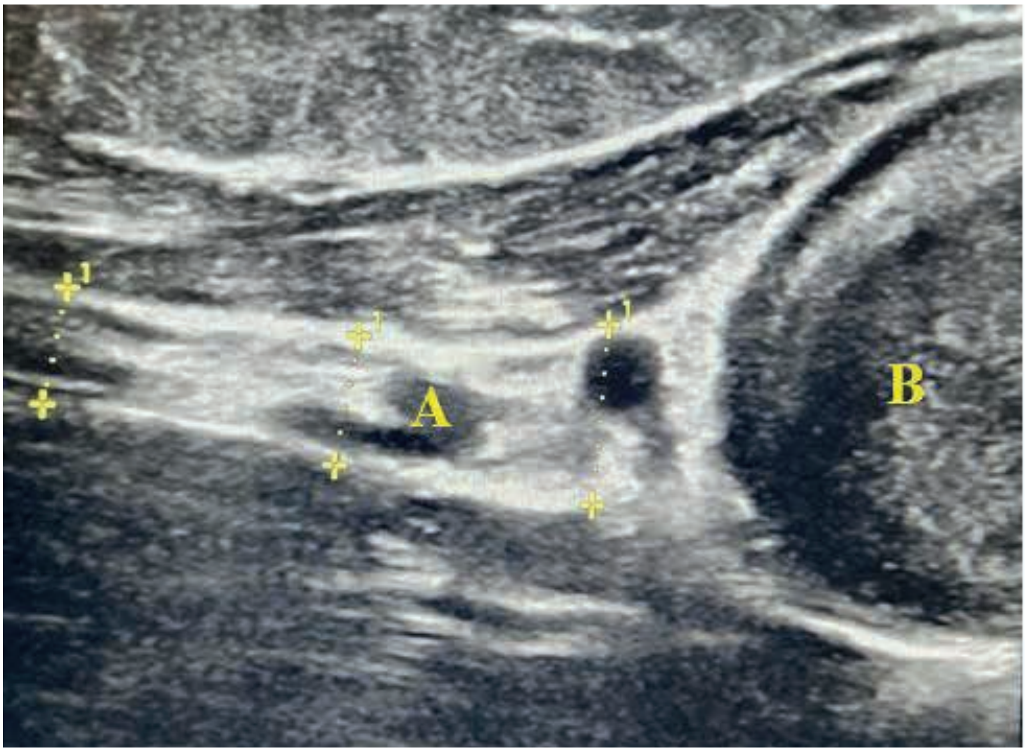

Figure 2. Intraoperative ultrasound: nerve bundle (A) and intraneural neuroma (B)

The neuroma was removed through a transverse resection. The excised segment of the altered nerve was then sent for histological testing. Upon visualization of the nerve stumps, clearly defined and viable fascicles were identified. The gap between the proximal and distal ends of the nerve measured approximately 5.5 cm. Because the median nerve defect is large (5.5 cm), we decided to use guiding epineural sutures. These sutures connect the proximal and distal stumps. This step helps prepare for the second stage, which is nerve grafting.

Epineural sutures (nylon 6/0) were placed while the wrist was flexed at about a 60° angle. This position helped to bring the nerve ends close together with good tension (Figure 3).

This technique keeps the nerve segments in the right position. It reduces rotation and twisting. Also, it offers stability until the graft is stitched.[13] The nerve ends were securely fixed along the anatomical axis. Visually, there was no suture material cut-through, and the fascicular structure remained intact.

Immobilization: The wrist was kept flexed at about 60° with a cast. This position helped relieve stress on the sutures and lower tension at the anastomosis site.

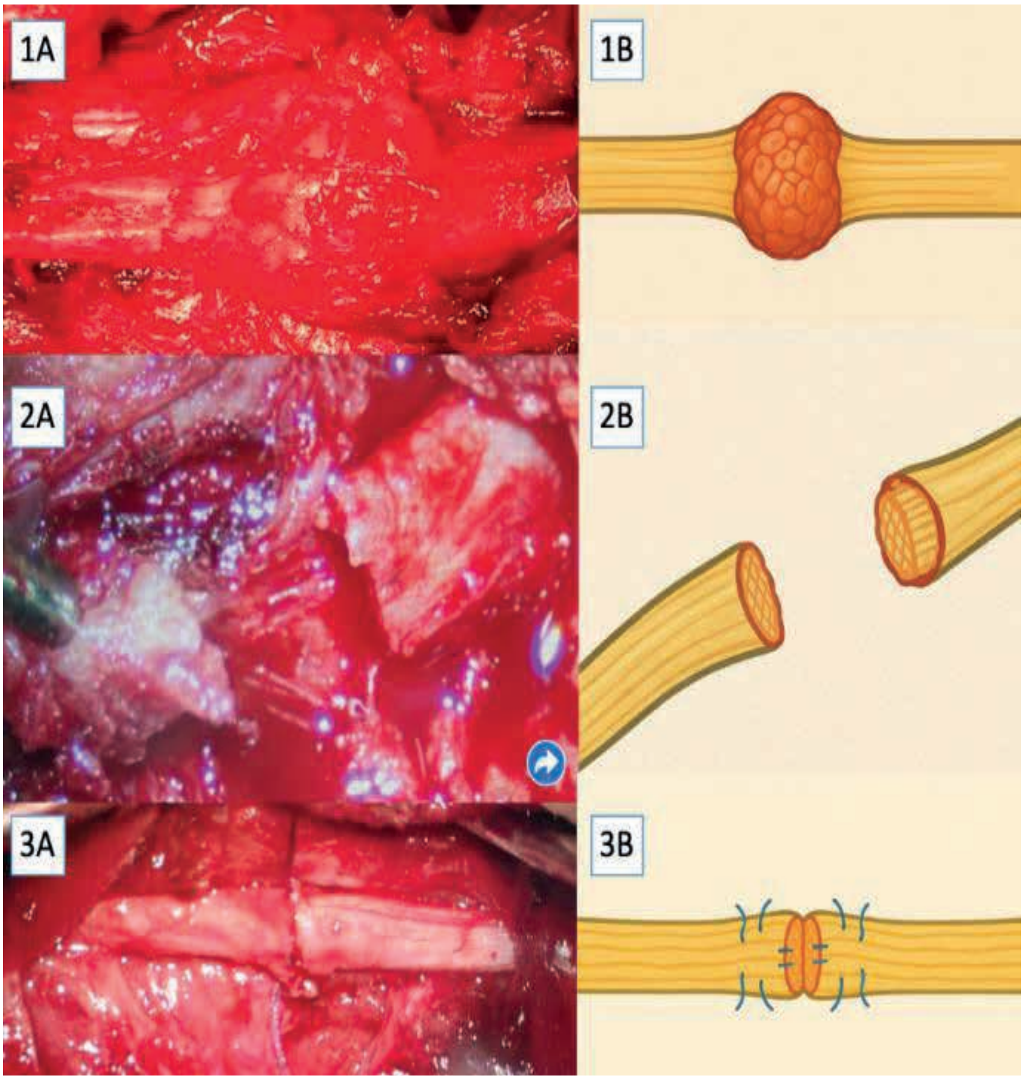

Figure 3.
Intraoperative stages of surgical treatment of post-traumatic median nerve neuroma using ultrasound navigation.
1A-1B: Image (1A) shows the intraoperative view: a solid nerve thickening with poorly defined borders and loss of fascicular structure, tightly adhered to surrounding scar tissue. Diagram (1B) illustrates a neuroma-in-continuity - a typical morphotype of post-traumatic neuroma with focal overgrowth in the nerve regeneration zone.
2A-2B: Stage of neuroma resection under intraoperative ultrasound guidance. Image (2A) shows the view after excision of the pathologically altered segment. Clearly outlined proximal and distal ends of the median nerve with preserved fascicular architecture are visible. Image (2B) depicts the resulting defect after neuroma removal, which requires reconstruction.
3A-3B: Image (3A) demonstrates the placed guiding epineural sutures to align the nerve ends along the anatomical axis in preparation for subsequent interpositional nerve grafting. Image (3B) illustrates the principle of nerve stump approximation with fixation under acceptable tension.

Histological examination of the excised lesion revealed morphological features characteristic of a traumatic neuroma (Figure 4).

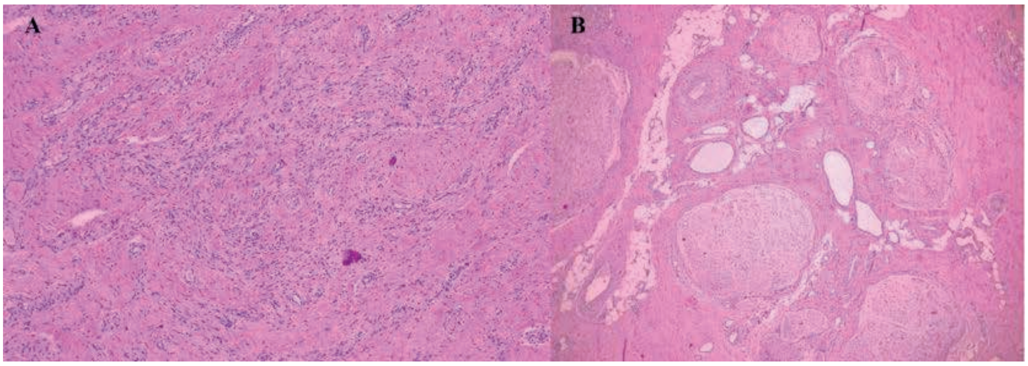

Figure 4.
Histological structure of the traumatic neuroma and peritumoral tissue (hematoxylin and eosin stain, ×100).
A - The area of the traumatic neuroma is composed of interwoven bundles of myelinated nerve fibers within a loose fibrous stroma, containing wavy, elongated cells with pale-staining nuclei and indistinct borders; in some areas, structures morphologically resembling Vater-Pacini and Meissner corpuscles are observed.
B - The peritumoral zone contains areas of mature fibrous and adipose tissue, blood vessels, and fragments of small nerve bundles, reflecting reactive tissue remodeling in response to chronic trauma.

In the recovery period, we saw good progress. Pain along the scar lessened. Swelling in the hand did not worsen. Also, there were no signs of infection or vascular issues. Sensory and motor deficits in the area innervated by the median nerve persisted. Allodynia and spontaneous pain were not present. On examination: the left hand was immobilized in a flexed position using a cast. Finger movement was preserved within the free zone. A stepwise extension rehabilitation plan was developed in preparation for the second stage (nerve grafting)[14]: first 6 weeks - the hand remains fixed in a flexed position (~60°) to reduce tension on the guiding sutures. From week 6 - gradual reduction of the flexion angle: to 45°, then to 30° after 3 weeks, and finally to 15-20° after another 3 weeks, with ongoing monitoring of clinical status and ultrasound imaging of nerve end approximation. We think this protocol will reduce tension on the nerve stumps. It will also help keep the nerve ends oriented and viable. This is important before the next step: interpositional nerve grafting. We plan to do this about 12-14 weeks after the first surgery, once the extension correction phase is complete.

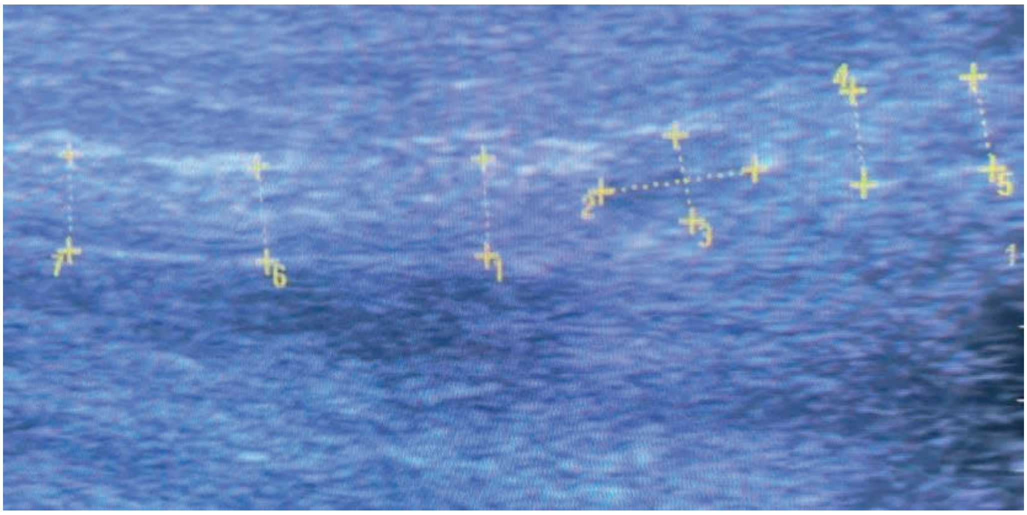

Figure 5.
Ultrasound examination of the median nerve, 1 month postoperatively. The tumor has been completely removed. The proximal and distal stumps of the median nerve are visualized, aligned along the anatomical axis. A gap of up to 5 mm is observed between them. The contours of the nerve segments are smooth, the structure is predominantly hypoechoic, with partial preservation of the fascicular pattern. No signs of mass lesion, significant perineural edema, or hyperperfusion were detected.

One month following surgery, follow-up ultrasound (Figure 5) revealed the stumps of the median nerve. They were located within the carpal tunnel and properly aligned along the anatomical axis. The distance between the stumps measured approximately 5 mm, indicating stable positioning after the placement of guiding epineural sutures. A reduction in hypoechogenicity and swelling was observed, suggesting an improvement in inflammatory changes. Partial restoration of the fascicular pattern may indicate early signs of nerve regeneration. No signs of hyperperfusion were detected on Doppler imaging, which may reflect the absence of active inflammation or neuroma recurrence. These ultrasound findings are interpreted as positive progress within the early recovery phase.

Throughout the postoperative period (Table 1), the patient demonstrated steady clinical stabilization. Sensory deficits in the median nerve distribution (digits I–III of the palm) persisted in the form of hypesthesia and partial anesthesia, but there was a marked reduction in paresthesia and spontaneous pain. Motor function of the finger flexors and thenar muscles remained weakened, with muscle strength assessed at 2-3/5 on the MRC scale. Although no definitive signs of motor regeneration were observed, this aligns with the expected neurophysiological stage of early recovery, particularly in the presence of a nerve gap bridged only by guiding epineural sutures.

Given the nature of the intervention, including delayed neuroplasty planning, rapid functional recovery is not anticipated at this stage. The patient's adherence to immobilization protocols has been consistent, and no complications such as joint contractures or autonomic disturbances have been reported.

Table 1.
Timeline of observation and treatment of a patient with post-traumatic median nerve neuroma

Date	Event / Intervention	Note
12.04.2020	Injury: laceration of the left wrist joint	Initial examination, wound debridement. Onset of numbness, paresthesia, and weakness in digits I–III
14.05.2020	Surgery: primary neurorrhaphy of the median nerve	Partial improvement, but pain and paresthesia persisted

2020–2022	Follow-up: progression of carpal tunnel syndrome, diagnosis of scar-compression neuropathy	No significant improvement
04.2023	ENMG: axonal-demyelinating lesion of the median nerve	
09.2024	MRI: signs of median nerve neuroma	
04.07.2024	Surgery: neurolysis of the median nerve in the left hand	Improvements were in consistent
21.10.2024	Rehospitalization	Persistent pain, numbness, weakness; neuroma confirmed by MRI/US
27.10.2024	Surgery: neuroma excision, placement of guiding epineural sutures under intraoperative US	Preparation for second-stage (interpositionalneuroplasty)
30.10.2024	Follow-up ultrasound (3 days post-op)	Visualization of nerve stumps, minimal edema
01.11.2024	Discharge from hospital	Immobilization in ~60° flexion cast, stable condition
27–30.11.2024	Follow-up: 1-month ultrasound	Visualization of nerve stumps, reduced edema, partial restoration of fascicular pattern
01.12.2024	Clinical examination: stabilization	No signs of deterioration; reduced paresthesia; motor function without marked improvement
Expected	Second stage: inter positional neuroplasty (approx. 12–14 weeks after first surgery)	Following phased extension rehabilitation

Discussion

Peripheral nerve injuries resulting in neuroma formation represent a significant medical issue. Epidemiological data reveal that around 3.3% of patients with upper limb trauma experience these injuries.[15] Post-traumatic neuromas are linked to intense pain and can impair function. They may result in disability. Therefore, diagnosing these lesions quickly and correctly is vital for effective surgery. From a pathophysiological standpoint, neuroma formation mechanisms involve atypical regeneration of nerve fibers, wherein axonal sprouts grow in a disorganized manner - lacking directed regeneration, formation of functional synaptic connections, and adequate interaction with Schwann cells. This stops remyelination and axonal guidance. As a result, fibrous (or neurofibrotic) tissue forms. This tissue disrupts axonal conductivity. Wallerian degeneration matters here. It causes lasting changes in nerve fibers and hurts their function.[16]

Traction-related nerve injuries can show effects not just at the injury site but also further away. In our case, the patient had a median nerve neuroma about 5 cm above the wrist. This finding may indicate that a traction mechanism caused the neuroma. These areas may create better conditions for tissue regeneration and nerve development.[17]

Timing is a key factor in the success of peripheral nerve surgery. The best time for surgery is within 2-3 weeks after an injury. At this stage, the axonal matrix is still intact, Schwann cell activity is strong, and there is a good chance for natural healing. Intervening too soon can be risky because of tissue swelling and trouble finding nerve endings. On the other hand, waiting too long raises the chances of neuroma, fibrosis, and nerve fiber loss. These issues can lower the chances of recovery.[12] In clinical practice, recurrence of neuroma following surgery is not uncommon. In our case, we believe that neuroma recurrence was due to incomplete excision of the pathological tissue. Other reasons for neuroma recurrence may be poor rehab after surgery or less effective microsurgery in the first neurorrhaphy.[18]

In recent years, the use of intraoperative ultrasound has grown. It aims to prevent neuroma recurrence and promote early reinnervation. Intraoperative ultrasound is a safe and effective way to see peripheral nerves and changes in real-time. In our clinical case, the neuroma resection zone was defined using the following ultrasound criteria: a sharp increase in nerve diameter proximal to the neuroma; loss of fibrillar signal in both transverse and longitudinal planes; edge asymmetry; presence of a hypoechoic solid lesion with a hyperechoic rim; and signs of uneven vascularization based on Doppler imaging.[12] This study showed that using intraoperative ultrasound makes neurolysis more precise. It also improves surgical outcomes for post-traumatic neuromas. This is especially true when the affected nerve is deep or in a hard-to-reach area.[19] Ultrasound can also check the correct position of nerve grafts and protectors (conduits). It helps during the resection of complex neuromas while keeping viable nerve segments intact. Souza et al. found that using ultrasound with protective conduits reduces pain, speeds up reinnervation, and improves nerve conductivity restoration.[20] In our case, intraoperative ultrasound was used for planning the incision, visualizing the borders of damaged nerve fibers, and determining the optimal site for suture placement. This helped to remove damaged tissues accurately in the visualization area. It also spared healthy nerve fibers. This may lower the chance of recurrence and speed up nerve function recovery in the patient.[11,21] For intraoperative ultrasound, use a probe with a frequency of 15-18 MHz for superficial nerves. For deeper nerves, a lower-frequency probe (9-12 MHz) works better.[22] The technique involves watching the surgery as it happens. This helps make the procedure more accurate and reduces tissue damage. Mixing ultrasound with surgical methods lets the surgeon make real-time adjustments. This leads to better outcomes.[10]

Research shows that to evaluate treatment results after neuroma surgery, ultrasound follow-ups should occur at 1 and 3 months post-operation.[23] In our case, ultrasound monitoring and functional testing at 1 month showed no signs of neuroma recurrence. The pain had resolved, and the hypesthesia in the median nerve area decreased. Thus, ultrasound navigation combined with surgical intervention significantly improved treatment outcomes.

We believe that intraoperative ultrasound is a key tool for surgeons dealing with various peripheral nerve problems. Additionally, advancements in ultrasound technology and improved probe resolution are boosting imaging quality and diagnostic accuracy. This progress will help treat peripheral nerve injuries more effectively in the future.[24,25]

Limitations. There were no limitations in this study because we described a single case of using ultrasound for the removal of a post-traumatic neuroma. Ultrasound has been used in peripheral nerve surgery for a long time and is known for its safety for both patients and surgeons. Given the small number of observations, we do not intend to make any epidemiological predictions. At the same time, the diagnostic and treatment method we used can be applied to all patients with similar post-traumatic neuromas.

What's known? Post-traumatic neuromas frequently cause chronic pain and functional deficits. Traditional surgical methods often show limited effectiveness and a high recurrence rate. Intraoperative ultrasound is a promising technique to enhance surgical precision, but its use remains limited due to insufficient technical resources in clinics and limited surgeon experience.

What's new? Our study demonstrates that intraoperative ultrasound effectively determines the location, size, depth, and resection margins of post-traumatic neuromas. It enables radical removal, reducing recurrence risk. In this case, ultrasound allowed precise resection while preserving healthy nerve tissue, facilitating better nerve reconstruction and potentially accelerating regeneration and functional recovery.

Conclusion

Median nerve neuroma is one of the most common neuromas of the upper extremity and ranks second in prevalence after ulnar nerve neuroma. Post-traumatic neuromas are benign lesions. They form when peripheral nerves regenerate in a disorganized way after an injury. According to various sources, the incidence of post-traumatic neuromas ranges from 1% to 10%, though in most cases, neuromas remain undiagnosed. Ultrasound is widely used for diagnosing post-traumatic neuromas, but this modern and accessible method is still rarely employed during surgical excision of neuromas. We shared a clinical case of a recurrent median nerve neuroma. This neuroma came after median nerve trauma and a previous excision. During surgery, we used ultrasound to locate the neuroma and check how big it was. This helped us decide how long the skin incision needed to be. Also, ultrasound helped us see the difference between scarred and healthy nerve tissue. We did microsurgical exploration and neurolysis of the nerve trunk in real-time. Then, we removed the neuroma and placed guiding epineural sutures. We used ultrasound guidance at each step of the surgery. As a result, we achieved complete removal of the neuroma and successfully placed guiding sutures between the proximal and distal stumps of the nerve. This procedure prepares for the second main treatment stage: median nerve neuroplasty. This stage will start after the extension correction phase, which takes about 12 to 14 weeks after the first surgery. After surgery, sensory and motor issues in the median nerve area continued. However, there was improvement, with less pain and reduced swelling in the hand. Our clinical experience shows that ultrasound is vital in modern traumatology and reconstructive neurosurgery. We strongly support its use as an essential tool.

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Author Contributions: H.M., R.T., V.A., M.S.: data collection, analysis, and structuring; H.M., V.A, R.T., M.S.: editorial and language revision; R.T., V.A.: systematization, preparation of graphical and tabular materials; S.D.: literature review, preparation of the original draft, data analysis, authorship of the "Discussion" section; D.Z.: statistical data processing, preparation of the "Materials and Methods" section, contribution to the main text writing; Y.S.: data structuring and formatting, preparation of illustrative and tabular materials, editorial revision.

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