Intraoperative ultrasound-assisted peripheral nerve surgery

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Historically, peripheral nerve surgery has relied on landmarks and fairly extensive dissection for localization of both normal and pathological anatomy. High-resolution ultrasonography is a radiation-free imaging modality that can be used to directly visualize peripheral nerves and their associated pathologies prior to making an incision. It therefore helps in localization of normal and pathological anatomy, which can minimize the need for extensive exposures. The authors found intraoperative ultrasound (US) to be most useful in the management of peripheral nerve tumors and neuromas of nerve branches that are particularly small or have a deep location. This study presents the use of intraoperative US in 5 cases in an effort to illustrate some of the applications of this useful surgical adjunct.

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Case Series

Case 1: Neurofibroma of the Right Greater Occipital Nerve

A 35-year-old woman who previously underwent a craniotomy presented with a painful lump over her right occipital bone. The lesion enlarged over a period of 6 months. Intraoperative US was used to identify the lesion, which appeared to be hypoechoic, elongated, and nodular. The authors found intraoperative ultrasound to be most useful in the management of peripheral nerve tumors and neuromas of nerve branches that are particularly small or have a deep location. This study presents the use of intraoperative US in 5 cases in an effort to illustrate some of the applications of this useful surgical adjunct.

However, the low risk and cost of intraoperative US make it an easily accessible tool to increase the accuracy and efficiency of peripheral nerve exposures (Figs. 1–4). We report here the use of intraoperative US in 5 cases.

Case 2: Multiple Traumatic Neuromas of the Arm and Hand After a Crush Injury

A 54-year-old woman suffered a crush injury, resulting in partial amputation of her left hand 12 years prior to presentation to our clinic. She previously underwent 2 resections of neuroma 2–3 years after her injury. She presented to our clinic with extreme hyperalgesia, allodynia, and
phantom limb pain. MRI done prior to surgery showed multiple neuromas in multiple peripheral nerve distributions (Fig. 2). Intraoperative US was used to guide dissection for a total of 8 neuromas. One large neuroma was identified as a hypoechoic mass arising from the anterior interosseous nerve in the forearm, which was treated with external neurolysis, fascicle splitting, and grafting, with intramuscular transposition. Two lesions were found arising from the ulnar nerve near Guyon’s canal, which were also treated with external neurolysis, fascicle splitting, and grafting, followed by intramuscular transposition. Two smaller dorsal digital neuromas and 3 small volar digital neuromas were also excised.

**Case 3: Medial and Lateral Sural Neuromas**

A 42-year-old man (a drummer) presented with pain, claudication, and cramping in his right leg. He previously underwent fasciotomy. Intraoperative US was used to localize 2 lesions, 1 arising from the medial sural nerve and 1 arising from the lateral sural nerve; both were hypoechoic and showed loss of fascicular pattern. Both were treated with excision and intramuscular transposition.

**Case 4: Iatrogenic Ilioinguinal Nerve Injury**

A 52-year-old man had experienced progressive pain in the region, which had now become disabling. On physical examination, he was found to have a positive Tinel’s sign on the medial aspect of the scar and was taken to surgery. Intraoperative US was used to identify a 5-mm hypoechoic nodular mass in the area of his previous surgery and to guide dissection down to the right ilioinguinal nerve. A Prolene (Ethicon) stitch was found through the neuroma, which was treated with excision and intramuscular transposition.

**Case 5: Cutaneous Nerve of Thigh Schwannoma**

A 44-year-old man had pain in his right popliteal fossa. Five years earlier, he had experienced the same pain and 2 schwannomas were removed from his right calf; a third was left behind because the prior surgeon found it “attached to a nerve.” We re-explored the area, using intraoperative US for guidance (Fig. 3). Attached to a cutaneous nerve was a rounded hypoechoic nodule, which was treated with excision, while preserving the parent nerve.
Intraoperative ultrasound-assisted peripheral nerve surgery

Pathology revealed the mass to be a schwannoma. Figure 4 shows the setup of the operating room with the US machine and radiologist.

Discussion

Minimal-access surgery is an important aspect of today’s neurosurgical practice. In the brain, intraoperative localization of small and deep lesions relies heavily on stealth MRI navigation, stereotaxy and, to a lesser extent, intraoperative US. In the spine, accurate placement of pedicle screws relies on either stealth CT navigation or intraoperative fluoroscopy. Stealth navigation is only possible when there is a fixed relationship between the navigation frame and the target. This is not feasible when working on extremities, due to their high mobility (multiple joints) and easy distortion of soft tissues with dissection and retraction. We find intraoperative US particularly useful in the management of peripheral nerve tumors and neuromas of nerve branches that are particularly small or have a deep location. Localization by palpation or correlation with preoperative diagnostic studies may be adequate in large and superficial lesions. However, surgical targets that are deep seated, multiple, and complex may not be amenable to surface localization at the time of surgery. Additionally, in cases of traumatic and iatrogenic neuromas, scarring can be a formidable adversary that increases operative time, extent of dissection, and frustration. The cases presented here demonstrate the use of the intraoperative US technique.

Multiple neuromas were resected in Cases 2 and 3; intraoperative US was helpful for incision planning, localization of the parent nerves, and identifying the multiple neuromas. In these cases, the use of intraoperative US immediately after resection was able to confirm resection of all neuromas prior to closing. In Case 2 in particular, the patient had significant allodynia and would not allow anybody to touch her hand while she was awake, which rendered preoperative localization by palpation or US impossible. Intraoperative mapping under general anesthesia allowed accurate localization and resection of 8 neuromas. It is worth mentioning that successful surgical technique, including localization, equals good outcomes. The patient’s pain and allodynia significantly improved to the point that 3 months after surgery, she was asking about getting a prosthetic hand.

In Cases 1, 3, 4, and 5, we explored previous operative beds, dealing with abnormal planes related to postoperative scarring. It is for these cases that intraoperative US...
has been particularly helpful in identifying normal neurovascular and muscular structures, identifying pathology, and limiting the dissection necessary to perform safe and adequate surgery. In Case 4 in particular, finding the ilioinguinal nerve (which is very small) within a mass of scar tissue without any intraoperative guidance would have been very challenging and frustrating.

From a technical standpoint, to optimize US imaging, the highest-frequency US probe possible should be used. However, high-frequency probes have less deep-tissue penetration. The choice of probe, therefore, depends on the depth of the pathology. As summarized nicely by Koenig et al., superficial lesions, such as the median nerve, should be examined with 15–18-MHz transducers, whereas deep nerves, such as the sciatic nerve or the brachial plexus, are better examined with 9–12-MHz transducers.

The US appearance of peripheral nerves is typically dark nerve (hypoechoic) seen on a bright (hyperechoic) background. Often the nerve itself will have a fascicular echotexture, which can help differentiate it from tendons, which have a more fibrillar texture. The quality of the US machine is also key in obtaining high-resolution imaging.

One challenge to the use of intraoperative US is the availability and willingness of an experienced radiologist and/or technician to come to the operating room. This factor can be mitigated as the surgeon gains familiarity with ultrasonographic appearance of nerves and lesions, as well as the technical nuances of using a US machine.

Conclusions

Minimally invasive surgical approaches are appealing to patients and surgeons. In peripheral nerve surgery, refining the localization of normal and pathological anatomy can minimize the need for extensive exposures, decrease incision size, improve cosmesis, decrease operative time, reduce postoperative pain, and improve patient and surgeon satisfaction. We find it particularly useful when dealing with multiple lesions, small lesions, deep or difficult-to-localize nerves, and in scarred operative beds, whether from previous surgery or trauma. Similar to the emergence of electrophysiology as standard practice in peripheral nerve diagnosis and stealth navigation in localizing deeply seated brain tumors, it is probable that the use of intraoperative US assistance will gain comparable traction.

Looking forward, neurosurgeons will benefit from a detailed understanding of the ultrasonic anatomy of the peripheral nerves and the associated pathologies. Improvements in technology have made US increasingly useful as a real-time imaging modality. High-resolution US can define not only nerves and pathology, but also intraneural anatomy. The ultrasonographic fascicular anatomy, which has become substantially more important in the era of nerve transfers, will be an element of peripheral nerve surgery that trainees and experienced surgeons alike will not be able to overlook.

The cases presented here demonstrate the situations that are particularly amenable to intraoperative US assistance. We have found that the low risk, low cost, and ease of intraoperative US assistance are beneficial to both surgeon and patient.

References


Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Hanna, Haldeman. Analysis and interpretation of data: all authors. Drafting the article: all authors. Critically revising the article: all authors. Approved the final version of the manuscript on behalf of all authors: Hanna. Administrative/technical/material support: Haldeman.

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