Ultrasound-guided percutaneous injection of methylene blue to identify nerve pathology and guide surgery

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OBJECT The objective of this study was to provide a technique that could be used in the preoperative period to facilitate the surgical exploration of peripheral nerve pathology.

METHODS The authors describe a technique in which 1) ultrasonography is used in the immediate preoperative period to identify target peripheral nerves, 2) an ultrasound-guided needle electrode is used to stimulate peripheral nerves to confirm their position, and then 3) a methylene blue (MB) injection is performed to mark the peripheral nerve pathology to facilitate surgical exploration.

RESULTS A cohort of 13 patients with varying indications for peripheral nerve surgery is presented in which ultrasound guidance, stimulation, and MB were used to localize and create a road map for surgeries.

CONCLUSIONS Preoperative ultrasound-guided MB administration is a promising technique that peripheral nerve surgeons could use to plan and execute surgery.

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KEY WORDS ultrasonography; peripheral nerve; methylene blue

Peripheral nerve surgical targets are identified using a combination of preoperative imaging and intraoperative anatomical landmarks. Although this allows for successful localization of peripheral nerve lesions, it often involves extended surgical exposures with longer operative times and a related increase in morbidity. Surgeries should aim to optimize efficiency, accuracy, and safety to improve outcomes and minimize harm to the patient. In this study, we describe a technique in which 1) ultrasonography is used in the immediate preoperative period to identify target peripheral nerves, 2) an ultrasound-guided needle electrode is used to stimulate peripheral nerves to confirm their position, and then 3) a methylene blue (MB) injection is performed to mark the peripheral nerve pathology to facilitate surgical exploration.

Ultrasonography is a powerful tool that can provide the surgeon with real-time dynamic visualization of peripheral nerves and critical surrounding structures, and potentially provide insight on the underlying pathology. Compared with other navigation technology such as intraoperative MRI and CT, ultrasound has the advantage of being portable, cost-effective, and radiation-free (compared with CT). Ultrasonography is an inexpensive and widely available technology that provides dynamic imaging that can be easily incorporated into the operating room. Furthermore, several studies have confirmed the accuracy of ultrasonography in identifying peripheral nerves and its usefulness for guidance for the peripheral nerve surgeon.

The use of MB, also referred to as supravital staining in the literature, is a well-known technique in the field of anatomical study. On the surgical frontier, MB has been incorporated into the operating room safely by surgeons of various specialties to improve identification of vital
The operation proceeded in the usual fashion at this point.

Results

In all cases, the preoperative ultrasonography easily identified the nerve (Fig. 2B) and region of interest (Fig. 2A). Indirect stimulation of the target nerve, while maintaining direct ultrasound visualization, was confirmed prior to the injection of MB in all cases. An MB-colored surgical corridor was created in all cases, which allowed the surgeon to dissect with confidence toward the target structures quickly and efficiently while minimizing collateral trauma to surrounding tissues. Examples of operative dissections with MB staining are shown in Fig. 2C and Fig. 3C and described below. Methylene blue dye injections were always extraneural and typically stained the epineurium.

There were no cases in which patients experienced an allergic reaction to the MB injection. The needle used for nerve stimulation and for administration of the MB did not cause any complications, such as nerve injury or hematoma. In every surgery, the MB was present throughout the dissection, and it was useful for operative exposure. There were no patients that experienced permanent skin discoloration.

Illustrative Cases

Case 1

A 42-year-old man presented after having 7 years of left buttock pain, which was exacerbated by pressure (primarily sitting) and relieved by standing. The pain was unresponsive to physical therapy. His workup included an electromyogram that showed chronic reinnervation changes that were consistent with left sciatic neuropathy. He also received an MR neurogram, which was unrevealing (Fig. 2A). He did receive a treatment of botulinum toxin, which served as supporting evidence for left piriformis syndrome.
after piriformis syndrome. On physical examination, he had full motor strength, normal sensation, normal reflexes, and a negative straight leg raise test. He had focal tenderness to deep palpation over his left sciatic notch and maneuvers causing stretching of the piriformis muscle elicited deep left buttock pain.

Preoperatively, ultrasonography was used to identify the sciatic nerve, and MB was administered as described above (Fig. 2B). On surgical exploration, a vertical incision measuring 8 cm in length was centered about the needle site (Fig. 2C). The trail of MB was followed all the way to the piriformis muscle and the underlying sciatic nerve, which was identified using direct electrical stimulation to both its medial tibial and lateral peroneal components (Fig. 2D). It was noted during the operation that a fibrotic portion of the piriformis muscle was compressing the underlying proximal left sciatic nerve. Subsequently, the left sciatic nerve was fully decompressed both proximally and distally. Postoperatively the patient experienced a dramatic reduction in his left buttock pain.

MRI, which showed a right sciatic mass near the sciatic notch that measured 4 cm in diameter (Fig. 3A). On physical examination, she had full motor strength, normal sensation, normal reflexes, and a negative straight leg raise test.

Preoperatively, ultrasound-guided needle electrical stimulation was used to localize her mass in the right posterior buttock region (Fig. 3B). After this localization, MB was administered as described above (Fig. 3C). A 15-cm incision was centered over the mark from the ultrasound injection (Fig. 3C) and the MB tract was followed to the mass. A 4-cm mass was noted adjacent to the right sciatic nerve, and this was subsequently resected (Fig. 3D). The final pathology was a benign spindle cell neoplasm, compatible with a diagnosis of myxoma (Fig. 3E). Her right buttock pain and tenderness resolved following the surgery.

**Discussion**

The first study to use MB as an operative tool for peripheral nerve surgery, administered using ultrasound guidance, was by Gofeld et al. in 2013. Although that
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study did show the benefit of using ultrasonography and MB for localizing peripheral nerves, specifically for operations, it did not include a confirmatory test that could be performed prior to administration of MB to validate the intended nerve that was being localized. This study has this added dimension and security for localizing nerves, and that is the use of the ultrasound-guided cannulated needle, which provided nerve stimulation for further confirmation of the intended nerve target. Previously, Thomsassen et al. in 2013 described the use of ultrasound guidance and nerve-stimulator guided blocks for neurectomy. In this paper we present a novel technique that provides the peripheral nerve surgeon a helpful tool to plan and execute the surgery. It is a technique that uses readily available, portable, and cost-effective resources that could be easily implemented to the benefit of many patients with a wide range of peripheral nerve problems.

The added benefit of nerve stimulation is unique to this study. It provides a confirmatory motor or sensory response that can be appreciated prior to the administration of MB. This confirmatory variable could potentially prevent incorrectly identifying a target nerve on preoperative ultrasonography. Also, as shown in Fig. 1D and E, the nerve stimulation response that is being monitored by the neurophysiologist provides direct feedback about the distance between the needle and the target nerve.

Furthermore, ultrasonography may have additional roles in the perioperative and intraoperative management of peripheral nerve disease. Ultrasound mapping of nerve pathology may enable delineation of normal structures in relation to nerve pathology, which may assist in planning the optimal surgical approach. As an example, ultrasound may be used to identify the location of normal nerve fascicles in relation to peripheral nerve sheath tumors, thus minimizing the chance of iatrogenic nerve injury. The addition of MB staining of the chosen surgical path may further improve the safety and efficiency of the surgical procedure. Although there have been few publications stating concern for the safety of MB use in patients, this has been easily addressed in this technique by using a dilute concentration of MB at low volumes. Similarly, ultrasound mapping and guidance may enable safe and accurate percutaneous needle biopsies of suspected peripheral nerve sheath tumors.

Intraoperative ultrasonography applied to surgically exposed nerve lesions may provide the surgeon with another tool to evaluate nerve pathology, such as the extent of peripheral nerve injury following trauma. This could be further applied to peripheral nerve sheath tumor resection as a complement to the surgical microscope and intraoperative electrophysiology apparatus, to provide information regarding the internal characteristics of the tumor and its relationship to nerve structures, thereby possibly increasing the potential for normal nerve salvage.

Finally, ultrasound-guided near-nerve neurography may also be useful in the diagnostic workup of peripheral nerve lesions, particularly when evaluating early regeneration after peripheral nerve trauma. Presently, intraoperative compound nerve action potentials are recorded by exposing the nerve and applying electrodes directly to the nerve. Introducing electrodes next to the nerve using ultrasound-guidance techniques is a noninvasive option that may obviate the need for surgical exploration.

Fig. 3. Case 7. A patient with a sciatic myxoma. A: The MR neurogram is shown; the arrow indicates the tumor. B: The ultrasound image that was used for administration of MB is shown with the tumor in view. C and D: Intraoperative photographs of the sciatic myxoma. Shown in C is the initial subcutaneous dissection demonstrating the MB tract. Immediately prior to removal of the tumor a photograph was taken to show the tumor and normal sciatic nerve (D). E: After the tumor was removed, the borders of the tumor are shown with peripheral staining of MB.
Conclusions

Preoperative ultrasound/stimulation-guided MB administration is a promising technique that peripheral nerve surgeons could use to plan and execute surgery.

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: Kliot, Osorio, Breshears, Aleshi.
Acquisition of data: Kliot, Osorio, Breshears, Simon, Hastings-Robinson, Aleshi.
Analysis and interpretation of data: Kliot, Osorio. Drafting the article: Kliot, Osorio, Breshears, Arnaout, Hastings-Robinson. Critically revising the article: Kliot, Osorio, Arnaout, Simon, Aleshi. Approved the final version of the manuscript on behalf of all authors: Kliot. Statistical analysis: Osorio. Administrative/technical/material support: Osorio. Study supervision: Kliot, Osorio.

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