Identification of location of nerve catheters using pumping maneuver and M-Mode—a novel technique☆,☆☆,★

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Abstract

Background: Optimum positioning of the nerve catheter is crucial for a successful nerve block. We present a novel technique for confirmation of catheter position.

Methods: We are describing a novel technique for localization of the shaft and tip of the peripheral nerve catheter. After introduction of the catheter 3 to 5 cm beyond the needle tip and removal of the needle, the guide wire was reintroduced and was moved inward and outward rapidly. This movement produced the color Doppler effect along the track of the catheter and the catheter tip that helped us verify the proper positioning of the catheter.

Results: We used our technique in a cadaveric study for bilateral supraclavicular brachial plexus block, followed by a series of 5 patients undergoing femoral, sciatic (anterior approach), popliteal (2 patients), and brachial plexus blocks. Catheters were also identified on M-Mode sonography during pumping maneuver and during the injection of medications.

Conclusion: Pumping maneuver and M-Mode can be additional tools in the array of modalities applied to verify proper positioning of a nerve catheter.

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1. Introduction

Widespread application of ultrasound has enabled more anesthesiologists to perform peripheral nerve blocks with a high success rate [1–4]. In order to provide reliable continuous postoperative analgesia and improved patient satisfaction, eliminating secondary catheter failure is imperative. This is especially important for ambulatory patients.
because catheter replacement is not an option unless the patient returns to the medical facility. Verification of proper positioning of the peripheral nerve catheter, however, is still challenging. Commonly, the catheter itself cannot be readily imaged using ultrasound [4–6]. Therefore, different techniques have been used to locate the tip of the catheter with various success rates [2,4,7–12].

In the current technical report, we are introducing a new novel method for verification of placement of peripheral nerve catheters for continuous infusion of anesthetic drug called the pumping maneuver. A similar method was first described in 1990 by Bisceglia et al [13] and has also been applied in interventional cardiology literature with success [14–16]. The initial pumping maneuver was applied in simulation models only to enhance the echogenicity of the needle, whereas it was modified in interventional cardiology literature by utilization of a vibrating device and 3-dimensional ultrasonography [13–16]. We are presenting a simpler manual vibration/movement of the guide wire which can be imaged by a less costly conventional 2-dimensional ultrasonography and M-Mode.

2. Materials and methods

The study was performed in 2 phases: (a) cadaveric experiment and (b) patient trial.

1. Cadaveric experiments. After Cleveland Clinic Cadaveric Laboratory approval, we used frozen unembalmed human cadaver models. After proper positioning for supraclavicular block, a high-frequency (6–12 MHz) linear ultrasound transducer (Terason, Burlington, MA) was applied to image the anatomical landmarks. The transducer position was adjusted to achieve a short-axis view of the brachial plexus. Using in-plane technique, a 17-gauge, 3.5-inch Tuohy needle (Arrow by Teleflex, Research Triangle Park, NC) was advanced with direct imaging of the desirable location. A 19-gauge, 40-cm catheter (Arrow by Teleflex) was then introduced through the needle and advanced 3 to 5 cm past the tip of the needle. The guide wire and the needle were then removed. Subsequently, the guide wire was reintroduced through the catheter and was moved inward and outward rapidly. These movements were imaged with color Doppler mode of the ultrasound machine to verify proper positioning of the catheter track and catheter tip in the desirable location. M-Mode ultrasonography examinations were also performed in 3 patients (interscalene, femoral, and popliteal catheters). The M-Mode sonograms at the horizontal sweep speed of 1.25 cm/s were displayed on the video screen and also recorded on the built-in hard disk. The M-Mode images were obtained with the same transducer. The scan line is placed along the area where we thought the tip of the catheter would be located. M-Mode ultrasonography was applied during pumping maneuver and during the injection of medications.

Appropriate volume of local anesthetic was injected through the catheter with direct imaging with ultrasonography. The catheters were then tunneled through the skin and covered with transparent adhesive dressing. All blocks were performed preoperatively by the attending anesthesiologist who has substantial experience in nerve blocks and has been performing a large number of catheter placement on a regular basis (H.E.).

3. Results

3.1. Cadaveric experiment

We initially applied our pumping maneuver to localize the location of the catheter in a cadaveric specimen in order to test the feasibility of the technique. We started with brachial plexus block above the clavicle (interscalene) in frozen unembalmed human cadaveric specimen and repeated that with contralateral side. The localization of the shaft and tip of the catheter was congruous every time in both pumping maneuver and direct dissection of the tissue. The tip location was on the caudal aspect of the brachial plexus on both sides.
3.2. Patient trial

We then applied our technique to verify the proper positioning of the catheter in 5 patients who underwent femoral, anterior sciatic, popliteal (2 patients), and interscalene peripheral nerve catheters. During the pumping maneuver, before applying color Doppler, the catheters were identified as thick linear complexes with frequent reverberations. The reverberation artifacts were even observed distally (deeper) to the catheters location, although the catheters were not imaged.

Fig. 1 pictures the presence of the color Doppler effect deeper to fascia iliaca that verifies proper positioning of the catheter for femoral nerve block. Fig. 2 shows the application of the pumping maneuver in a deeper block-anterior approach to sciatic nerve. Fig. 3 verifies the positioning of the catheter tip within the divisions of the brachial plexus. Fig. 4 illustrates the color Doppler effect deep to the epimysium of the sciatic nerve before its branching.

M-Mode was used in 3 patients when the Doppler images were not conclusive for the position of the catheter (femoral, interscalene, popliteal nerve catheters). M-Mode was used during the pumping maneuver and during the injection of local anesthetic solution. We noticed a change in the appearance of the M-Mode trace between the soft tissues superficial to the proposed location of the catheter and tissues deeper to the catheter location, divided by the catheter location line (Fig. 5), a change resembling that between the sand and sea waves and also the one depicting the normal pleural line.

Initially a 2-dimensional image is acquired and the M-Mode single scan line is placed along the area of the proposed catheter tip location. The distance from the skin surface to the area of M-Mode pattern change (from linear to turbulent) was measured using the center point of the echogenic lines. This distance was noted to match the distance from the skin surface to where the Color Doppler effects of the pumping technique had been observed in the 2-dimensional image.

All of our patients experienced excellent pain control in the distribution of the blocked nerve while they had the catheter in place. The catheters of the patients who received lower extremity nerve blocks were removed while the patients were still in the hospital; the patient with interscalene block was discharged home with the catheter and an outpatient infusion pump. He was followed up by...
telephone during the time he had the catheter and confirmed sufficiency of the pain control.

4. Discussion

We are introducing a relatively novel technique, called pumping maneuver, to appropriately verify the proper placement of the peripheral nerve catheters under ultrasound guide. In this technique, we use a catheter whose guide wire extends to the tip and can be moved in and out fast enough to create a pumping effect. This pumping effect can induce movement within the Doppler detected frequency, which can be detected by either Doppler velocity imaging or power Doppler imaging mode, which are both available in most conventional ultrasound machines. Doppler velocity imaging can detect the velocity of the movement along the beam direction, whereas the power Doppler imaging can measure the power of the signal shift received and therefore only indicates the presence or absence of movement. Power Doppler imaging can be very useful in this technique because it is less dependent on the angle of the beam and the frequency of the movement [17]. Moreover, the pumping effect transiently increases the echogenicity of the catheter by formation of microbubbles around and inside both the catheter tip and the catheter shaft.

We also introduced another new concept, as an adjunct to localize the catheter using the M-Mode ultrasonography. We investigated a new application for this old ultrasonography modality. M-Mode cursor was placed over the presumed location of the catheter, and two different patterns were observed on the screen: the motionless image of the tissues before the pumping technique or injection of medication shown as the “horizontal waves,” and the image demonstrating a granular pattern deeper to the catheter location during the pumping technique and during injection of a local anesthetic.

Because proper positioning of the catheter tip is crucial in the success of the postoperative pain control, multiple authors have
suggested an array of modalities to verify the placement of the tip of a peripheral nerve catheter [2,4,8–12]. However, accuracy of these modalities has not been investigated in larger studies. There are also some ongoing attempts to produce catheters with enhanced echogenicity of the tip, but these catheters are not widely applied yet and also increase the cost.

Injection of a small volume of air to verify the placement of peripheral nerve catheters has been reported in 2 studies; however, both authors admitted that the influence of this technique in proper positioning of the catheter was unknown [2,12]. Other authors investigated the application of fluid injection in verification of the appropriate placement of the peripheral nerve catheters [8,9]. The other method applied to verify the placement of peripheral nerve catheters is injection of agitated fluid, which resulted in satisfactory outcome in 2 studies [4,10].

Piezoelectric vibrating needles and catheters have also been reported; the vibrations are transmitted down the shaft of the needle and the stylet of the catheter and facilitate their imaging by color Doppler imaging [18]. However, this costly technique has only been reported in a cadaveric model that has less complexity and less potential for artifacts.

All the above-mentioned techniques have been shown to be successful at various rates for verification of proper positioning of a peripheral nerve catheter. However, they have not been investigated in interventional or controlled studies with larger sample sizes, and their sensitivity, specificity, and negative and positive predictive values are still subject to further studies. Moreover, injection of air, fluid, or agitated fluid distorts the anatomy, and therefore, imaging and any further adjustment of the catheter can be challenging afterward, as injection of air into soft tissue leads to deterioration of image quality. Microbubbles cause acoustic shadowing that obscures the target area and can persist for up to 2 minutes or more.

The main limitation of both techniques is that it could be difficult to make distinction between the movement of shaft of the catheter and the tip of the catheter. To obtain the best color change, we have to know the direction of the local anesthetic injection inside the catheter and the direction of the ultrasound beam; if the flow is perpendicular to the beam, there is no relative motion and will not be able to detect it. Moreover, the frequency of pumping the guide wire is not always predictable; therefore, it is not clear which Nyquist frequency we have to use to optimally detect the color Doppler effect. In addition, the distinction between the color Doppler effect and the M-Mode changes of the catheter tip from the surrounding vessels might be difficult in some cases because of the close proximity of the target nerves to many vascular structures. The risks of reintroduction of the guide wire are not known either; for example, reinsertion of the guide wire can uncoil the catheter tip, which can cause the catheter tip to move away from the target location. There are also some technical limitations; for example, some guide wires are not as long as the catheter, or some catheter kits do not provide a guide wire at all. The application of M-Mode can be limited by the fact that the transducer has to be kept in a fixed location during the injection of the medication and pumping. Moreover, detection of the catheter motion is dependent on the transducer angulation and location relative to the catheter. Further studies are necessary to demonstrate if the M-Mode yields high enough resolution to determine the distance of the catheter from the skin and its location, in addition to the potential for pulsed-wave Doppler ultrasound to detect the catheter location during injection of the medication.

Our technique is a supplement to the array of modalities already available for imaging of the tip of a peripheral nerve catheter, with more or less comparable limitations experienced with other techniques. Therefore, “pumping technique” and M-Mode can be used in addition to other current methods in clinical use.

5. Conclusions

We are introducing a novel technique, called pumping maneuver and M-Mode ultrasonography to verify the proper placement of the peripheral nerve catheters under ultrasound guide. Those 2 techniques can be a useful and safe adjunct in the array of modalities applied to verify proper positioning of a peripheral nerve catheter, especially in patients with difficult anatomy, and in deeper blocks. However, further studies are needed to evaluate the accuracy of this technique and compare it with already existing techniques.

References


