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ORIGINAL ARTICLE

Preliminary experience with epidural and perineural catheter localization with pulsed wave Doppler ultrasonography

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ABSTRACT

BACKGROUND: Various methods for peripheral nerve and epidural catheter location assessment exist, with varying degrees of ease of use, utility, and accuracy. Pulsed wave Doppler (PWD) evaluates the presence of fluid flow and is possible modality to assess the location of a percutaneously inserted perineural catheter.

METHODS: A retrospective chart review was conducted in which PWD ultrasonography was used to confirm the position of nerve catheters for regional anesthesia. Data was collected to assess 24-hour postoperative pain scores, opioid consumption, complications, and the incidence of catheter replacement.

RESULTS: Eighty-six patients were included; average age was 58 years and a 27% incidence of chronic pain. These catheters were left in place based on the PWD images. Three catheters failed and a total of 16 catheters were repositioned. In the first 24 hours average pain scores ranges between 3.5 to 5.9 and median postoperative opioid consumption range was 11.3 mg to 60.8 mg. For epidural catheters, PWD changes were more obvious with air injection and there was only one episode of hemodynamic instability.

CONCLUSIONS: Our preliminary experience with PWD ultrasonography suggests that they may offer the ability to selectively assess flow at different locations to identify the proper location of epidural and perineural catheters. Future randomized, controlled investigations are warranted to further evaluate the effectiveness and safety of this modality.

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KEY WORDS: Ultrasonography, Doppler, pulsed - Ultrasonography - Nerve block.

The increased use of ultrasound worldwide has enabled the majority of anesthesiologists to place peripheral nerve catheters.¹⁻⁷ Verification of proper position of the catheter at the time of placement and afterward is challenging, yet essential for catheter efficacy. Various techniques have been used to locate the tip of peripheral nerve catheters and epidural catheters with

various success rates.⁸ Currently, there is no gold standard method or technique for evaluating peripheral nerve or epidural catheter tip location.

Pulsed wave Doppler (PWD) ultrasonography allows the measurement of velocities at a single point, or within a small window of space known as the sample volume. The ultrasound transducer projects a pulsed signal to a predetermined depth

chosen by the operator, and a returned signal is created by a reflected frequency shift due to the flow of fluid or blood at that sample volume. PWD is only sensitive to flow within the sample volume region, which allows for the detection of flow at a specific location. The ability to select a specific sample volume is a potential advantage over two-dimensional ultrasound and color Doppler for accurate determination of the catheter location. Presently, PWD is commonly used for flow assessment in arteries and veins, but its use in catheter location assessment has only been reported by using an acoustically active endovascular catheter.^{9, 10} In the following report, we present our preliminary experience with catheter localization using PWD ultrasonography to detect the tips of epidural catheters as well as peripheral nerve catheters in various anatomical locations (adductor canal, femoral, popliteal, sciatic, interscalene, supraclavicular, infraclavicular, lumbar plexus, quadratus lumborum, and thoracic paravertebral).

Materials and methods

After institutional review board (IRB) approval (Cleveland Clinic, Cleveland, Ohio IRB # 15-509), a chart review was performed, identifying patients who had a peripheral nerve or epidural catheter verified utilizing PWD Ultrasonography from January 2015 to September 2016. The risks and benefits of the regional anesthesia technique were discussed with patients at the time of placement, and their verbal consent for the procedure

was obtained; however, written, informed consent was waived for this retrospective series by the IRB. Data was obtained from the Cleveland Clinic Perioperative Health Documentation System, EPIC notes, and physician notes.

A low-frequency (2-5 MHz) curvilinear transducer was used for neuroaxial, thoracic paravertebral, lumbar plexus, quadratus lumborum, and sciatic catheter insertions. A high-frequency (6-12 MHz) linear ultrasound transducer was used for all other peripheral blocks. The transducer was covered with a sterile, disposable plastic sheath.

An in-plane ultrasound approach was used for all conventional catheter through needle peripheral catheters. A 17 gauge Tuohy needle (StimuCath, Arrow by Teleflex, Research Triangle Park, NC, USA) was advanced with direct imaging to the desired location; followed by insertion of a 19 gauge perineural catheter (Arrow by Teleflex) advanced 3 to 5 cm past the tip of the needle.

PWD technique for peripheral nerve catheter detection

The transducer position was adjusted to achieve a two-dimensional short axis ultrasound view of the nerve plexus or the tissue plane of interest, with the target location positioned perpendicular to the ultrasound beam as much as possible (Figure 1, 2, 3). We used 4-step procedure: First, the target location is determined using anatomic landmarks identified on ultrasound image, the target is defined as in Supplementary Digital Mate-

Figure 1.—Images for lower extremity PWD (Adductor, femoral, sciatic subgluteal and sciatic popliteal). A) Adductor canal catheter.

SM: sartorius muscle; N: femoral nerve; FA: femoral artery.

B) Sciatic subgluteal PWD.

SN: sciatic nerve at the area of the sample volume of the PWD.

C) Sciatic nerve in the popliteal area.

N: nerve component toward right is the tibial nerve, N: nerve component toward left is the common peroneal nerve.

Figure 2.—Image for inter scalene PWD.

SCM: sternocleidomastoid muscle; ASM: anterior scalene muscle; C5, C6, C7: nerve roots of brachial plexus; MSM: middle scalene muscle

rial 1: Supplementary Table I. Second, the PWD mode was activated and displayed on the video screen with a sample volume of 1-5 mm (Figure 1, 2, 3). The sample volume was positioned in the area of intended catheter tip location as explained in Supplementary Digital Material 1: Supplementary Table I. PWD was applied during the injection of normal saline. A high injection velocity leads to an increase in Doppler shift and a pronounced response on the screen, this high velocity of the flow results in a phenomenon called “aliasing”. Saline flow in the targeted area around the catheter tip location was visualized as aliasing signal during saline injection. Third, if the PWD changes were not conclusive after injection of saline, a small amount of air (0.5-

TABLE I.—Demographic data.

Age (years, mean)	57.6
Gender (% women)	46.5
BMI (kg/m ²) (mean)	30.7
ASA Score (N.)	
1	1
2	19
3	54
4	12
Surgical procedure (N.)	
Intra-abdominal surgery	38
Shoulder surgery	6
Knee surgery	27
Hip surgery	3
Other lower extremity	7
Other upper extremity	3
Thoracic surgery	2
History of chronic pain (% yes)	27.4
Regional anesthesia procedure (N)	
Epidural	19
Adductor canal block	16
Femoral nerve block	12
Popliteal nerve block	3
Sciatic nerve block	3
Interscalene block	6
Infralavicular block	2
Supraclavicular	2
Lumbar plexus block	2
<i>Quadratus lumborum</i> block	18
Paravertebral block	3

1 mL) was injected to better detect the transient PWD changes at the depth of the catheter.

Next, if the signal were not visualized, the PWD sample volume moved away from the expected anatomical location of the catheter then the imaging procedure was repeated. Peripheral nerve catheters considered to be properly posi-

Figure 3.—Images for truncal PWD (Lumbar plexus, paravertebral and anterior subcostal quadratus lumborum catheter).

A) lumbar plexus catheter.

PMM: Psoas major muscle

B) paravertebral catheter using parasagittal view.

TP: transverse process; CTL: costo-transverse ligament

C) QL: *quadratus lumborum* with anterior subcostal approach.

Figure 4.—PWD positive signal outside this correct anatomical location.

A) Positive PWD when injection through anterior *quadratus lumborum* catheter, and the PWD location was inside the *quadratus lumborum* muscle (PWD showed intramuscular location of the catheter).

P: transvers process; PM: psoas major; QL: *quadratus lumborum*.

B) Femoral nerve catheter location above the fascia iliaca.

FA: femoral artery, FN: femoral nerve, FL: fascia lata, FI: fascia iliaca.

tioned if the PWD flow was detected in the appropriate anatomical locations (Supplementary Digital Material 1: Supplementary Table I).

When the PWD signal was absent at the desired location, and or detected outside the intended anatomical area, the peripheral nerve catheters considered as incorrectly placed and the procedure repeated (Figure 4A, B).

PWD technique for epidural catheter detection

Low-frequency curvilinear ultrasound probe was manipulated to obtain a parasagittal oblique

interlaminar (PO) view to visualize two successive laminae, interlaminar space at the level of the epidural catheter insertion, and the posterior complex (ligamentum flavum, epidural space and dura). The optimal image for accurate epidural catheter placement would include visualization of the ligamentum flavum and dura as separate structures with the PWD sample volume between them. This ideal view would be difficult to obtain in the thoracic area so the sample volume inserted at the posterior complex area.

The PWD sample volume was inserted over

Figure 5.—A, B) Epidural PWD. Showing positive PWD when injection saline through epidural catheter at the posterior complex.

the posterior complex while saline was injected concomitantly through the epidural catheter (Figure 5). Saline flow through the catheter was visualized as aliasing signal during saline injection. If color signals were not visualized on one side of the spine, a parasagittal oblique interlaminar view was obtained on the other side by repeating the same procedure. If PWD failed to detect any flow at the level of catheter insertion, the imaging procedure was repeated at one or two vertebral levels above and below the site of catheter insertion on both sides of the spine.

As in peripheral nerve catheters; if the PWD changes were not conclusive after injection of saline, a small amount of air (0.5-1 mL) was injected.

When the PWD signal was absent epidural catheters considered as incorrectly placed and the procedure repeated and repeat procedure verified with PWD.

Primary peripheral catheter failure defined as: absence of sensory dermatomal coverage in the corresponding cutaneous sensory distribution immediately after the insertion of the catheter and local anesthetic injection in spite of presences of positive PWD signal, which indicating a correct catheter location.

Primary epidural catheter failure defined as: absence of sensory dermatomal coverage in the corresponding cutaneous sensory distribution in the recovery room postoperatively in spite of presences of positive PWD signals, which was indicating a correct catheter location.

Results

Eighty-six patients were included, and patient's demographics summarized in Table I. In first 24 hours average pain scores ranges between 3.5 to 5.9 and median postoperative opioid consumption range was 11.3 mg to 60.8 mg (Table II).

PWD imaging led to the identification of a catheter in the incorrect fascial plane in varying percentages of patients depending on block type (Table II). Three catheters failure (3.5% of all patients) were reported, 2 (12.5%) in adductor canal and 1 (8.3%) in femoral. A total of 16 catheters (18.6%) were repositioned based on the PWD data. In these instances, the new position following withdrawal and reinsertion was confirmed with PWD ultrasound technique. There was one episode of hemodynamic instability in a patient who underwent epidural placement.

Discussion

The current report describes our preliminary experience with a novel method for the assessment of epidural and peripheral nerve catheter tips using PWD ultrasonography. PWD ultrasonography may be a possible modality to localize perineural and epidural catheters. There was a low rate of catheter failure 3.5%, and catheter replacement after repositioning and verification and no adverse side effects resulting directly from this ultrasound method. Many operators

TABLE II.—Results by block type.

Block type	Epidural	Adductor canal	Femoral	Popliteal	Sciatic	Inter-scalene	Supra-clavicular	Infra-clavicular	Lumbar plexus	Quadratus lumborum	Paravertebral
N.	19	16	12	3	3	6	2	2	2	18	3
Primary catheter failure (N. %)	0	2, 12.5%	1, 8.3%	0	0	0	0	0	0	0	0
Postoperative opioid consumption* (median)	24 mg	17.5 mg	33.9 mg	45.5 mg	26 mg	11.3 mg	15 mg	28.5 mg	55.8 mg	60.8 mg	20 mg
Average pain score**	4.2	3.6	5.2	4.9	3.5	3.5	4.2	5.3	5.9	5.3	3.7
Catheter reposition (N. %)	2 (11%)	3 (19%)	2 (17%)	1 (33%)	1 (33%)	1 (17%)	0 (0%)	1 (50%)	0 (0%)	4 (22%)	1 (33%)

*In first 24 hours, morphine equivalent dose; **in first 24 hours, 10 point scale; ***catheter determined to be outside of correct fascial plane by PWD, leading to repositioning of catheter, and subsequent confirmation by PWD to be in the desired location.

performed the ultrasound procedures, PWD technique with success, improving the generalizability of the technique and make it less operator dependent. PWD may add to the practitioner's armamentarium in the ultrasound evaluation of nerve catheters and epidural by enabling precise assessment of flow at different depths and locations. It has the benefits of being non-invasive, easy to interpret, providing real-time results, and is accessible on most ultrasound machines. We selected absence of sensory dermatomal coverage as failure to the catheter PWD localization, as pain scores and opioid requirements can be influenced by a variety of factors and its interpretation is subject to bias.

One of the most common problems associated with nerve catheter involves accurate placement of the catheter. Multiple methods are currently used for peripheral catheter localization include: peripheral nerve stimulation,^{11, 12} injecting air^{2, 13} and non-agitated^{14, 15} or agitated^{4, 16} solutions under ultrasound; using catheters with echogenic modifications;^{14, 17, 18} blindly inserting the catheter prior to the injection of local anesthetic and using the achievement of anesthesia to confirm the catheter tip location;⁸ using ultrasound to observe the movement of tissue elicited by the catheter tip;⁸ repeatedly advancing and retracting the guide wire within the catheter to create motion that is detected by color Doppler US (pumping maneuver);¹⁹ and performing CT.⁸ M mode ultrasonography is another modality allowing verification of peripheral nerve and epidural catheters placement.^{19, 20}

Methods for epidural catheter assessment include using electrocardiography guidance,²¹ fluoroscopy, optical reflectance spectroscopy, and near-infrared tracking systems.⁸ Even with all of these technologies, failed anesthesia and analgesia with epidural catheters remains a common occurrence, reaching an incidence of around 30%.^{22, 23}

The PWD system transmits a short burst of ultrasound toward the target and then switches to receive mode to interpret the returning echoes. PWD can be detected by an examination of the spectral display, a pattern commonly referred to as a clean envelope. In phased arrays ultrasound transducers, PWD can be used simultaneously

with the two-dimensional image. One of the advantages of the PWD is that you can visualize the whole image of the anatomical area but only analyze the flow at the sample volume in the desired location, (as the remaining of the returned ultrasound signals outside the sample volume is ignored).

Detection of the sample volume by PWD can be influenced by several factors. The high velocity of the flow results in a phenomenon called "aliasing" which leads to an inability to accurately measure flow velocities and direction. The consequences of the aliasing phenomenon are not essential in catheter localization, as accurate estimates of the velocity and direction of flow are not essential.

The Doppler shift is also increased when the ultrasound beam is more aligned to the direction of flow, *i.e.* with a smaller angle of insonation. Increasing the angle of insonation to 90 degrees (ultrasound beam perpendicular to the direction of flow) will possibly result in small or no observed Doppler shift. Angulating the probe cephalad or caudad might be necessary to observe Doppler changes.

There are several maneuvers that may improve the sensitivity of PWD to detect the catheter location during the injection (Supplementary Digital Material 2, Supplementary Table II).

The biggest limitation is its retrospective design of different blocks with lack of control group and also limits the usefulness of the pain scores and the opioid consumption data. It did not have sufficient numbers for each anatomical location and local anesthetic dosage to determine the gold standard spread pattern for each block. In addition, we could not confirm that the absence of the expected ultrasound findings always indicates a misplaced catheter. Also, inadequate pain scores may occur despite the accurate location of the catheter, particularly in our study population with prevalence of chronic pain patients (27.4%). Finally, it did not use other imaging tools to confirm correct catheter location and to establish the accuracy of PWD mode.

Obtaining an optimal view for PWD assessment proved challenging and operator dependent in certain cases for deep blocks and epidurals.

Translational artifact, which is caused by the movement of the surrounding vessels or quick movement of the ultrasound probe, can also occur. This issue can be overcome by applying PWD wave detection only at the time of medication or saline injection.

Conclusions

Our preliminary experience with PWD ultrasonography suggests its ability as marker to verify the catheter tip location for peripheral nerve and epidural catheters location. The use of PWD has not been reported before and it is in early stages of development. It is difficult to have an accurate insight into its potential especially in an absence of a gold standard for catheter localization, with continuing improvement in ultrasound technology, PWD might prove to be superior to traditional methods. Future randomized, controlled investigations are warranted to further evaluate the effectiveness of this modality, and its comparative effectiveness *versus* other methods.

What is known:

- Verification of proper position of the catheter at the time of placement and afterward is challenging, yet essential for catheter efficacy

What is new:

- PWD ultrasonography may be a possible modality to accurately localize perineural and epidural catheters, which allows the measurement of velocities at a single point, or within a small window of space known as the sample volume
- PWD ultrasonography suggests its ability as marker to verify the catheter tip location for peripheral nerve and epidural catheters location
- Future randomized, controlled investigations are warranted to further evaluate the effectiveness of this modality, and its comparative effectiveness *versus* other methods.

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