Use of colour Doppler and M-mode ultrasonography to confirm the location of an epidural catheter - a retrospective case series

L'utilisation du Doppler couleur et de l'échographie en mode M afin de confirmer l'emplacement d'un cathéter péridural – une série de cas rétrospective

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Abstract

Purpose Epidural anesthesia and analgesia has a reported failure rate ranging from 13% to 32%. We describe a technique using colour Doppler and M-mode ultrasonography to determine the position of the epidural catheter after placement in adults.

This report was previously presented, in part, at the Annual meeting of American Society of Regional Anesthesia, Boston, MA in May 2013.

This report describes human research. IRB contact information: Institutional Review Board, Cleveland Clinic IRB OS-1 Cleveland Clinic 9500 Euclid Avenue Cleveland, OH 44195, Phone: 216-444-2924; E-mail: IRB@ccf.org.

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Methods This retrospective review included 37 adult patients who received postoperative epidural analgesia and underwent technically difficult epidural catheter placement. The demographic characteristics, type of surgery, use of ultrasonography, method of insertion, intervertebral level, and success of epidural localization using colour Doppler were noted for each patient. Pain scores on postoperative day 1 and the presence of a patchy block were also reviewed.

Results Colour Doppler study helped to indicate the catheter's path from the skin to the epidural space during saline injection in 33 patients (89%). Saline flow within the epidural space (catheter tip confirmation) was successfully detected with colour Doppler in 25 patients (67.5%) and with M-mode ultrasonography in 28 patients (75%). Appropriate dermatomal analgesia was noted in 35 patients (94.5%) during local anesthetic infusion.

Conclusion Our preliminary data suggest the feasibility of using colour Doppler and M-mode ultrasonography to confirm proper epidural catheter placement.

Résumé

Objectif L'anesthésie et l'analgesie péridurale ont un taux d'échec rapporté se situant entre 13 % et 32 %. Nous décrivons une technique utilisant le Doppler couleur et l'échographie en mode M afin de déterminer l'emplacement du cathéter péridural après son positionnement chez des patients adultes.

Méthode Ce compte rendu rétrospectif a examiné le cas de 37 patients adultes ayant reçu une analgesie péridurale postopératoire et chez lesquels le positionnement du cathéter péridural s'était avéré difficile d'un point de vue technique. Les caractéristiques démographiques, le type de chirurgie, l'utilisation de l'échographie, la méthode

d'insertion, le niveau intervertébral et la réussite de la localisation périurale à l'aide du Doppler couleur ont été notés pour chaque patient. Les scores de douleur au premier jour postopératoire et la présence d'un bloc inégal ont également été passés en revue.

Résultats L'étude du Doppler couleur a permis d'indiquer le chemin du cathéter de la peau à l'espace périurale à l'aide d'une injection de solution saline chez 33 patients (89 %). Le flux de la solution saline dans l'espace périurale (confirmation de la pointe du cathéter) a été détecté avec succès grâce au Doppler couleur chez 25 patients (67,5 %) et grâce à l'échographie en mode M chez 28 patients (75 %). Une analgésie des dermatomes appropriés a été notée chez 35 patients (94,5 %) pendant la perfusion de l'anesthésique local.

Conclusion Nos données préliminaires suggèrent la faisabilité d'une utilisation du Doppler couleur et de l'échographie en mode M afin de confirmer le bon positionnement du cathéter périurale.

Failure of epidural analgesia is not uncommon and has been evaluated in various retrospective studies.¹⁻³ The reported incidence of failed epidural analgesia varies from 13% to 32% depending on the definition adopted by the investigators.^{1,4-6}

Primary epidural failure occurs for many reasons.⁷ Secondary failure, reported in 6.8% of obstetrical patients,⁴ may be due to inadvertent outward catheter migration during patient movement⁸ or migration through an intervertebral foramen.^{3,9} Because the success of epidural analgesia depends on a correct catheter location within the epidural space, a noninvasive bedside method to confirm its location would be beneficial. Here, we provide a preliminary report of using colour Doppler and M-mode ultrasonography to confirm epidural catheter positioning in adults.

Methods

After obtaining institutional review board approval and a waiver of informed consent, 37 adult patients who underwent technically difficult epidural catheter placement (Arrow FlexTip Plus, a single-hole catheter, Arrow International Inc., Morrisville, NC, USA) between May 2013 and September 2015 were included in this retrospective review. The presence of one or more of the following characteristics defined a difficult placement: 1) anatomical challenges - e.g., scoliosis, obesity (body mass index $> 35 \text{ kg}\cdot\text{m}^{-2}$) - and poor surface landmarks; 2) more

than three attempts to achieve successful needle entry; 3) loss of resistance was considered atypical by the operator; 4) difficult threading of the catheter. Patient data were obtained via review of their electronic medical records. The demographic characteristics, type of surgery, use of ultrasonography, method of insertion, intervertebral level, and success of epidural localization were noted for each patient. The regional anesthesia and pain management team at the Cleveland Clinic assessed pain scores and the presence of a patchy block on postoperative day 1.

Technique of colour Doppler-guided epidural confirmation

Ultrasonography is not routinely used to perform neuraxial blockade in our institution. The exception is when difficulty is anticipated or it is needed as a rescue strategy. For the patients in this study, when difficulty was encountered with epidural catheter placement, the catheter location was first assessed by colour Doppler imaging using a 5.0- to 2.5-MHz curvilinear ultrasound probe (4C-SC curvilinear ultrasound probe, GE Healthcare; or C5-2s convex array transducer, Mindray DS, USA). To maintain sterility, the probe was housed within a sterile sheath, and sterile ultrasound gel was used.

Initially, a parasagittal oblique interlaminar (PO) view was obtained by placing the ultrasound probe in the parasagittal plane and by tilting it medially to visualize the laminae and interlaminar spaces, at the level of catheter insertion. The probe was then manipulated carefully to visualize the posterior complex (ligamentum flavum, epidural space, dura). The colour Doppler function was turned on to examine the path of the catheter and/or the posterior complex while saline was injected concomitantly through the epidural catheter (Fig. 1). Saline flow through the catheter was visualized as a blue and red mosaic as the signal aliased from one colour to the next, assisting in identification of the track of the catheter and its final location. If colour signals were not visualized on one side of the spine, the PO view was similarly obtained on the other side. If no signals were detected at the level of catheter insertion on either side, the imaging procedure was repeated at one or, at most, two vertebral levels above and below the site of catheter insertion on either side of the midline (Fig. 2). If none of the PO views with colour Doppler could detect the catheter, visualization was attempted using the transverse interlaminar view at the level of catheter insertion, especially for catheters inserted at the low thoracic (T9-12) and lumbar locations. In either of these views, the catheter track was visualized as a vertical line represented by a blue and red mosaic in the area of the interspinous ligament or the erector spinae muscle, approaching the posterior complex (Video 1 as

Fig. 1 Pictorial representation of the parasagittal oblique view of the epidural space (A) and cross sectional anatomy (B), depicting colour Doppler and M-mode visualization of the epidural catheter

Electronic Supplementary Material). With the catheter track seen at the site of catheter insertion, the catheter tip was visualized at the same level with a slight change in the probe's angulation or at one or two levels above or below the insertion site. The catheter inside the epidural space was visualized though the interlaminar space as an approximate circular blue and red mosaic within the posterior complex, deep to the lamina but superficial to the intrathecal space (Video 2 as Electronic Supplementary Material).

Colour Doppler signals depicting the path of the catheter from the skin to the epidural space in the transverse interlaminar view and PO view are shown in Fig. 3 and Fig. 4A, respectively. Colour Doppler signals in Fig. 4B represent the saline flow through the catheter in the epidural space. Images of the catheter track and its position in the epidural space were obtained in succession, not simultaneously. The position of the probe, depth of the colour Doppler box, and Doppler gain may be optimized to maximize the quality of the colour Doppler signal. Colour power Doppler was utilized when colour Doppler failed to detect a discernible colour signal. Although the epidural catheter could not be directly visualized in the ultrasonographic image, the flow of injected saline through the epidural catheter could be identified.

Additionally, M-mode ultrasonography was used to identify the catheter's position. Once an optimal image of the posterior complex was obtained, the M-mode scan line was placed perpendicular to the posterior complex for the purpose of detecting changes in the image characteristics. Before saline injection, the image appears as motionless horizontal lines. During the bolus saline injection, however, the appearance transiently changes to a granular

pattern at the depth of the catheter (Fig. 5). Video 3 (as Electronic Supplementary Material) depicts the epidural catheter location using M-mode scanning.

Results

The mean (SD) age of the patients was 60.7 (13.8) yr with a mean (SD) body mass index of 28.7 (6.1) kg·m⁻². All patients had one or more of the inclusion criteria for difficult epidural placement. One investigator (H.E.) performed all of the colour Doppler and M-mode examinations. Real-time ultrasonography guidance was utilized in 15 patients, and pre-scanning was used to identify landmarks in 11 patients.

Colour Doppler studies helped identify the catheter path, from the skin to the epidural space, during saline injection in 33 patients (89%). The catheter tip position was identified in 25 patients (67.5%) according to the colour changes within the posterior complex. We were not able to visualize the catheter in any of the patients without colour Doppler.

In two patients, anterior displacement of the dura was observed during a saline bolus injection through the lumbar epidural catheter. It was likely due to better sonographic windows in the wider lumbar interspace compared with those of the thoracic interspaces. M-mode ultrasonography was successfully used to confirm the location of the epidural catheter in 28 patients (75%). During their daily follow-up, the acute pain service team found that analgesia during epidural local anesthetic infusion was effective in 35 patients (94.5%). Although a pain score of > 4 on postoperative day 1 was initially reported in 13 patients,

Fig. 2 Various positions of the ultrasonography probe with respect to the insertion site of the epidural catheter to maximize the chance of determining the catheter location. (A) right, above it; (B) right, below it; (C) left, above it; (D) left, below it

adjusting their epidural infusion rate and bolus doses helped achieve adequate analgesia in eight of these patients. Three patients had chronic back pain at baseline, which was attributed to inadequate analgesia. Two patients (5.5%) had patchy epidurals, which did not respond to changes in the epidural infusion rates.

The catheter was visualized at the catheter insertion level in 20 patients (14 were seen on the right-side PO view; six on the left-side PO view). The catheter was visualized at one level higher than the insertion site in five patients (three on the right-side PO view; two on the left side) and at two levels higher in one patient on the right-

Fig. 3 Colour Doppler image, transverse interlaminar view, shows the path of the catheter. AP = articular process; CD = colour Doppler; ES = erector spinae muscle; IT = intrathecal space; PC = posterior complex; TP = transverse process

Fig. 4 Colour Doppler images, parasagittal oblique view, show the track of the catheter from the skin to the epidural space (A) and the flow of saline through the catheter in the epidural space (B)

side PO view. The catheter was visualized at one level lower than the insertion site in seven patients (four on the right side; three on the left side). The catheter was not visualized at all in four patients (4/37), resulting in a failure rate of 11% for this technique. In two patients, the epidural catheter was found to be misplaced, one intrathecally and one paravertebrally.

Catheter within the intrathecal space

In one patient, after three failed attempts at catheter insertion, a fourth attempt was made at the T11-12 interspace using real-time ultrasonographic guidance with the PO view. The epidural catheter - inserted and advanced using the in-plane approach - entered the epidural space

Fig. 5 M-mode ultrasonography shows changes in image characteristics (white arrow) with injection of saline through the epidural catheter in the epidural space

after loss of resistance to normal saline. Although the aspiration test was initially negative, cerebrospinal fluid (confirmed by glucose analysis) was intermittently aspirated after administration of the test dose. Colour Doppler ultrasonographic evaluation, using the transverse interlaminar view at the T12–L1 level, also showed the catheter tip within the intrathecal space (Fig. 6; Video 4 as Electronic Supplementary Material) as indicated by a colour Doppler shift from the posterior complex to the anterior complex, which was likely due to the turbulent flow created by the injected saline. This is in contrast to a signal confined to the posterior complex in the case of epidural placement. Excess gain may falsely extend the colour change from one compartment (e.g., epidural space)

Fig. 6 Transverse interlaminar view shows colour Doppler characteristics following intrathecal placement of catheter. AP = articular process; CD = Colour Doppler; IS = intrathecal space

to another (e.g., intrathecal space), leading to incorrect image interpretation. In this case, colour Doppler showed a burst of colour Doppler shift within the intrathecal space.

Catheter in the paravertebral space

In another patient, it was difficult to thread the epidural catheter. Colour Doppler showed colour changes deep to the costotransverse ligament in close proximity to the transverse process (Fig. 7), suggesting a paravertebral location.

Discussion

Our preliminary data suggest that it is feasible to use colour Doppler and M-mode ultrasonography to evaluate epidural catheter positioning. A step-by-step guide to colour Doppler- and M-mode-guided epidural confirmation is outlined in Fig. 8. Recommendations for obtaining an optimal image are listed in the Table.

A clinical response to a local anesthetic in the form of dermatomal anesthesia remains the ‘gold standard’. However, it might take time to elicit such a response. Various novel methods have been described to ascertain the position of an epidural catheter without local anesthetic injection, but none has found a place in routine practice. The epidural stimulation test can be technically difficult^{10,11} and is not useful after local anesthetic administration. Injection of contrast dye¹² involves radiation exposure. Transducing the epidural space pressures and showing a unique waveform confirms epidural location,¹³ but it requires special equipment. Epidural localization using ultrasound^{14,15} and colour

Fig. 7 (A) Ultrasonographic sagittal section of the paravertebral space with colour Doppler interrogation to determine the location of the epidural catheter. (B) Pictographic representation of the anatomy

Fig. 8 Stepwise guide to ultrasonographic scanning for epidural localization

Doppler¹⁶ has been reported in a pediatric population (i.e., infants), in whom a non-ossified spine allows easy ultrasound penetration. In contrast, our study provides a detailed evaluation on the use of colour Doppler to assess epidural catheter positioning in adults. Colour Doppler can also aid in bedside identification of catheter malpositioning. We also speculate that colour Doppler signals within the paravertebral space or intrathecal space could signify a misplaced epidural catheter, as described in two of our patients.

The colour Doppler technique has several limitations. First, a good sonographic window and images are necessary

in this view. The equivalent location of colour change with Doppler imaging is shown as blue

for successful use of this imaging technique. For example, three of four patients in whom the epidural catheter could not be identified using colour Doppler were > 80 yr of age and presented with challenging sonographic windows. The presence of ligamentous calcification and scoliosis might have prevented ultrasound penetration, resulting in failure to detect the colour Doppler signals. Second, it might be difficult to distinguish the catheter tip from the catheter shaft. If colour flow is observed within the posterior complex or deep to the ligamentum flavum, however, the catheter tip is likely within the epidural space because we used single-hole catheters. Third, if the catheter tip has migrated through the intervertebral foramina, colour Doppler signals might still be seen within the epidural space, thus giving a false-positive test. Fourth, although subdural catheter placement rarely occurs, it might be difficult to differentiate it from epidural placement. Finally, colour Doppler signals from blood vessels could mimic saline flow through the epidural catheter. The main distinguishing feature is a pulsatile signal for vessels versus signals only during manually controlled saline injection.

It is important to emphasize that the quality of the colour Doppler signal is dependent on factors such as injection velocity, ultrasound frequency, angle of insonation, and

Table Recommendations for optimal colour Doppler ultrasonography scanning for confirmation of epidural catheter location

1. Colour Doppler box should cover the interlaminar space, including the posterior complex, intrathecal space, and anterior complex, starting with the side of the insertion in the paramedian approach
2. Keep the posterior complex within the focal zone
3. Select an adequately small sector for colour Doppler, such as to keep the frame rate highest
4. Set an optimal colour Doppler gain to minimize the signals (artefacts) from surrounding tissue. A high gain setting would substantially worsen image quality. A lower gain setting (<50) with minimal probe movement is ideal for reducing artefacts
5. Low frequency probes have better penetration and are less susceptible to aliasing at high velocities, which is expected on injection of saline through a small catheter
6. Use colour power Doppler to avoid the aliasing phenomenon, although it may lead to noise and artefacts

avoidance of excessive gain. No Doppler shift would be appreciated with a perpendicular angle of insonation. In this case, power Doppler imaging might be beneficial for detecting flow.

M-mode ultrasonography has been used to verify the proper placement of peripheral nerve catheters.¹⁷ With the high temporal resolution of this modality, small and subtle changes in image characteristics during epidural saline injection could be detected, provided the interlaminar sonographic window is sufficient. M-mode imaging could also help estimate the depth of the catheter from the skin.

Our case series has several limitations. It is a retrospective review and thus suboptimal for evaluating a new investigative procedure. We did not have a sufficient number of patients to determine the positive or negative predictive value. Also, we evaluated only patients with difficult epidural placement and did not follow a uniform protocol for epidural placement. In addition, as one operator performed all the ultrasonography scans, the generalizability of this technique has yet to be evaluated. In addition, whether an absence of the described findings always indicates a misplaced catheter requires further investigation. Finally, we did not use other radiological tools (e.g., *x-ray*, computed tomography, magnetic resonance imaging) to confirm correct epidural catheter location and to establish the accuracy of colour Doppler imaging. An inadequate pain score using a visual analog scale or a patchy block may occur despite accurate location of the catheter within the epidural space. Hence, these measures cannot serve as markers of successful colour Doppler localization.

Conclusion

This case series supports the feasibility of a non-invasive technique using colour Doppler and M-mode ultrasonography to identify the epidural catheter location in adults, especially those with difficult anatomical landmarks. Future prospective studies to compare the accuracy of Doppler and M-mode ultrasonography with other confirmatory imaging tools are necessary before offering this tool for routine clinical use.

Conflicts of interest Vincent Chan received ultrasonography equipment support for research from BK Medical and consultation fees from Philips Medical Systems and Smiths Medical.

Editorial responsibility This submission was handled by Dr. Philip M. Jones, Associate Editor, *Canadian Journal of Anesthesia*.

Author contributions Hesham Elsharkawy helped design the study, conduct the study, analyze the data, and write the manuscript. He is the author responsible for archiving the study files. Abraham Sonny helped design the study, conduct the study, analyze the data, and write the manuscript. Srinivasa Raghavan

Govindarajan helped analyze the data and write the manuscript. Vincent Chan helped design the study and write the manuscript. All of the authors approved the final manuscript.

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References

1. Ready LB. Acute pain: lessons learned from 25,000 patients. *Reg Anesth Pain Med* 1999; 24: 499-505.
2. Rigg JR, Jamrozik K, Myles PS, et al. Epidural anaesthesia and analgesia and outcome of major surgery: a randomised trial. *Lancet* 2002; 359: 1276-82.
3. Collier CB. Why obstetric epidurals fail: a study of epidurograms. *Int J Obstet Anesth* 1996; 5: 19-31.
4. Pan PH, Bogard TD, Owen MD. Incidence and characteristics of failures in obstetric neuraxial analgesia and anesthesia: a retrospective analysis of 19,259 deliveries. *Int J Obstet Anesth* 2004; 13: 227-33.
5. Motamed C, Farhat F, Remerand F, Stephanazzi J, Laplanche A, Jayr C. An analysis of postoperative epidural analgesia failure by computed tomography epidurography. *Anesth Analg* 2006; 103: 1026-32.
6. Hermanides J, Hollmann MW, Stevens MF, Lirk P. Failed epidural: causes and management. *Br J Anaesth* 2012; 109: 144-54.
7. Sharrock NE. Recordings of, and an anatomical explanation for, false positive loss of resistance during lumbar extradural analgesia. *Br J Anaesth* 1979; 51: 253-8.
8. Hamilton CL, Riley ET, Cohen SE. Changes in the position of epidural catheters associated with patient movement. *Anesthesiology* 1997; 86: 778-84.
9. Dirscherl KR, Leschka S, Filipovic M. Transforaminal migration of an epidural catheter. *Can J Anesth* 2017. DOI:10.1007/s12630-016-0789-5.
10. Tsui BC, Gupta S, Finucane B. Confirmation of epidural catheter placement using nerve stimulation. *Can J Anaesth* 1998; 45: 640-4.
11. Forster JG, Niemi TT, Salmenpera MT, Ikonen S, Rosenberg PH. An evaluation of the epidural catheter position by epidural nerve stimulation in conjunction with continuous epidural analgesia in adult surgical patients. *Anesth Analg* 2009; 108: 351-8.
12. Uchino T, Hagiwara S, Iwasaka H, et al. Use of imaging agent to determine postoperative indwelling epidural catheter position. *Korean J Pain* 2010; 23: 247-53.
13. Ghia JN, Arora SK, Castillo M, Mukherji SK. Confirmation of location of epidural catheters by epidural pressure waveform and computed tomography cathetergram. *Reg Anesth Pain Med* 2001; 26: 337-41.
14. Willschke H, Marhofer P, Bosenberg A, et al. Epidural catheter placement in children: comparing a novel approach using ultrasound guidance and a standard loss-of-resistance technique. *Br J Anaesth* 2006; 97: 200-7.
15. Ueda K, Shields BE, Brennan TJ. Transesophageal echocardiography: a novel technique for guidance and placement of an epidural catheter in infants. *Anesthesiology* 2013; 118: 219-22.
16. Galante D. Ultrasound detection of epidural catheters in pediatric patients. *Reg Anesth Pain Med* 2011; 36: 205.
17. Elsharkawy H, Vafi Salmasi, Abd-Elsayed A, Turan A. Identification of location of nerve catheters using pumping maneuver and M-Mode—a novel technique. *J Clin Anesth* 2015; 27: 325-30.