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ORIGINAL ARTICLE

Color your epidural: color flow Doppler to confirm labor epidural needle position

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ABSTRACT

BACKGROUND: Labor epidural analgesia success depends on precise needle position placement within the epidural space, with reported failure rates to be as high as 32%. In this study, we describe a novel technique employing color Doppler to aid in the confirmation of the correct position of the epidural needle tip.

METHODS: Retrospective evaluation of 35 patients who received labor combined spinal-epidural (CSE) with confirmation of epidural needle position with color flow Doppler (CFD) ultrasonography. Demographic data, intervertebral level of insertion and dermatome sensory level were extracted. Video and image evaluation of CFD patterns were used to confirm epidural needle tip and catheter position. CFD was used to visualize intrathecal injection of local anesthetic in two patients.

RESULTS: Three different color flow patterns were visualized after the loss of resistance technique: visualization of a red and blue mosaic adjacent to the posterior complex, a mosaic pattern enveloping the trajectory of the epidural needle, and a linear deeper mosaic color pattern during spinal injection in relation to the posterior complex. Identification of epidural needle tip and epidural catheter tip occurred in 77% and 37.1% of patients, respectively.

CONCLUSIONS: CFD is a novel and useful technique to confirm the precise position of the epidural needle tip in the context of labor analgesia. Identification of the epidural catheter with CFD is difficult despite an adequate CSE technique.

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KEY WORDS: Obstetric labor; Epidural injections; Color Doppler ultrasonography; Pregnancy.

Obstetric anesthesia and analgesia rely heavily on proper needle placement technique. Labor epidural needle insertion and catheter placement are however blind procedures. Needle insertion is usually guided by palpation of external anatomic landmarks over the lumbar spine. Advancement of the needle from the supraspinous ligament to the epidural space is directed by loss of resistance to the injection of normal saline or air, as the epidural needle emerges from the ligamentum flavum to find its final position in the epidural space. Despite the use of an adequate technique, epidural analgesia failure rates have been reported in up to 32% of cases,[1-4] underscoring the fact that this method is not entirely reliable, and also depends on the anesthesiologist's level of training.[5] A noninvasive approach to confirm the correct position of the epidural needle prior to injection of local anesthetics into the epidural space, would thus be beneficial.

Ultrasound (US) is a noninvasive approach increasingly used in the obstetric anesthesia practice.[5] Two-dimensional ultrasound can accurately identify the vertebral level along the sagittal plane and the midline across the transversal axis, improving the identification of the optimal puncture site.[6, 7] Ultrasound-guided epidural placement requires fewer puncture attempts in comparison to the loss of resistance test alone.[6, 7] Furthermore, pre-procedure ultrasound guidance is particularly useful in patients in whom difficulty with epidural placement is anticipated (*e.g.* scoliosis, previous spinal surgery, morbid obesity).[8-10] The use of color flow Doppler (CFD) may further aid in defining the epidural space.[11]

CFD utilizes Doppler information obtained from signals sent to and received from a transducer. The principles of CFD are similar to those of pulsed wave Doppler (PWD). Data obtained from the ultrasound transducer signal provides information with respect to fluid flow, that aids in the detection of an indwelling catheter by means of the application of either PWD or CFD.[12] However, CFD offers two main advantages over PWD: a broader range of interrogation, and the possibility to assign differential color-coding based on flow direction. Frequency shifts caused by fluid flow are estimated at each point within an interrogated region, thus yielding information on both fluid direction and speed. In the case of CFD, this information is color-encoded and displayed over the two-dimensional image. CFD has been recently used to determine the position of the epidural catheter. Reports have shown the usefulness of M-mode ultrasonography to detect epidural catheter location.[11] However, its role in labor epidural has yet to be defined. We conducted this study to describe the use of CFD to confirm the position of the tip of the epidural needle in the context of labor analgesia. We hypothesized that CFD is a feasible method for identifying proper epidural needle placement prior to epidural catheter advancement.

Materials and methods

After obtaining approval by the Institutional Review Board and a waiver of informed consent, thirty-five pregnant patients who underwent an ultrasound guided labor epidural between August of 2017 and June of 2018, were included in this retrospective review. The ultrasound guided labor epidural was used in those in which an anticipated technical difficulty with landmark epidural space localization was expected. These included those patients with diagnosis of obesity, defined as Body Mass Index (BMI) ≥35 kg/m^2, and lumbar scoliosis, as well as those with poorly defined surface lumbar bone anatomy. Patients with history of spine surgery were excluded. Patient data were obtained from the institutional electronic medical records. Demographic data, intervertebral level of insertion, dermatome level, and failure rate of epidural needle placement using CFD were noted for each patient.

Labor analgesia was obtained *via* a combined spinal epidural technique. Sterile preparation and draping of the area was followed by placement of a curvilinear ultrasound transducer in a sterile sheath. The ultrasound was used to identify the interspinous space.[12] The epidural needle was guided with the use of ultrasound direction by the use of an out of plane technique. A two-hand technique was used to manipulate the needle and the ultrasound probe. A 17-G Tuohy needle (B. Braun Medical, Inc., Bethlehem, PA, USA) was advanced until loss of resistance to normal saline was attained. Confirmation of the epidural space with the use of CFD was then obtained after injection of up to 10 mL of normal saline through the epidural needle. A 27-G pencil-point spinal needle (B. Braun Medical, Inc.) was then introduced through the epidural needle until cerebrospinal fluid (CSF) was obtained. Use of intrathecal fentanyl or local anesthetic plus fentanyl was then used as a bolus in the spinal space. A 21-G epidural catheter (B. Braun Medical, Inc.) was then threaded into the epidural space.

Color flow imaging in the lumbar spine

All CFD images were performed with a Phillips CX50 ultrasound machine using a 5.0 MHz curvilinear probe (Koninklijke Phillips N.V., Amsterdam, The Netherlands) A two-dimensional transverse interspinous view was used to visualize the posterior complex (ligamentum flavum, epidural space and dura) (Figure 1). After loss of resistance to normal saline, the CFD function was turned on to examine flow through the epidural needle tip. The ultrasound probe was positioned in the transverse axis slightly below the epidural needle but still in the interspinous space (Figure 2). Two-dimensional (2D) ultrasound images were initially obtained after making adjustments

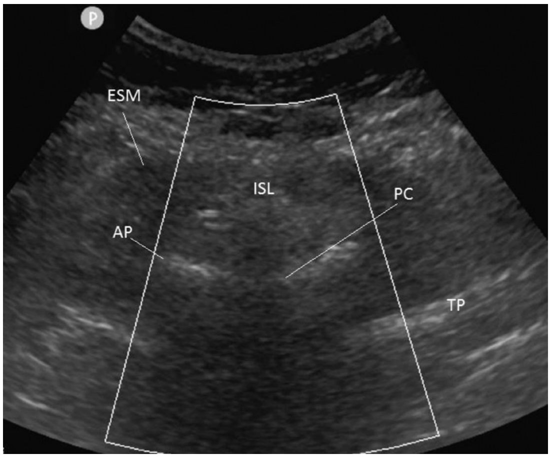

Figure 1.—Normal sonoanatomy of the transverse interspinous space at the lumbar spine. The region of interest has been selected to improve image resolution before turning CFD on and appears as a rectangle on the image.
ESM: erector spinae muscle; AP: articulation process; TP: transverse process; ISL: interspinous ligament; PC: posterior complex.

Figure 2.—View of the epidural needle and its relation to the curvilinear ultrasound probe.

on the ultrasound system. These include an appropriate scanning depth (6-12 cm), using the “penetration” or “general” frequency range and adjusting the gain or the time gate compensation to improve image resolution. The CFD function was then turned on and then the window was adjusted to be centered over the area of interest. We adjusted color baseline to enhance the qualitative depiction of flow. We also increased color gain to amplify the appearance of flow changes. The color gain was adjusted to a level that provided the best image while avoiding the display of random color speckles.

The orientation and tilt of the ultrasound probe was essential for optimal visualization of the CFD pattern. The best views were obtained while the probe was tilted upwards, parallel to the lumbar spinous process orientation, in order to avoid shadow interference cast by the spinous process bony structure. This maneuver optimized the 2D view by minimizing the shadowing caused by bony structures. Five milliliters of sterile saline were administered as a flush through the needle while recording the CFD images. The same procedure was repeated with a slow injection of 5 mL of saline. Ultrasound acquisition images were obtained and analyzed by two anesthesiologists (ERP and AR) experienced with the use of ultrasonography (three years of experience using ultrasound for epidural placement). The speed of injection was not standardized.

The color scale was adjusted to maximize color flow while avoiding excessive aliasing. The best images were best seen with a color scale on the range of 12-20 without needing to adjust the baseline. After identification of the epidural space with CFD, the spinal needle was used to confirm return of CSF. The primary method of detecting the epidural needle was after confirmation of CSF. We had CSF return in all patients in this study. After placement of the epidural catheter, parasagittal and transverse views with CFD were obtained to identify location of the catheter within the epidural space. Two levels above and below the insertion site were used to locate the epidural catheter. The same settings previously described on the CFD were used while trying to locate the catheter in the space. Continuous data were reported as mean, standard deviation and range. Frequency distribution was used to describe categorical variables.

Results

Thirty-five patients were included in the study. The mean age of the patients was 28.6±6 years, BMI 35.2±8.2 kg/m^2, and gestational age 38.3±1.7 weeks. Demographic variables are shown in Table I. We were able to visualize the posterior complex in 100% of the patients when we initially scanned the lumbar spine before the procedure. Identification of the posterior complex using CFD while the epidural needle was possible in place was 27 of the 35 patients (77%).

TABLE I.—*Demographic variables.*

Demographic data	Mean±SD	Range
Age	28.6±6	20.1-46.5
BMI	35.2±8.2	22.6-58
Gravida	3.11±2.1	1-11.0
Para	2.71±2.1	1-10.0
Gestational age	38.34±1.7	34-40

The application of CFD created three very distinct patterns. The first pattern was the visualization of color flow through the epidural space, which consisted of a red and blue mosaic at a level adjacent to the posterior complex (Figure 3). The second one was also a mosaic pattern, but this one closely enveloping the trajectory of the epidural needle itself (Figure 4). The third one displayed the spinal space as a linear mosaic color pattern occurring at deeper level in reference to the posterior complex (approximately 0.5cm) in relation to the posterior complex (Figure 5). The epidural pattern confirmed needle tip position, while the needle pattern confirmed the trajectory of the needle to the epidural space. In no patients was the epidural needle tip directly identified without the use of two-dimensional ultrasound. All patients had positive return of CSF after insertion of a 27-G pencil point spinal needle through the Tuohy epidural needle. In two patients, we used CFD to visualize the intrathecal injection of the spinal dose of local anesthetic (Figure 4). In all patients the epidural pattern of flow as well as the epidural space pattern correctly identified the epidural space. In those patients in whom the posterior complex was not visualized with CFD (N.=8), the epidural needle orientation limited the tilt of the ultrasound probe. Despite the inability of CFD to detect epidural tip needle placement in those cases, we had confirmation of needle placement after loss of resistance by return of cerebrospinal fluid with spinal needle insertion. In one case, despite the loss of resistance, the CFD pattern of the needle identified its position off the midline and out of the epidural space, in relation to bony structures. Readjusting the needle position, the epidural space was located, and the tip position was confirmed by the use of CFD.

Table II shows the level of insertion and dermatomal sensory level achieved with the CSE technique measured two hours after the procedure. This was done to assess the analgesic ef-

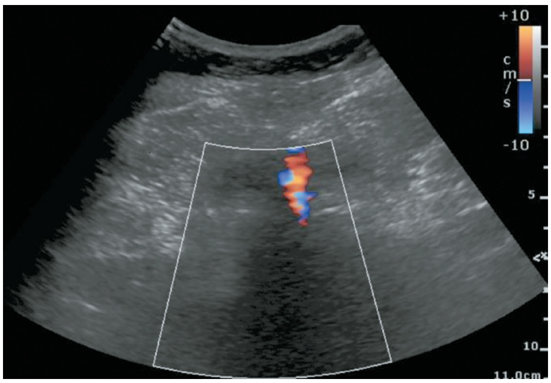

Figure 3.—CFD turned on. Area of interest showing the first pattern of epidural location of needle tip.

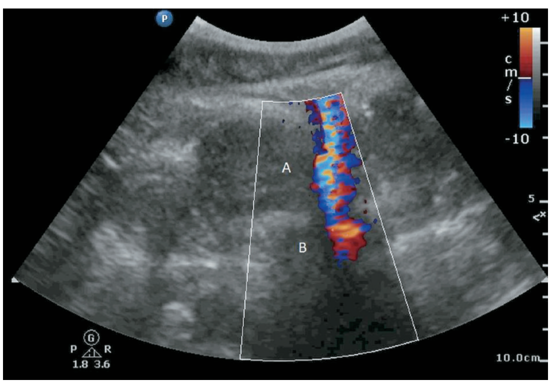

Figure 4.—CFD turned on. An area of interest showing second pattern corresponding to epidural needle trajectory (A). Note that the distal mosaic (B) corresponds to the epidural space where the needle tip is positioned.

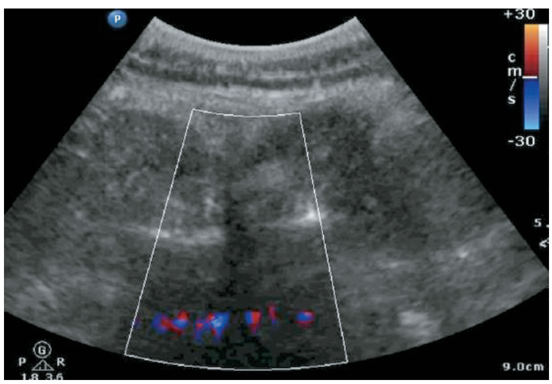

Figure 5.—CFD turned on showing color flow distal to the posterior complex in the intrathecal space.

Table II.—*Epidural needle level of placement and dermatomal sensory level achieved with the CSE technique measured two hours after the procedure.*

Level of placement	N. (%)
L3-L4	17 (48.6%)
L4-L5	18 (51.4%)
Dermatome sensory level	
T4	2 (5.7%)
T7	2 (5.7%)
T8	1 (2.9%)
T10	27 (77.1%)
T12	1 (2.9%)
Uneven level (T8/L1)	2 (5.7%)
Good pain management	35 (100%)

fect of the epidural catheter rather than the effect of the initial spinal dose. Quality of labor analgesia was rated as satisfactory in 100% of patients. Twenty-seven patients (77.1%) had a T10 dermatomal level, whereas an uneven level was observed in two patients (Table II). The epidural catheter tip was visualized in 13 patients (37.1%). When the catheter tip was visualized, it was present at the spinal level of insertion in 100% of the patients (Figure 5).

Discussion

Our study shows that CFD is a useful technique to confirm the adequate position of the epidural needle tip in the context of labor analgesia. CFD is a function embedded in most ultrasound machines and helps in guiding the epidural needle tip into the proper position before advancement of the epidural catheter.

Two-dimensional ultrasound is being increasingly employed to delineate the anatomical landmarks of the lumbar spine and for real-time insertion of the epidural needle.[13-15] Although the distance between the skin and the posterior complex identified with ultrasound assists in the prediction of needle depth evaluation,[15] in some parturients (*e.g.* obese and morbidly obese patients) the release of the pressure applied to the ultrasound probe used to mark the insertion point changes the original measure. This situation makes this method unreliable and inconsistent.[16] Additionally, in patients with abnormal spine anatomy, simple ultrasound may be challenging.[17] In our study, we focused on the direct identification of the epidural space with the use of CFD, rather than on predicted epidural space depth. The accurate identification of the epidural space would be expected to reduce the risk of complications such as accidental dural puncture, which occurs in 0.19% to 3.6% of cases after labor epidural insertion[18, 19] and potentially limit the false positive rate with the loss of resistance technique.

Ultrasound real-time epidural needle placement has been described with the use of two ultrasound planes. Grau *et al.* described a real-time two-operator technique in a paramedian sagittal scan to guide the out-of-plane epidural needle advancement during a CSE procedure.[14] Karmakar *et al*. described an in-plane paramedian sagittal scan technique.[20] The authors used a spring saline loaded syringe to detect loss of resistance and recorded 2D ultrasound changes. The reported changes included anterior displacement of the posterior dura and widening of the epidural space, which were present in 53.3% of the cases. They were also unable to see the needle tip at all times and had to resort to shaking the needle and observing tissue movement, which carries a degree of needle location uncertainty. The transverse view that we used in our study facilitates a single-operator maneuverability through the interspinous space.[15] Manipulation of the ultrasound probe with this technique is operator-friendly, as the same person can inject saline through the epidural needle while assessing CFD. Of note, the ultrasound probe is not used for real-time needle insertion but for confirmation of epidural needle tip location. This means that once loss of resistance occurs, one hand can be used to inject saline while the other hand sustains the probe. Regardless of the technique used to locate the epidural needle tip on the posterior complex, the operator has to face unwanted ultrasound artifacts, as bony structures cause acoustic shadowing and epidural space depth limits image resolution. CFD could potentially be used to 'color' the epidural needle trajectory to add information to 2D ultrasound techniques.

Accurate positioning of the epidural needle tip is absolutely necessary for adequate analgesia provided through the epidural catheter. Different tests are available to detect epidural location of the epidural tip. Loss of resistance (to air or normal saline) is the most widely used method. Since its introduction by Sicard and Forestier, the loss of resistance technique has been embraced by most anesthesiologists. However, despite a positive loss of resistance test, lumbar epidural failure rate remains as high as 27-32%.[21] Failure might be due to a false positive loss of resistance test secondary to degeneration of spinous ligaments with cavity formation, paraspinous muscle infiltration or a faulty syringe.[22-24] Other methods to identify the epidural space such as attachment of an epidural balloon to the needle,[25] bioimpedance,[26] optical reflectometry,[27] optical tomography,[28] nerve stimulation,[29] sound detection,[30] detection of syringe plunger pressure,[31, 32] and non-invasive pressure detector[33] are either expensive or impractical and have not shown to be superior to the traditional loss of resistance technique.[29] Our results show a failure rate of CFD to identify needle tip position in the epidural space in around one fourth of cases. However, in those patients, labor analgesia was satisfactory. We might argue that although CFD may not be able to eliminate the risk of a failed epidural, it may prove to be a useful tool to reduce the overall analgesia failure that occurs in approximately one fourth to one third of patients reported in the literature. Our study evaluated a possible role for the use of color Doppler to confirm epidural needle tip position in labor analgesia and thus could have implications for decreasing the rate of false loss of resistance tests.

There are studies on CFD and neuraxial anesthesia. CFD has been used to identify the caudal space and to confirm epidural injection in children.[30, 31] Ultrasound penetration through ossified structures is more difficult in the adult population due to the dark acoustic shadowing generated. Elsharkawy *et al.* retrospectively studied 37 patients with technically difficult epidural catheter placement using color Doppler ultrasonography to identify the position of the catheter.[11] The authors were able to identify the catheter tip and the segment from the skin to the epidural space in 89% and 67.5% of the patients, respectively. In their study, the tip of the epidural needle was not evaluated. In our study, we were not able to replicate their results. Our results showed a lower rate of visualization of the epidural catheter. The discrepancy with Elsharkawy's findings occurred despite having used a similar technique described by the authors. However, the use of parasagittal views, thoracic *versus* lumbar vertebral levels, and bilateral and multilevel scans might contribute to the differences encountered between the two studies. Interobserver variability is also a potential factor to explain the discrepancy between studies.

To the best of our knowledge, our study is the first one evaluating the position of the epidural needle with color Doppler ultrasound. Determining the adequate position of the needle is critical in obstetric anesthesia settings to ensure adequate labor analgesia and to avoid complications related to accidental intrathecal or intravascular injection. Indirect methods to rule out malposition of the catheter include a test dose containing lidocaine with epinephrine, and institution dermatomal sensory block. The use of a test dose in laboring patients is controversial. Calimaran *et al*. studied the effect of a lidocaine-epinephrine test dose after CSE for labor analgesia on motor response, finding that it caused interference with simple motor tests and motor function.[32] In labor, immobility may be associated with patient dissatisfaction and complications related to venous stasis. Furthermore, being able to sit upright and walk during labor reduces labor duration and risk of cesarean birth.[33] Norris *et al.* advocated for the avoidance of the test dose altogether in labor epidural analgesia.[34] Although, being able to consistently identify the epidural position of the needle tip with CFD might provide assurance to the anesthesiologist to not use the test dose, there is still a potential risk of catheter advancement into the subarachnoid or intravascular spaces. In our study, we were able to identify the difference in observed CFD patterns between the epidural and the intrathecal spaces. Elsharkawy reported a successful experience to detect accidental dural puncture with PWD in a thoracic epidural procedure. To our knowledge, ours is the first reported experience with CFD to confirm intrathecal needle position. We were able to identify the only one false positive loss of resistance epidural needle placement with the use of CFD and make immediate corrective action.

Confirmation of accurate epidural placement in labor is achieved through adequate dermatomal level and analgesia. If analgesia is inadequate, a new epidural procedure may be warranted. Our findings support the idea that intraprocedural confirmation of epidural needle position with color Doppler ultrasonography allows the immediate undertaking of corrective actions, avoiding the need for a second procedure should analgesia fail. On the other hand, in circumstances where a test dose is contraindicated, the use of CFD may help reduce, albeit not eliminate, the risk of intravascular or intrathecal injection. We might argue that the combination of CFD and M-mode might be complementary to detect epidural catheter position.[11] Further research is needed to confirm this assumption.

Limitations of the study

Our study has several limitations stemming from the ultrasound technology itself. Aliasing is produced by the velocity differential of the injection of saline that overshadows the discrete changes responsible for the three CFD patterns described. Aliasing is an imaging artifact that can be prevented by the adjustment of the CFD parameters including moving the color baseline, increasing the velocity scale and using a low-frequency transducer.[35] The scanning angle also influences CFD shifts. Under ideal conditions, the angle of insonation should be as close to zero degrees to detect Doppler shifts. In our study, the scanning angle was difficult to adjust due to the close proximity between needle shaft and ultrasound probe, and the effect of bony prominences on visualization of deep structures. We used a low-frequency transducer probe and were able to adjust the color baseline to lessen aliasing in order to obtain better-defined images. The epidural space has blood vessels that might be confused with the epidural injection through the needle. However, a typical blood vessel image is smaller, more circumferential and pulsatile in nature. We also did not use power Doppler.

The retrospective nature of our study also limits its ability to standardize the technique (*e.g.* speed of saline injection, optimal probe tilt) and to fully evaluate the performance of this innovative technique. The sample size limited our ability to calculate predictive values for the technique.

Conclusions

Future research is warranted to evaluate performance of Doppler ultrasound in labor analgesia in terms of procedural time, quality of pain control and patient satisfaction. Since our patient population exhibited BMI values that were not on the high range, future studies should focus on the technical feasibility and performance of CFD in morbidly obese parturients. Given the different ultrasound guided epidural techniques, we believe that further research would be necessary to compare CFD with other ultrasound-based techniques.

What is known

- Labor epidural needle insertion and catheter placement are blind procedures with a high failure rate.
- The use of ultrasound to guide epidural needle placement is emerging as a safe alternative to the blind techniques used.

What is new

- Color flow Doppler (CFD) can be used to confirm the adequate position of the epidural needle tip in the context of labor analgesia.
- The technique uses a transverse ultrasound plane and application of CFD in the region of the posterior complex.
- Three CFD patterns may assist in guiding the needle to the epidural space. This includes a pattern for the epidural space itself, one surrounding the epidural needle and another one for the intrathecal space.

References

1. Hermanides J, Hollmann MW, Stevens MF, Lirk P. Failed epidural: causes and management. Br J Anaesth 2012;109:144–54.

2. Motamed C, Farhat F, Rémérand F, Stéphanazzi J, Laplanche A, Jayr C. An analysis of postoperative epidural analgesia failure by computed tomography epidurography. Anesth Analg 2006;103:1026–32.

3. 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.

4. Ready LB. Acute pain: lessons learned from 25,000 patients. Reg Anesth Pain Med 1999;24:499–505.

5. Teissler H, Lozano C, Plavsic SK. The Use of Ultrasonography for the Guidance of Epidural Analgesia in Obstetric Anesthesia. Donald School J Ultrasound Obstet Gynecol 2014;8:44–51.

6. Cork RC, Kryc JJ, Vaughan RW. Ultrasonic localization of the lumbar epidural space. Anesthesiology 1980;52:513–6.

7. Saravanakumar K, Rao SG, Cooper GM. Obesity and obstetric anaesthesia. Anaesthesia 2006;61:36–48.

8. McLeod A, Roche A, Fennelly M. Case series: ultrasonography may assist epidural insertion in scoliosis patients. Can J Anaesth 2005;52:717–20.

9. Peng PW, Rofaeel A. Using ultrasound in a case of difficult epidural needle placement. Can J Anaesth 2006;53:325–6.

10. Gnaho A, Nau A, Gentil ME. Real-time ultrasound-guided epidural catheter insertion in obese parturients. Can J Anaesth 2015;62:1226–7.

11. Elsharkawy H, Sonny A, Govindarajan SR, Chan V. Use of colour Doppler and M-mode ultrasonography to confirm the location of an epidural catheter - a retrospective case series. Can J Anaesth 2017;64:489–96.

12. Carvalho JC. Ultrasound-facilitated epidurals and spinals in obstetrics. Anesthesiol Clin 2008;26:145–58.

13. Chin KJ, Karmakar MK, Peng P. Ultrasonography of the adult thoracic and lumbar spine for central neuraxial blockade. Anesthesiology 2011;114:1459–85.

14. Grau T, Leipold RW, Fatehi S, Martin E, Motsch J. Real-time ultrasonic observation of combined spinal-epidural anaesthesia. Eur J Anaesthesiol 2004;21:25–31.

15. Grau T, Leipold RW, Conradi R, Martin E, Motsch J. Ultrasound imaging facilitates localization of the epidural space during combined spinal and epidural anesthesia. Reg Anesth Pain Med 2001;26:64–7.

16. Sahota JS, Carvalho JC, Balki M, Fanning N, Arzola C. Ultrasound estimates for midline epidural punctures in the obese parturient: paramedian sagittal oblique is comparable to transverse median plane. Anesth Analg 2013;116:829–35.

17. Chin KJ, Macfarlane AJ, Chan V, Brull R. The use of ultrasound to facilitate spinal anesthesia in a patient with previous lumbar laminectomy and fusion: a case report. J Clin Ultrasound 2009;37:482–5.

18. Sprigge JS, Harper SJ. Accidental dural puncture and post dural puncture headache in obstetric anaesthesia: presentation and management: a 23-year survey in a district general hospital. Anaesthesia 2008;63:36–43.

19. Berger CW, Crosby ET, Grodecki W. North American survey of the management of dural puncture occurring during labour epidural analgesia. Can J Anaesth 1998;45:110–4.

20. Karmakar MK, Li X, Ho AM, Kwok WH, Chui PT. Real-time ultrasound-guided paramedian epidural access: evaluation of a novel in-plane technique. Br J Anaesth 2009;102:845–54.

21. Sicard J, Forestier J. Radiographic method for exploration of the extradural space using Lipiodol. Rev Neurol (Paris) 1921;28:1264–6.

22. 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.

23. Patel N, Eckersall S, Ling A. False positive 'loss of resistance' syringe. Anaesthesia 2005;60:630.

24. Gupta B, Sharma S, D'souza N, Kaur M. Pseudo loss of resistance in epidural space localization. Saudi J Anaesth 2010;4:117–8.

25. Fyneface-Ogan S, Mato CN. A clinical experience with epidural balloon in the localisation of the epidural space in labouring parturients. Nig Q J Hosp Med 2008;18:166–9.

26. Kalvøy H, Frich L, Grimnes S, Martinsen ØG, Hol PK, Stubhaug A. Impedance-based tissue discrimination for needle guidance. Physiol Meas 2009;30:129–40.

27. Ting CK, Tsou MY, Chen PT, Chang KY, Mandell MS, Chan KH, *et al.* A new technique to assist epidural needle placement: fiberoptic-guided insertion using two wavelengths. Anesthesiology 2010;112:1128–35.

28. Zysk AM, Nguyen FT, Oldenburg AL, Marks DL, Boppart SA. Optical coherence tomography: a review of clinical development from bench to bedside. J Biomed Opt 2007;12:051403.

29. Elsharkawy H, Sonny A, Chin KJ. Localization of epidural space: A review of available technologies. J Anaesthesiol Clin Pharmacol 2017;33:16–27.

30. Raghunathan K, Schwartz D, Connelly NR. Determining the accuracy of caudal needle placement in children: a comparison of the swoosh test and ultrasonography. Paediatr Anaesth 2008;18:606–12.

31. Tsui B, Leipoldt C, Desai S. Color flow Doppler ultrasonography can distinguish caudal epidural injection from intrathecal injection. Anesth Analg 2013;116:1376–9.

32. Calimaran AL, Strauss-Hoder TP, Wang WY, McCarthy RJ, Wong CA. The effect of epidural test dose on motor function after a combined spinal-epidural technique for labor analgesia. Anesth Analg 2003;96:1167–72.

33. Lawrence A, Lewis L, Hofmeyr GJ, Dowswell T, Styles C. Maternal positions and mobility during first stage labour. Cochrane Database Syst Rev 2009;(2):CD003934.

34. Norris MC, Fogel ST, Dalman H, Borrenpohl S, Hoppe W, Riley A. Labor epidural analgesia without an intravascular "test dose". Anesthesiology 1998;88:1495–501.

35. Kruskal JB, Newman PA, Sammons LG, Kane RA. Optimizing Doppler and color flow US: application to hepatic sonography. Radiographics 2004;24:657–75.

Conflicts of interest.—The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

Authors' contributions.—Efrain Riveros-Perez contributed to the study design, data collection and analysis, and helped construct the manuscript. He is responsible for maintaining the study files. Camila Albo contributed to study design and to write the manuscript. Enoe Jimenez contributed to study design and to write the manuscript. Thomas Cheriyan helped with data analysis and manuscript construction. Alexander Rocuts contributed to the study design, data collection and analysis, and helped construct the manuscript. All of the authors approved the final manuscript.

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