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ORIGINAL ARTICLE

Ultrasound decreases the failed labor epidural rate in resident trainees

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ABSTRACT
Background: Epidural analgesia is widely used for pain relief during labor. The purpose of this study was to determine if ultrasound measurement of the depth from skin to epidural space before the epidural technique decreases the failure rate of labor analgesia. A secondary objective was to correlate ultrasound depth to the epidural space with actual depth of the needle at placement.
Methods: In this prospective, randomized, non-blinded study, 370 parturients requesting labor epidural analgesia were randomized to receive their epidural technique by first year anesthesia residents with or without prior ultrasound determination of epidural space depth. Outcome variables included the incidence of epidural catheter replacement for failed analgesia and the number of epidural attempts and accidental dural punctures.
Results: The ultrasound group had fewer epidural catheter replacements ($P < 0.02$), and epidural placement attempts ($P < 0.01$) compared to the control group. Pearson's correlation coefficients comparing the actual versus ultrasound estimated depth to the epidural space in the longitudinal median and transverse planes were 0.914 and 0.909, respectively. Pearson's correlation coefficient comparing the ultrasound estimated depths to the epidural space in the transverse and longitudinal median planes was 0.940. No significant differences were noted with respect to staff interventions, top-ups, accidental dural punctures, and delivery outcome.
Conclusions: Ultrasound measurement of the epidural space depth before epidural technique placement decreases the rate of epidural catheter replacements for failed labor analgesia, and reduces the number of epidural attempts when performed by first year residents and compared to attempts without ultrasound guidance.

Keywords: Ultrasound; Labor epidural; Failed epidural; Resident trainees

Introduction

The failure rate for labor epidural analgesia has been reported to range from 1.5–20%.[1,2] Ultrasound imaging is becoming the clinical standard to facilitate peripheral nerve blocks because it improves success rates and increases efficiency.[3–5] In January 2008, the National Institute for Health and Clinical Excellence (NICE) issued guidance on the use of ultrasound imaging to facilitate catheterization of the epidural space.[6] The aim of this study was to determine if ultrasound measurement of epidural space depth before labor epidural placement by residents decreases the replacement rate of epidural catheters for failed analgesia. A secondary objective was to correlate the ultrasound estimated depth of the epidural space with the actual needle depth at the time of placement.

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Methods

After approval by the Magee-Womens Hospital institutional review board, informed written consent was collected from 370 laboring parturients, who were randomized consecutively by a computerized schema (Quattro Pro, Corel Corporation, Ottawa, Canada) into one of two groups for their epidural technique: (1) The US Group, in which the epidural depth was determined by ultrasound before siting; or (2) The Control Group, in which siting occurred without prior use of ultrasound imaging. The study was not blinded to the subject or investigator. All women who requested labor epidural analgesia were eligible to participate, assuming they did not meet the exclusion criteria (presence of coagulopathy, previous spinal surgery, or local anesthetic allergy). Obese parturients (BMI $\geq 30\ kg/m^2$) were not excluded from the study.

First year (first clinical anesthesia year [CA-1]) residents performed all epidural techniques under direct staff anesthesiologist supervision. Residents were not randomized to the US Group or Control Group. All

residents involved in the study had no more than five epidural placement attempts before initiation of the study.

Patients assigned to the US Group had ultrasound visualization in the longitudinal median and transverse planes with estimation of the distance from skin to ligamentum flavum (posterior dura) before insertion of the epidural catheter (Figs. 1 and 2). Because ultrasound visualization is dependent on the skill of the user, all ultrasound examinations were performed by the primary investigator who had performed ultrasound-guided epidural catheter placements for 6 months before initiation of the study. The Sonosite Micromaxx® ultrasound system (SonoSite, Bothell, WA) with a 2–5-MHz curved array probe was used for this study.

The study protocol followed the standard labor epidural technique at our institution, with the only exception being the use of ultrasound in the intervention group to measure the depth to the epidural space, determine midline, insertion point, and needle direction before epidural catheter insertion. The sitting position was maintained throughout ultrasound visualization and epidural placement. The intervertebral space was determined by palpation of the posterior superior iliac crest and on Tuffier's line, the vertebral interspace was identified and marked with an indelible marker. This mark was used to visualize both the longitudinal median and transverse ultrasound planes, confirm midline, and determine the final insertion point at the intervertebral space which gave the best view of the ligamentum flavum.

Using a sterile technique, the epidural was performed using the midline approach in both groups through a 17-gauge Tuohy needle at the L3–4 or L4–5 vertebral interspace using loss of resistance to saline. The epidural catheter (Arrow FlexTip Plus®, Arrow International, Reading, PA, USA) was inserted 5 cm into the epidural space and then secured with adhesive dressing and tape. All patients were given an initial bolus of 10 mL 0.1% ropivacaine and fentanyl 100 μg and placed on a standard continuous maintenance epidural infusion of ropivacaine 0.1% with fentanyl 2 μg/mL at 12 mL/h.

The primary investigator performed ultrasound imaging on patients allocated to the US Group and informed the trainee (who was present during ultrasound visualization) of the measured distance from skin to ligamentum flavum (epidural space depth) in both the longitudinal median and transverse planes. The primary investigator also confirmed the midline and the direction for the ultrasound probe that provided the best image of the ligamentum flavum/posterior dura in the transverse approach. The longitudinal median plane was visualized by positioning the ultrasound probe vertically in the median (midline) plane, parallel to the long axis of the spine (Fig. 1). A "saw" sign, which represents the spinous processes (saw teeth) and the hyperechoic band at the base of the saw was confirmed. The transverse plane was visualized with the probe placed horizontally, perpendicular to the long axis of the spine in the intervertebral space (Fig. 2). In the midline, the spinous process was identified as a small hyperechoic signal immediately underneath the skin that continued as a long hypoechoic (dark) acoustic shadow. The probe was then moved slightly cephalad or caudad to capture a view of an acoustic window (vertebral interspace). In the midline and within the vertebral interspace, an equal

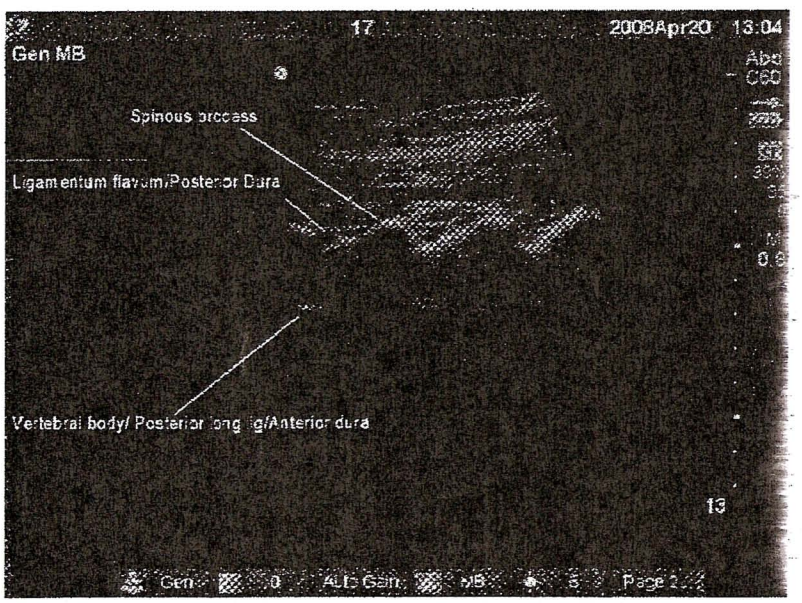

Fig. 1 Longitudinal median ultrasound plane.

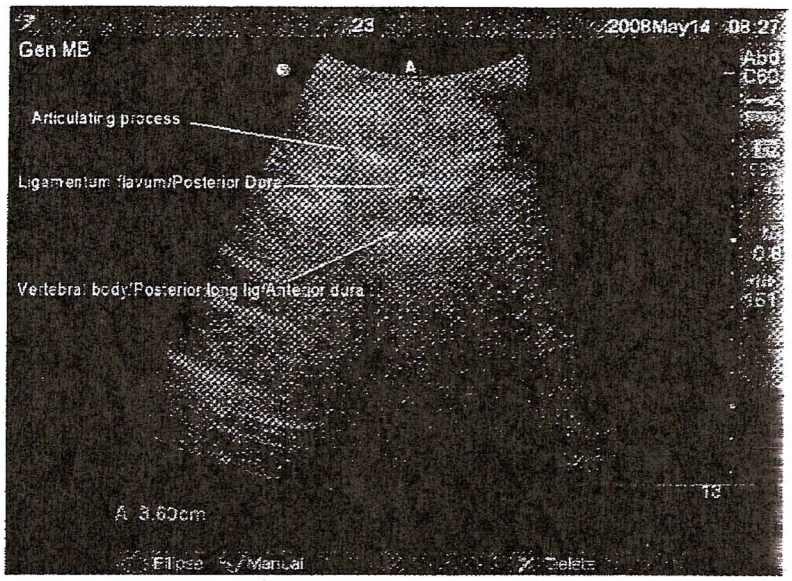

Fig. 2 Transverse ultrasound plane.

sign (=) could be seen where the upper and lower parallel lines represent the ligamentum flavum/posterior dura and vertebral body/posterior longitudinal ligament/anterior dura, respectively (Fig. 2).

An epidural insertion attempt was defined as advancement of the needle in an effort to enter the epidural space; a needle requiring withdrawal for redirection or reinsertion was counted as an additional attempt. Staff intervention occurred if the trainee required more than six attempts. A failed epidural technique was defined as an epidural catheter requiring replacement during labor. Early and late failures were defined according to whether the catheter required replacement within or after the first 90 min following insertion, respectively. An attending staff anesthesiologist who was blinded to whether ultrasound was used made the decision regarding epidural catheter replacement. The visual analogue scale [VAS] score (0 = no pain, 10 = worst pain) was used to assess pain before and after epidural activation and when assessing patients for inadequate analgesia. A failed epidural technique was defined as a block providing inadequate analgesia (VAS > 3/10) despite the following sequential steps: (1) a 10-mL bolus of the epidural infusion mix and reassessment at 15 min; (2) a second 10-mL bolus of the epidural infusion mix and reassessment at 15 min; and (3) a 5-mL 1.5% lidocaine bolus.

Measured variables included personal and obstetric data (age, height, weight), number of pregnancies, parity, failed epidural rate, epidural insertion attempts, staff interventions (need for the attending anesthesiologist assistance during the placement attempt), number of epidural top ups required, accidental dural puncture (ADP) rate, maternal delivery outcome (vaginal delivery, caesarean delivery, forceps/vacuum assist). In the US Group, both the transverse and longitudinal median planes were used to measure the distance from the skin to the epidural space (ligamentum flavum/posterior dura) before epidural placement. Lastly, the actual epidural needle depth to the epidural space measured to the nearest 0.5 cm was recorded.

The incidence of failed epidural technique (an epidural requiring replacement) at Magee-Womens Hospital is approximately 8% (Quality Assurance data, 2000–2005). We hypothesized that by utilizing ultrasound to determine epidural depth before labor epidural catheter insertion, the rate of failed epidural techniques would be reduced from 8% to 2%, a failure rate similar to techniques performed by experienced practitioners. Using Fisher's Exact (NQuery Advisor 4.0™, Statistical Solutions, Saugus MA, USA) to determine sample size, 185 patients per group were required to detect statistical significance at α 0.05 and a power of 0.80.

Interval data were analyzed using the t test and reported as mean (±SD), nominal data were analyzed using chi-square, and ordinal data were analyzed using Mann–Whitney rank sum test and reported as median (range). Fisher's Exact test was used for data analysis when fewer than five events (failed epidural blocks) occurred. A secondary objective was to correlate ultrasound depth to the epidural space with actual depth of the needle at placement. Pearson's coefficient was used to determine correlation between the depth to the epidural space measured both in the longitudinal median plane and in the transverse ultrasound plane. Pearson's coefficient was also used to determine correlation between the longitudinal median and the transverse US planes.

To quantify the benefit with the use of ultrasound in reducing the epidural failure rate, the number needed to treat (NNT) was calculated. The NNT is the inverse of the absolute risk reduction (ARR), which is the difference between the control event rate (CER = number of epidural failures in the non-ultrasound group) and the experimental event rate (EER = number of epidural failures in the ultrasound group). Therefore, NNT is equal to 1/ARR or (1/CER − EER).

Stepwise multivariate linear regression analysis was used to determine which parturient characteristics were statistically significant ($P < 0.05$) in predicting the distance from the skin to the epidural space. Variables used in the multivariate linear regression analysis included; age, height, weight, gestational age, number of pregnancies, parity, cervical dilation, station, and VAS pain scores.

Results

From August 2007 to April 2008, a total of 370 parturients were studied; 189 in the US Group and 181 in the Control Group. All women who were approached participated in the study. During the study period, 15 anesthesia trainees performed the epidural techniques. Personal and obstetric data are presented in Table 1. All patients enrolled completed the study. No important differences were noted between groups with respect to age, height, weight, gestation, number of pregnancies, and parity (Table 1). Likewise, no important differences were noted with respect to cervical dilation, station at epidural placement, and initial VAS. Ultrasound scanning added 60 (±15) s to the mean preparation time.

In the US Group, there were three failed epidural blocks, compared to 10 in the Control Group. Only one block in the US Group was an early failure compared to six in the Control Group, (Table 2). The control group required more initial placement attempts. No resident had more than one failed epidural block.

The mean/actual clinical distance from skin to epidural space was less in the US Group compared to the Control Group (Table 2). Mean depths to the ligamentum flavum/dorsal dura as measured by longitudinal median, and transverse ultrasound planes are presented in Table 2. Both the longitudinal median and transverse ultrasound planes had high correlation with actual clinical depth to the epidural space. Pearson's correlation coefficients comparing clinical depth to longitudinal median and transverse ultrasound plane views were 0.914 and 0.909, respectively. Pearson's correlation coefficient comparing the transverse ultrasound plane to the longitudinal median ultrasound plane was 0.940. There was only one recognized ADP which went on to become a post dural puncture headache (PDPH) in the US Group. A second PDPH occurred in the US Group post delivery (Table 2). No significant differences were noted with respect to staff interventions, additional top-ups or delivery outcome.

An equation to determine the distance from the skin to the epidural space in the lower lumbar intervertebral area using stepwise multivariate linear regression analysis using height and weight as significant variables, revealed the distance to be:

$$\text{Epidural Depth} = 5.63 - [0.025 \times \text{Ht(cm)}] + [0.040 \times \text{Wt(kg)}]$$

Table 1 Personal and obstetric data

	Ultrasound ($n = 189$)	Control ($n = 181$)	P value
Age (years)	27.9 (±5.9)	28.5 (±6.1)	0.33
Height (cm)	161 (±6.7)	161 (±7.1)	0.61
Weight (kg)	84.1 (±19.0)	83.5 (±16.7)	0.75
BMI (kg/m^2)	32.5 (±7.4)	32.3 (±6.0)	0.78
Gestation (weeks)	38.8 (1.7)	38.6 (±2.0)	0.19
No. pregnancies	2 (1–7)	2 (1–13)	0.89
Parity	0 (0–6)	0 (0–11)	0.84

Data are mean (±SD) or median (range).

Table 2 Outcome data

	Ultrasound ($n = 189$)	Control ($n = 181$)	P value
Epidural depth (cm)			
Clinical	4.8 (±1.1)	5.1 (±1.0)	0.02
Longitudinal	4.6 (±0.9)		
Transverse	4.7 (±1.0)		
Failed epidural	3 (1.6%)	10 (5.5%)	<0.02
Failed early epidural	1 (0.5%)	6 (3.3%)	0.05[a]
Insertion attempts	1 (1–6)	2 (1–6)	<0.01
Staff intervention	54 (28.6%)	64 (35.4%)	0.2
Top-ups	0 (0–11)	0 (0–10)	0.63
Accidental dural puncture	1 (0.5%)	1 (0.6%)	0.5
Delivery type			
Spontaneous	157 (83.1%)	152 (84%)	0.93
Cesarean	26 (13.8%)	26 (14.4%)	0.99
Vacuum/forceps	6 (3.2%)	3 (1.7%)	0.54
Post dural puncture headache	2 (1.1%)	0 (0%)	0.5
Epidural blood patch	1 (0.5%)	0 (0%)	0.98

Data are mean (±SD), median (range), or number (%).
[a] Fisher's exact test used due to less than five failures in the US group.

Discussion

Our study indicates that ultrasound scanning to confirm the midline, determine needle direction, and measure the depth to the epidural space before epidural technique placement by CA-1 anesthesia residents decreases the epidural analgesia failure rate and the number of epidural attempts when compared to attempts without ultrasound scanning.

Common complications associated with the epidural technique for labor and delivery include failure to provide analgesia at rates of 1.5–20%,[1,2] and ADP rates

of 1–5%.[2,7–9] Furthermore, approximately half of ADP result in a PDPH.[7] Failed or inadequate blocks are frequently related to practitioner inexperience and can result from failure to identify the epidural space or from malposition of the epidural catheter.[10] Grau et al.[11] demonstrated improved epidural analgesia success rates of 86% versus 60% with and without ultrasound guidance, respectively; our overall higher success rates may have been due to the direct physical presence and supervision by the staff anesthesiologist.

Pregnancy is associated with tissue edema and weight gain, which can obscure anatomical landmarks, and hormonal changes, which can result in softening of ligaments, resulting in difficulty in finding the epidural space.[12] Ultrasound utilization for epidural placement allows determination of an epidural insertion point, provides an estimation of the angle of the needle during insertion, and allows measurement of the distance from skin to epidural space.[8] We believe this knowledge was helpful in the lower failed epidural analgesia rates in the US Group. The lower failed epidural rate with ultrasound was associated with a NNT of 26; twenty-six patients would need to have ultrasound epidural placement to reduce the risk of a failed epidural labor analgesic technique. At our institution, where approximately 25–30 epidural techniques are performed each day, at least one parturient per day would benefit from ultrasound use before the epidural technique.

Grau et al.[11] compared the quality of images obtained with transverse, median longitudinal and paramedian longitudinal approaches and suggested that the paramedian longitudinal approach was optimal. By contrast, Arzola et al.[13] observed that the transverse approach had enough diagnostic accuracy and precision to be used as a preferred "single-screen" method. We found that both approaches had high correlation with each other and with the actual epidural needle depth. We suggest that the longitudinal plane be first used to identify the epidural space and measure depth, with further visualization and confirmation in the transverse plane. The direction of the probe used for transverse plane visualization should be used for the epidural needle placement.

Although the mean clinical distance from the skin to the epidural space was less in the US Group versus Control Group, this may have been due to actual clinical measurements being rounded up or down to the nearest tenth of a cm to more closely approximate the estimated distance. While this difference was statistically different, the small differences were most likely not clinically significant. A high correlation between ultrasound estimated depth and clinical depth have been previously reported by Currie,[14] and slight differences are to be expected.[1] These differences are attributed to: (1) the ultrasound probe and epidural needle being at different angles to the skin (optimal correlation if both perpendicular to the skin);[14] (2) the epidural needle being off midline in trajectory:[1] and (3) the blunt epidural needle causing tissue deformation.[1] Since ultrasound measurements in both planes had a high correlation with clinical findings, averaging of multiple measurements in each plane is probably unnecessary. Nevertheless, epidural space identification with loss of resistance to air or saline should still be employed.[12,13]

The limitations of this study include the lack of investigator and patient blinding, the inherent limitations of ultrasound imaging,[15] and the absence of trainee randomization or tracking the number and type of procedures (with and without ultrasound guidance) performed by each resident over the course of the study. Moreover, we used pre-placement ultrasound evaluation instead of real-time guidance for the epidural technique placements; this was in keeping with our hypothesis and the majority of previous studies of epidural catheter placement with ultrasound.[1,11–15] However, epidural needle tip visualization throughout the procedure is difficult, with the potential of mishaps.[16]

In conclusion, ultrasound measurement of the depth of the epidural space before insertion of an epidural catheter for labor resulted in a reduced rate of catheter replacements for failed epidural labor analgesia and fewer insertion attempts.

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