Original Article
Correlation of actual epidural depth with ultrasound estimates in paramedian sagittal oblique and transverse median plane in parturients: a prospective cross-sectional study

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Abstract: Purpose: In this prospective, cross-sectional, observational study, the accuracy and precision of actual epidural depth (ND) with ultrasound estimates of epidural depth (ED) in the paramedian sagittal oblique plane (PSO) and transverse median plane (TM) in parturients was assessed. Methods: Ninety parturients scheduled for cesarean section asking for combined spinal epidural anesthesia were recruited. ED was assessed in PSO and TM planes with a 5-2 MHz curved array probe. The least possible pressure was applied on the probe during ultrasound examination. All epidurals were located by a midline approach at L3-4 level by an anesthesiologist blinded to ED but informed about the insertion point. ND was marked on the needle with a sterile marker. Precision between the measurements were assessed by Pearson correlation coefficient and Lin's concordance correlation coefficient (CCC). Bland-Altman test was used to assess the 95% limits of agreement (LOA) between measurements. Results: The mean (SD) ultrasound estimated ED in the PSO and TM plane and ND were 56.07 (9.31) mm, 55.99 (9.15) mm, and 56.17 (9.28) mm respectively. CCC between ND and US estimated ED in PSO plane was 0.9929, and 0.9928 in TM plane. Bland-Altman analysis showed -1.13-1.03 mm 95% limits of agreement between ND and ultrasound estimated ED in PSO plane and -1.15-0.98 mm in TM plane. There was a strong correlation between the ND and ultrasound estimates of epidural depth in PSO and TM planes. Conclusion: Both planes can be used interchangeably for preprocedural estimation of ED in parturients asking for labor epidurals.

Keywords: Cesarean section, combined spinal epidural, epidural depth, paramedian sagittal oblique, transverse median, ultrasound

Introduction

Combined spinal epidural anesthesia (CSE) is used for labor anesthesia and analgesia since it was first described by Brownridge [1]. In 1982 Coates [2] defined the needle-through-needle technique for CSE and two years later Currie [3] introduced it to labor anesthesia. Meanwhile Cork [4] defined the localization of epidural space with ultrasound in 1980 and four years later Currie [3] introduced the use of ultrasound for epidural depth measurement. This is not surprising because while a novel technique is developing, the way to make it safer and easier is being studied at the same time.

Localization of anatomical landmarks and the desired intervertebral space in obstetric patient population is generally difficult and misleading with traditional palpation method [5-7]. Because of the loosening of the soft tissue and ligamentum flavum during pregnancy, false loss of resistance can be achieved leading to failed regional anesthesia or further advancement of epidural needle resulting in unintentional dural puncture. Preprocedural assessment of the skin to epidural depth provides an accurate provision about the length of epidural needle that can safely be advanced [3, 8-14].

In previous studies ultrasound estimates of skin to epidural space depth in transverse median plane and longitudinal plane were assessed for their correlation with actual epidural depth [10, 15-18]. Only one study was conducted with obese (body mass index > 30 kg/m^2) parturi-

ents exploring the correlation between transverse and paramedian sagittal oblique plane ultrasound estimates of epidural depth with the actual epidural depth [19].

The aim of this study was to explore the precision and accuracy of ultrasound estimated skin to epidural space depth in paramedian sagittal oblique plane (PSO/ED) and transverse median plane (TM/ED) with the actual epidural depth (ND) in term parturients scheduled for cesarean section with CSE.

Materials and methods

Subjects

This prospective cross-sectional study of healthy parturients scheduled for cesarean section with CSE was conducted from 01 June, 2018 to 30 October, 2018 to assess the precision and accuracy between the ND, PSO/ED, and TM/ED. Written informed consent was obtained from all parturients. The study was prepared in accordance with the Declaration of Helsinki and strengthening the reporting of observational studies in epidemiology (STROBE) guidelines.

After approval from the Institutional Review Board, Ethical Committee consent was approved (2017-20/242, 26/12/2017) and the study was prospectively registered at Australian New Zealand Clinical Trials Registry (ACTRN12618000-578202, 16/04/2018).

Parturients with American Society of Anesthesiologists (ASA) physical status II-III, singleton term pregnancies (37-42 weeks of gestation) aged 18-40 years scheduled for cesarean section with CSE were included in the study. Parturients with neurological diseases, vertebral column anomalies, history of spine or spinal canal surgeries, ASA physical score greater than III, multiple pregnancies, complicated pregnancies, emergency cesarean sections, coagulopathy or history of anticoagulant medication use, and patients rejecting CSE were excluded from the study.

Following standard ASA monitorization (electrocardiogram, heart rate, pulse oximeter, non-invasive blood pressure), a 16G intravenous cannula was secured for intravenous infusion.

Demographic data was recorded for every parturient. Skin to epidural space depth measurements with ultrasound in the transverse median plane (TM) and paramedian sagittal oblique plane (PSO) were recorded in millimeters. The ND was accepted as a gold standard for epidural depth and recorded.

Ultrasound scanning

After standard ASA monitorization, parturients were positioned at sitting position on the operation table with a footstool under their feet and ankles flexed with 90°. Neck was flexed so as the chin was touching the chest wall. This is the standard position used in our institution while performing regional anesthesia for labor. All ultrasound examinations (US) were performed before CSE procedure by the same investigator who had a five-year experience in spinal sonoanatomy. A portable ultrasound with a 2-5 MHz curved array probe (esaote MyLab30Gold; esaote, Italy) was used for skin to epidural space depth assessment and a built in caliper was used for epidural depth measurements. The pressure applied on the probe was released gradually to minimize measurement errors due to soft tissue compression until the US image was still legibly visible. The screen was frozen to measure the skin to epidural space depth. The distance between the skin and the posterior border of the posterior complex (i.e. ligamentum flavum + posterior epidural space + posterior dura mater) was measured and accepted as the epidural depth (ED) in both PSO plane and TM plane.

Paramedian sagittal oblique plane measurements

While the patient was sitting on the operation table in the CSE procedure position, ultrasound gel was wiped on the back of the parturient under non-sterile conditions. Ultrasound examination started at the midline from caudal to visualize the continuous hyperechoic line of sacrum. Then the probe was advanced cranially until the L3-4 intervertebral space was localized in the center of the probe. The skin was marked at the midpoint of the curved array probe on both sides. Then the probe was located 2-3 cm lateral to the midline and tilted to visualize the epidural space in PSO view (**Figure 1**). After obtaining clear vision of lamina, posterior complex (ligamentum flavum, posterior epidural space, posterior dura), intrathecal space, and anterior complex (anterior dura and reflection of vertebral body) the pressure on the
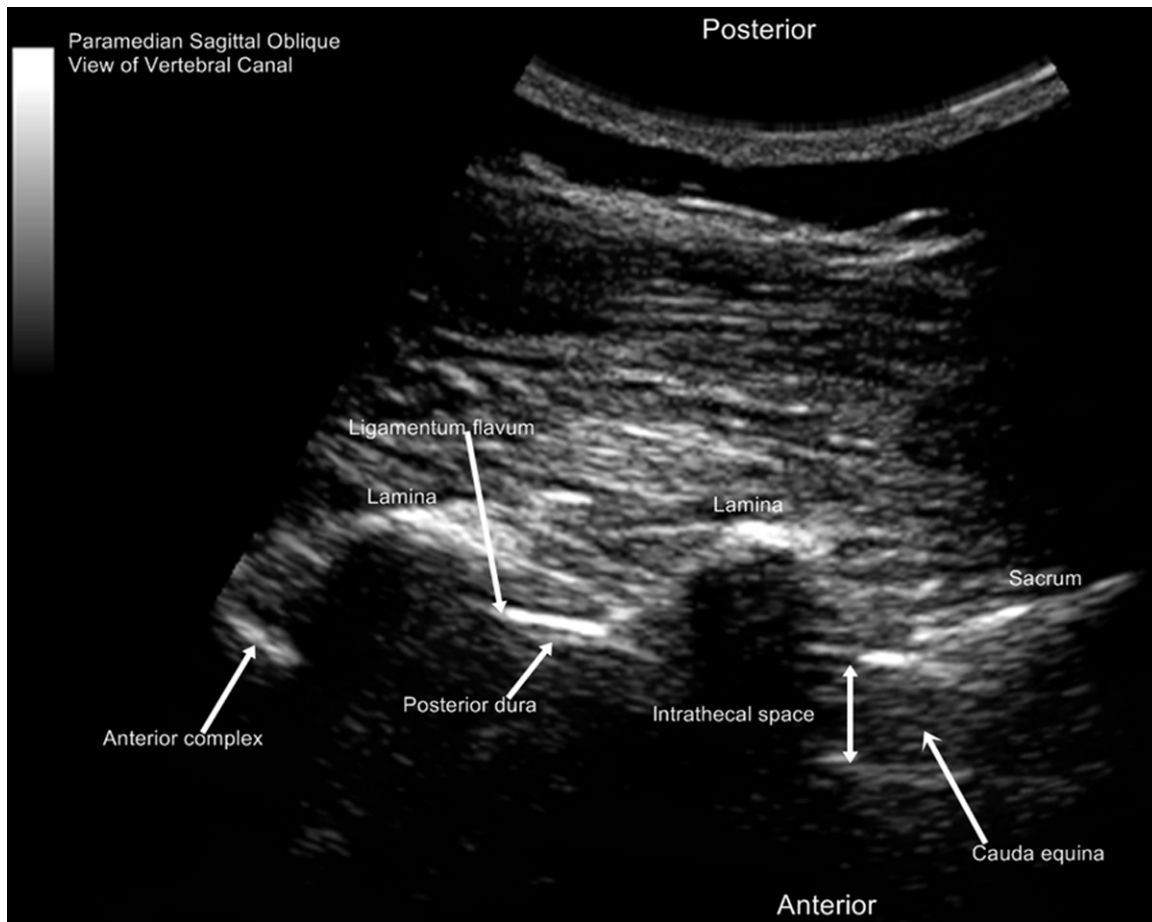
Figure 1. Paramedian sagittal oblique view of vertebral canal.

probe was released gradually to decrease the pressure applied on the soft tissue until the anatomical structures were still legibly visible. The screen was frozen for PSO/ED measurements with the built in caliper of the ultrasound.

Transverse median plane view

After completion of PSO plane assessment of the epidural space, the probe was oriented to the horizontal plane at the level of predetermined L3-4 intervertebral space. Moving the probe cranially or caudally, the spinous process was determined and centered on the screen. The skin was marked at midpoint of the probe on both sides to determine the midline. Then the probe was moved to the acoustic window at L3-4 interspace to obtain TM view (**Figure 2**). After clear visualization of the articular processes, transverse processes, posterior complex, and vertebral body the pressure on the

probe was released as aforementioned and the screen was frozen for the measurement of TM/ED with the built in caliper of the ultrasound.

Combined spinal epidural procedure

With the completion of US measurements, the predetermined skin marks were elongated to intersect in vertical and horizontal planes. The intersection point was determined as the insertion site for the Tuohy needle (**Figure 3**). Ultrasound gel was cleansed from patients' back. Following standard sterile draping a staff anesthesiologist in charge of the patient who was blinded for the US measurements of epidural depth but had the knowledge of L3-4 interspace performed CSE. All CSE procedures were done with a midline approach. Skin was infiltrated with 2 ml of 2% lidocaine. The Tuohy (Espocan + Docking System + perifix® Soft Tip, BB-raun, Melsungen, Germany) needle was advanced until the anesthesiologist got the feeling of
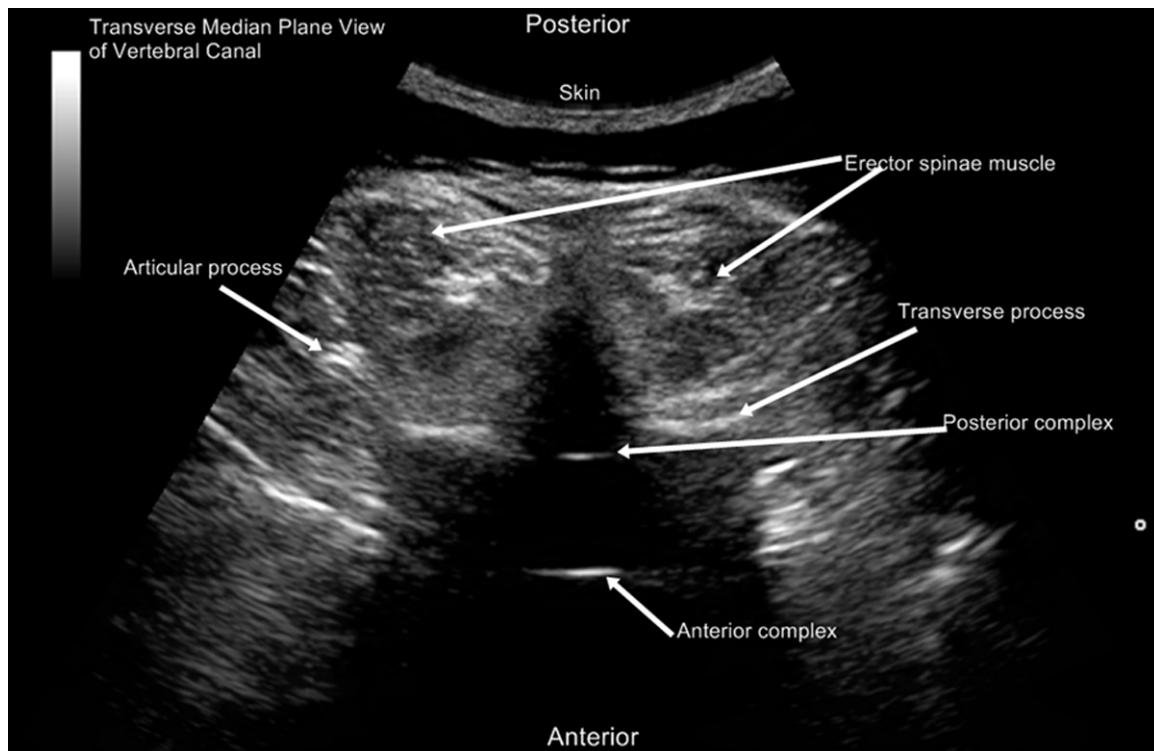
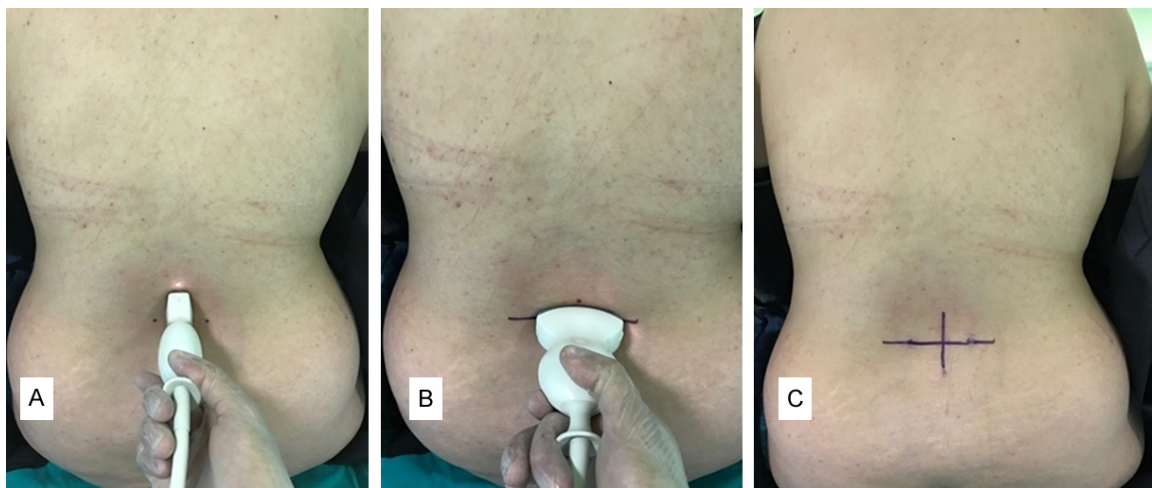**Figure 2.** Transverse median plane view of vertebral canal.

Figure 3. Determination of epidural insertion point. A: Longitudinal median plane; B: Transverse median plane; C: Intersection of transverse and vertical marks representing the epidural insertion point.

needle fixation in the posterior longitudinal ligament. The guide of the epidural needle was removed and the air filled injector was locked on the hub of Tuohy needle. Epidural space was localized with loss of resistance to air in all parturients. Once the anesthesiologist located the epidural space, a sterile marker band was at-

tached on the Tuohy needle for the measurement of ND. Spinal needle was advanced with needle-through-needle technique and 13.5 mg hyperbaric bupivacaine was injected. The spinal needle was withdrawn and the epidural catheter was advanced five centimeters in epidural space. The Tuohy needle was removed

Table 1. Characteristics and anthropometric measurements of parturients

Characteristics	Mean	SD	Range
Maternal age (years)	28.19	4.85	18-40
Height (cm)	162.6	6.2	149-176
Weight (kg)	81.9	12.4	57-120
BMI (kg/m^2)	31.0	4.5	21.9-43.0
PSO/ED (mm)	56.07	9.31	41.40-85.20
TM/ED (mm)	55.99	9.15	41.20-85.10
ND (mm)	56.17	9.28	42.00-86.00

BMI: body mass index, PSO/ED: ultrasound estimate of the epidural depth measured with ultrasound in paramedian sagittal oblique plane, TM/ED: ultrasound estimate of the epidural depth measured with ultrasound in transverse median plane, ND: actual needle depth, SD: standard deviation.

gently to measure ND with a tape measurer that had centimeter and millimeter lines. Parturients were positioned to supine with left lateral uterine tilt.

The primary outcomes of the study were the determination of PSO/ED and TM/ED in parturients scheduled for cesarean section with CSE. Another primary outcome was the determination of ND. The last primary outcome of the study was to determine the correlation between these three measurements. The objective of this study was to explore the accuracy and precision between the ND, PSO/ED and TM/ED in parturients undergoing cesarean section with CSE.

Statistical analysis

Data obtained from ninety parturients were analyzed. There were no dropouts. The statistical analysis of data was performed with IBM SPSS 21.0 (SPSS Inc., Chicago, IL, USA) package program. Analysis of descriptive data was expressed as mean and standard deviation for continuous parameters and percentages for nominal parameters. A bivariate linear correlation analysis (Pearson correlation analysis) was used to test the correlation between ND, PSO/ED, and TM/ED.

Bland-Altman analysis was performed to place the magnitudes of the differences between the two measurements in a more clinical context [20, 21]. The mean difference was calculated by subtracting the two variables divided by two. The mean value of measurements was calcu-

lated by the summation of the two variables divided by two. The 95% limits of agreement between the two measurements with a probability of 95% were determined. This analysis was graphically plotted where y-axis represented the mean difference between the two measurements and x-axis represented the mean of the two measurements. Normal distribution of data was analyzed with Shapiro-Wilk test.

The accuracy of the measurements was analyzed with Lin's concordance correlation coefficient (CCC) [22, 23]. CCC for ND with PSO/ED and TM/ED and the CCC for PSO/ED with TM/ED were plotted on a figure showing the deviation from the best fit line (accuracy) and the line of perfect agreement (precision).

Sample size

The sample size of the study was calculated with MedCalc Software (Medcalc Software bvba, Acacialaan 22, 8400, Ostend, Belgium) based on a study by Arzola [15]. The correlation coefficient between ultrasound depth and needle depth was 0.88 and the mean difference was 0.01 cm with a standard deviation of 0.3 cm in that study. Based on this data a sample size of 81 parturients would be necessary for a power level of 80% with an expected mean difference of 0.01 mm, and expected standard deviation of differences 0.5 with a type I error of 0.05. Ninety parturients were recruited to compensate for the probable dropouts and to increase the power.

Results

A total of ninety parturients from June to October 2018 and data from all parturients were analyzed. The mean age of parturients was 28.18 ± 4.85 (range 18-40 years), mean body mass index (BMI) was 31.01 ± 4.53 (range 21.87-43.03). Fifty parturients had a BMI ≥ 30 kg/m^2, and forty had a BMI < 30 kg/m^2. All parturients received combined spinal epidural anesthesia with loss of resistance to air technique at L3-4 interspace with the midline approach. Patient characteristics and anthropometric measurements are presented in **Table 1**.

The PSO/ED was 56.07 ± 9.31 mm (range 41.40-85.20 mm), the TM/ED was 55.99 ± 9.15 mm (range 41.20-85.10 mm) and the ND

Table 2. Agreement between ultrasound estimated epidural space depth and actual epidural depth

	PSO/ED-ED	TM/ED-ND	PSO/ED-TM/ED
CCC	0.9929	0.9928	0.9959
95% CI	0.9892-0.9953	0.9891-0.9952	0.9939-0.9973
Pearson's r (Precision)	0.9929	0.9931	0.9961
Bias correction factor (Accuracy)	0.9999	0.9997	0.9998
95% limits of agreement (mm)	-1.1356	-1.1594-0.9838	-0.7761-0.8495
Mean difference (mm)	-0.0511	-0.0878	0.0367

CCC: Lin's concordance correlation coefficient, 95% CI: 95% confidence interval, PSO/ED: ultrasound estimate of the epidural depth measured with ultrasound in paramedian sagittal oblique plane, TM/ED: ultrasound estimate of the epidural depth measured with ultrasound in transverse median plane, ND: actual needle depth.
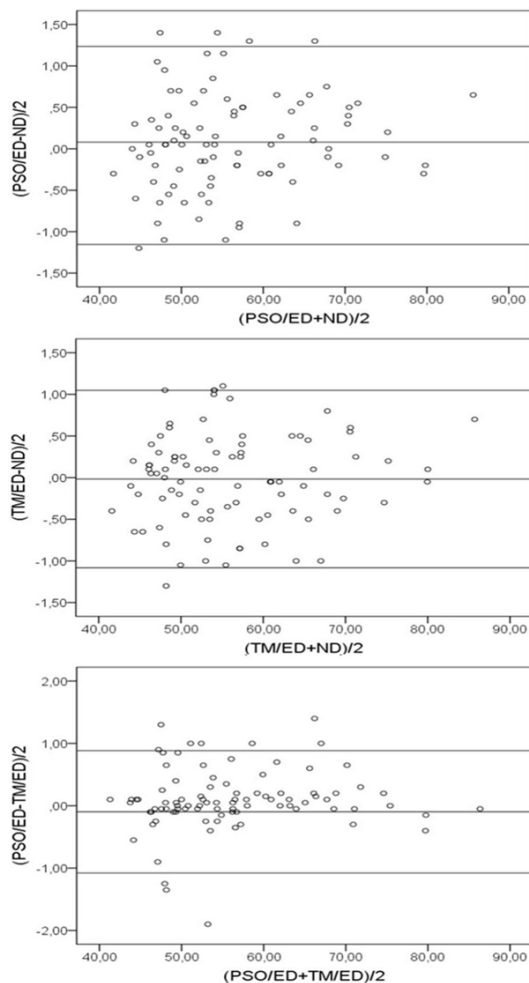

Figure 4. Bland-Altman analysis. PSO/ED: ultrasound estimate of the epidural depth measured with ultrasound in paramedian sagittal oblique plane, TM/ED: ultrasound estimate of the epidural depth measured with ultrasound in transverse median plane, ND: actual needle depth to epidural space.

was 56.17 ± 9.28 mm (range 42.00-86.00 mm) (**Table 1**).

Bland-Altman analysis showed that the mean difference between PSO/ED and ND was -0.05 mm (95% Limits of agreement -1.14-1.03 mm), the mean difference between TM/ED and ND was -0.08 mm (95% Limits of agreement -1.16-0.98 mm), and the mean difference between PSO/ED and TM/ED was 0.04 mm (95% Limits of agreement -0.78-0.85 mm) (**Table 2** and **Figure 4**). All differences presented normal distribution (P > 0.05).

Concordance correlation coefficient (CCC) between PSO/ED and ND was 0.9929 (95% confidence interval 0.9892-0.9953) with an accuracy of 0.9999 and a precision of 0.9929. CCC between TM/ED and ND was 0.9928 (95% confidence interval 0.9891-0.9952) with an accuracy of 0.9997 and a precision of 0.9931. The CCC between PSO/ED and TM/ED was 0.9959 (95% confidence interval 0.9939-0.9973) with an accuracy of 0.9998 and a precision of 0.9961 (**Figure 5**).

Discussion

Preprocedural ultrasound estimates of both PSO/ED and TM/ED provide a reliable estimate of the ND with a high precision and accuracy facilitating the CSE procedure in parturients scheduled for cesarean section. It is very important to emphasize that as described by Sahota [19] and also highlighted in this study, after obtaining the clear image of the vertebral sonoanatomy the pressure applied on the curved array probe should be released until the structures are still legibly visible to obtain precise measurements.

Loosening of the ligaments and soft tissue, increased subcutaneous adipose tissue and edema, and the changes in the axis of spinal
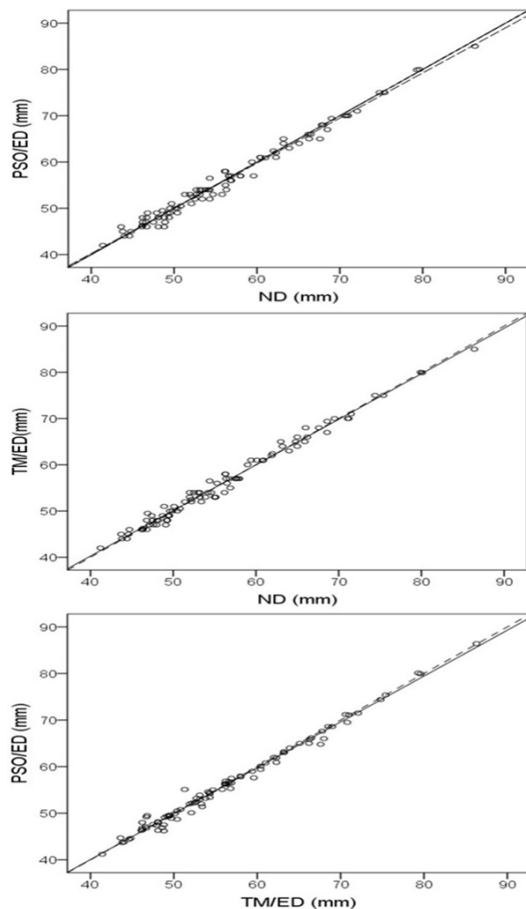
Figure 5. Concordance correlation coefficient plots. Dotted lines represents the best fit line, solid lines represent the reference line. PSO/ED: ultrasound estimate of the epidural depth measured with ultrasound in paramedian sagittal oblique plane, TM/ED: ultrasound estimate of the epidural depth measured with ultrasound in transverse median plane, ND: actual needle depth to epidural space.

column during pregnancy is associated with misleading results while determining the epidural insertion point with traditional palpation method [24-26]. These limitations force the anesthesiologist to perform pre-procedural assessment of epidural space whenever eligible during labor epidurals.

The correlation between ND and PSO/ED in general obstetric population has not been reported in the literature yet. Sahota [19] have reported the use of paramedian sagittal oblique plane ultrasound scanning in obese parturients and suggested that ultrasound estimates of the depth to epidural space in PSO plane have a good correlation with the actual epidural

depth. The results reported here are in agreement with this suggestion. The accuracy (0.9999) and the precision (0.9929) of ND with PSO/ED in this study were almost excellent.

Several previous studies reported the correlation of ND with TM/ED [9, 10, 15-18, 25]. Grau [9] and Arzola [15] have concluded in their studies that transverse plane ultrasound estimates of the epidural space was in good agreement with the needle depth and could be a reliable guide to facilitate labor epidural insertion. In accordance with these former studies our TM/ED measurements had a very good accuracy (0.9997) and an almost excellent precision (r = 0.9931) with ND.

The aforementioned modified ultrasound scanning technique is very effective to minimize underestimation of the epidural depth. Despite using this technique both PSO/ED and TM/ED measurements were under the ND (mean values are 56.07 ± 9.31 mm, 55.99 ± 9.15 mm, and 56.17 ± 9.28 mm respectively). However this difference does not make sense in clinical practice. Both PSO/ED and TM/ED warrant reliable estimates for ND both in obese and non-obese parturients. The precision and accuracy of PSO/ED reported in this study should be validated by new clinical trials in the general population.

One of the limitations in our study was that the anesthesiologist locating the epidural space was knowledgeable about the exact location for needle insertion at L3-4 interspace although s/he was blinded for the ultrasound estimated depths of epidural space. This information might have introduced a potential for bias. But for ethical reasons and to increase patient safety this knowledge had to be provided to the anesthesiologist in charge of the patient. A second limitation of the study was the number of needle insertions, redirection attempts, and the time spent for ultrasound imaging was not recorded.

All parturients included in the study had successful labor anesthesia with CSE. None of the patients had dural puncture. No complications were reported during the CSE procedure and 24 hours postoperatively related to CSE anesthesia.

In conclusion, both PSO/ED and TM/ED have a high correlation and accuracy with ND. Gra-

dually decreasing the pressure applied on the probe decreases the probability of underestimation of epidural depth. Although both measurement techniques provide a good estimate of the epidural depth, it must be acknowledged that none of the ultrasound estimated epidural depths discard the use of loss of resistance technique while performing labor epidurals.

Disclosure of conflict of interest

None.

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