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ORIGINAL ARTICLE

Abdominal girth has a strong correlation with ultrasound-estimated epidural depth in parturients: a prospective observational study

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Abstract

Background Preprocedural ultrasound examination of vertebral column guides to locate desired intervertebral space and provides a prevision of needle trajectory and estimated needle depth in parturients. The objective of this study was to assess the correlation between ultrasound-estimated epidural depth (ED) with abdominal girth (AG), body mass index (BMI), weight, height, and age.

Methods In this prospective, observational study, ultrasound imaging was done at L3–4 interspace in transverse median plane (TP) and paramedian sagittal oblique plane (PSO) to obtain ultrasound estimates of skin to epidural space depth. Combined spinal epidural anesthesia was performed at L3–4 interspace. AG, BMI, age, height, and weight were recorded for every parturient.

Results Data from 130 parturients were analyzed. Estimated ED was 56.5 ± 9.5 mm in TP, 57.5 ± 9.3 mm in PSO, and actual epidural depth was 57.9 ± 9.4 mm. Correlation coefficients between ED and AG were 0.797 in TP (95% CI 0.727–0.854, $p < 0.001$) and 0.803 in PSO (95% CI 0.733–0.857, $p < 0.001$). Correlation coefficients between ED and BMI were 0.543 in TP (95% CI 0.405–0.661, $p < 0.001$) and 0.566 in PSO (95% CI 0.428–0.680, $p < 0.001$). Correlation coefficients between ED and weight were 0.593 in TP (CI = 0.466–0.695, $p < 0.001$) and 0.615 in PSO (CI = 0.500–0.716, $p < 0.001$). Height and age had no significant correlation with ED.

Conclusions Abdominal girth has a strong correlation with ultrasound-estimated epidural depth in parturients.

Keywords Abdominal girth · BMI · Weight · Epidural · Ultrasound

Introduction

Combined spinal epidural anesthesia (CSE) is widely used during elective cesarean section [1–3]. CSE provides advantages of both spinal and epidural anesthesia by reducing the onset time of anesthesia and the need for local anesthetic dose meanwhile providing a route for postoperative analgesia and reducing the risk of conversion to general anesthesia [4–6].

Neuraxial anesthesia is technically demanding and is recommended to be performed by experienced specialists [7]. Localization of epidural space in parturients is challenging due to normal anatomical changes of vertebrae during pregnancy (tissue edema, weight gain, hyperlordosis, and progressive pelvic rotation over the long axis of the vertebral canal) [8, 9]. If the epidural needle is located external to the ligamentum flavum due to false loss of resistance, it will result in failed epidural anesthesia [10]. If the needle is advanced further beyond posterior dura, it will result in an unintended dural puncture [10].

The use of ultrasound for the detection of epidural depth has become more popular in the last 2 decades which provides preliminary information about the length of the epidural needle to be advanced through a predetermined needle trajectory [1, 11–15].

Although ultrasound guidance provides a reliable prediction of needle depth to locate epidural space, it is not always attainable in every operation room, especially in developing countries. X-rays and CT have problems of radiation exposure, and image information of the lumbar spine is often limited. Therefore, a reliable formula estimating the

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epidural depth derived from the anthropometric measures of the patients may guide the clinicians to identify the desired intervertebral space. Several prior studies focused on the correlation of skin to epidural depth with patient characteristics as age, weight, height, and body mass index (BMI), and many formulations have been proposed to predict the skin to epidural space depth [10, 16–22].

Distribution of fat tissue changes during pregnancy. Fat accumulation is more in the abdominal region [23]. This redistribution may increase the distance from skin to epidural space. We hypothesized that the abdominal girth correlated with the skin to epidural space depth in parturients with uncomplicated pregnancies.

The aim of the current study was to determine the correlation of ultrasound-estimated skin to epidural depth in both transverse median plane (TP) and paramedian sagittal oblique plane (PSO) with abdominal girth (AG), age, weight, height, and BMI of parturients scheduled for elective cesarean section with CSE.

Methods

This prospective, observational study was conducted from 31 May, 2018 to 31 August, 2018 to assess the correlation between the ultrasound-estimated skin to epidural depth in TP and PSO with the AG, weight, height, age, and BMI of parturients. After approval from the institutional review board of Ahi Evran University Training and Research Hospital (an affiliation hospital), ethical committee consent was approved from Ahi Evran University Faculty of Medicine Clinical Researches Ethics Committee (26/12/2017, 2017-20/242) and the study was prospectively registered at Australian New Zealand Clinical Trials Registry (ACTRN12618000584235, 16/04/2018). Written informed consent was obtained from all parturients. The study was prepared following the Declaration of Helsinki and strengthening the reporting of observational studies in epidemiology (STROBE) guidelines.

Parturients with American Society of Anesthesiologists (ASA) physical status II–III, singleton term pregnancies, aged 18–45 years scheduled for elective cesarean section with CSE were included in the study. Parturients with neurological diseases, vertebral column anomalies, history of spine or spinal canal surgeries, fetal presentation anomalies, multiple pregnancies, complicated pregnancies (polyhydramnios and oligohydramnios), presence of fetal anomaly, history of anticoagulant drug use, and patients rejecting CSE were excluded from the study.

Following the acceptance of the patient to the operation room, parturients were monitored with electrocardiogram, pulse oximeter, and non-invasive blood pressure, and a 16-G catheter was secured on the dorsum of the left hand for intravenous infusion. Patient age, height, weight, and BMI were recorded. AG was measured at the level of umbilicus of the parturient at sitting position by a tape measure in the horizontal plane.

Ultrasound scanning

Ultrasound scanning (US) was performed before performing CSE at sitting position. All USs were performed before sterile draping by the same investigator who had a 5-year experience in spinal ultrasonography. A portable ultrasound with a 2–5 MHz curved array probe (Esaote MyLab30Gold, Italy) was used for skin to epidural depth assessment, and a built-in caliper was used for measurements. The pressure applied on the probe was released gradually until the US image was still visible to minimize the measurement error and the screen was frozen to measure the skin to epidural space depth. The distance between skin and the posterior complex (components of the posterior complex are: ligamentum flavum, epidural space, and posterior dura mater) was measured and accepted as the epidural depth in both PSO and TP view on the US image.

PSO US was performed initially for the identification of the upper border of the sacrum and the adjacent lamina. The curved array probe was located in midline over the sacral region to identify the hyperechoic continuous line of the sacrum. Once the laminas were visualized, L3–4 interspace was centered and marked with a permanent marker on the skin. Then the probe was moved 1–2 cm laterally from the midline and tilted obliquely to obtain PSO view of the vertebral canal. What we saw in the US from backward to front in PSO view was the skin, subcutaneous tissue, erector spinae muscle, lamina, posterior complex, subarachnoid space, and cauda equine located in subarachnoid space, anterior dura mater, posterior longitudinal ligament, and the vertebral body.

After completion of PSO measurement, the ultrasound probe was located at predetermined L3–4 interspace in the horizontal orientation, perpendicular to the long axis of the vertebral canal to gain the TP view. Anatomical structures identified in TP were the spinous process, transverse processes, articular processes, posterior complex, and vertebral body. The screen of US was frozen for measurement of skin to epidural space depth in TP. The spinous process was centered, and the skin was marked with a permanent marker. The probe was then moved cephalad or caudal to locate the acoustic window to determine the optimal trajectory of the epidural needle.

Combined spinal epidural anesthesia procedure

After completion of US assessments, parturients were kept at sitting position as their US was performed, and the skin was cleansed from ultrasound gel. The predetermined midline skin marks were elongated in longitudinal and horizontal axis at L3–4 interspace level. The intersection of both lines was determined as the point of insertion for the Tuohy epidural needle (BBraun Melsungen AG, Melsungen, Germany). After conventional sterile draping and local infiltration of the skin and subcutaneous tissue with 2 ml 2% lidocaine, a staff anesthesiologist performed the CSE procedure with midline approach. The Tuohy needle was introduced until the needle was fixed in the interspinous ligament and then the needle was advanced by the loss of resistance to air technique until the epidural space was localized. The spinal needle was introduced through the Tuohy needle (needle-through-needle) and locked on the epidural needle with the sensation of dural puncture. After observation of free-flowing cerebrospinal fluid, the intrathecal drug was administered. The spinal needle was removed, and the epidural catheter was fixed for postoperative analgesia with 5-cm advancement to the epidural space. Before removing the epidural needle, a sterile band was stuck on the Tuohy needle at the level of skin-epidural needle intersection point to measure the actual epidural depth. Tuohy needle was then withdrawn, and the actual epidural depth was measured on the epidural needle between the tip of the epidural needle and the sterile marker with a tape measure that had millimeter calibration. The patient was then turned to supine with left lateral uterine displacement.

The objective of the study was assessing the correlation between ultrasound estimates of skin to epidural depth in both TP and PSO with AG, age, weight, height, and BMI in uncomplicated parturients scheduled for elective cesarean section with CSE. A mathematical equation was generated to estimate the epidural depth from the linear regression analysis of the parturients' data.

Statistical analysis

The statistical analysis of all data was performed with IBM SPSS 21.0 (SPSS Inc., Chicago, IL, USA) package program. Descriptive data were expressed as means and standard deviations for continuous parameters and percentages for nominal parameters. A bivariate linear correlation analysis (Pearson correlation analysis) was used to test the correlation between the ultrasound-estimated skin to epidural depth in PSO and TP with the age, weight, height, AG, and BMI of parturients. A linear regression analysis was used with the stepwise method to detect the correlation between the ultrasound estimates of the skin to the epidural depth and parturients' age, weight, height, AG, and BMI at both PSO and TP assessments. Skin to epidural depth was determined as the dependent variable, and the patient characteristics and anthropometric measures were the independent variables. A p value < 0.05 was considered statistically significant.

The sample size of the study was calculated using the data obtained from the preliminary results of the study with G*Power 3.1.9.2, a flexible statistical power analysis package program. Five patient variables were included in the current study. Minimum required sample size (n) was 129 to detect a desired statistical power level of 0.95 at a probability level of 0.05.

Results

Prospective data of 130 parturients were collected in the study. All the parturients completed the study. Epidural needle placement was done with the loss of resistance to air in all the parturients with midline approach. None of the patients had unintended dural puncture during the epidural procedure of CSE. No complications were reported during the surgery and 48 h postoperatively. Maternal demographic data are presented in Table 1.

The epidural depth measured by ultrasound at L3–4 interspace was 57.5 ± 9.3 mm and 56.5 ± 9.5 mm for PSO and TP, respectively. The correlation of actual epidural depth with the ultrasound estimates of epidural depth at PSO and TP were 0.992 and 0.991, respectively ($p < 0.001$ for both). Estimated epidural depth in PSO was strongly correlated with AG ($r = 0.801$, $p < 0.001$), BMI ($r = 0.566$, $p < 0.001$), and weight ($r = 0.615$, $p < 0.001$) of parturients (Table 2). Age ($r = 0.138$, $p = 0.118$) and height ($r = 0.170$, $p = 0.053$) of parturients did not have a statistically significant correlation with estimated epidural depth in PSO. Estimated epidural depth in TP had a high correlation with AG ($r = 0.797$, $p < 0.001$), BMI ($r = 0.543$, $p < 0.001$), and weight ($r = 0.593$, $p < 0.001$) of the parturients (Table 2). Age ($r = 0.139$, $p = 0.114$) and height ($r = 0.169$, $p = 0.055$)

Table 1 Demographic characteristics and anthropometric measurements of parturients

ASA-PS I/II/III (n)	0/126/4
Age (years)	28.6 ± 4.9
Weight (kg)	82.6 ± 12.9
Height (cm)	162.3 ± 6.3
BMI	31.3 ± 4.5
AG (cm)	114.8 ± 9.4
ED/PSO (mm)	57.5 ± 9.3
ED/TP (mm)	56.5 ± 9.5
ED/Actual (mm)	57.9 ± 9.4

Values are expressed as mean ± standard deviation except for ASA

ASA-PS American Society of Anesthesiologist physical status, *BMI* body mass index, *AG* abdominal girth, *ED/PSO* ultrasound-estimated skin to epidural depth in paramedian sagittal oblique plane, *ED/TP* ultrasound-estimated skin to epidural depth in transverse median plane, *ED/Actual* actual skin to epidural depth

Table 2 Correlation of patient variables and anthropometric measurements with ED/PSO and ED/TP

	ED/PSO				ED/TP			95% CI
	r	p	R^2	95% CI	r	p	R^2	
Age (years)	0.138	0.118	0.02	−0.035–0.303	0.139	0.114	0.02	−0.034–0.304
Weight (kg)	0.615	< 0.001	0.38	0.495–0.712	0.593	< 0.001	0.35	0.489–0.694
Height (cm)	0.170	0.053	0.03	−0.002–0.333	0.169	0.055	0.03	−0.003–0.331
BMI	0.566	< 0.001	0.32	0.437–0.673	0.543	< 0.001	0.29	0.409–0.654
AG (cm)	0.801	< 0.001	0.64	0.729–0.855	0.797	< 0.001	0.64	0.725–0.853

ED/PSO Ultrasound-estimated skin to epidural depth in paramedian sagittal oblique plane, *ED/TP* Ultrasound-estimated skin to epidural depth in transverse median plane, *BMI* body mass index [weight/(height)^2], *AG* abdominal girth, *r* Pearson correlation coefficient, *p* statistical significance, R^2 coefficient of determination, *95% CI* 95% confidence interval for Pearson correlation coefficient (r)

had no correlation with estimated epidural depth in TP measurements. According to linear regression model, best predictive formula for estimated epidural depth in PSO was [$a = 0.794 \times b - 33.7$] where a = estimated epidural depth in PSO in millimeters and b = AG in centimeters. The formula to predict estimated epidural depth in TP was [$a = 0.809 \times b - 36.3$] where a = estimated epidural depth in TP in millimeters and b = AG in centimeters.

Discussion

Our study confirmed that there was a strong correlation between the ultrasound-estimated skin to epidural depth in both PSO and TP with parturients' AG, weight, and BMI. The mathematical formula derived from the statistical analysis provided a reliable estimate of epidural depth that can increase the safety while performing CSE for cesarean section.

Due to the technical difficulty of epidural anesthesia in parturients, preprocedural knowledge about the depth of epidural space is of great importance. Ultrasound estimates of the skin to epidural space depth provide important and dependable information for the needle depth and the needle trajectory [12–15, 24]. Former studies reported that either TP or PSO view could be used to estimate the skin to epidural depth [11, 25]. In the present study the correlation coefficient of actual epidural depth with the ultrasound-estimated epidural depth in PSO was 0.992 and 0.991 in TP. These findings are in agreement with the study of Arzola et al. [11], and Sohota et al. [25].

Several previous studies suggested mathematical equations to estimate the skin to epidural space depth [10, 16, 18–22, 26–28]. In Craig et al. [28] study, they reported that there was a linear relationship between the depth of needle insertion and patient height, which is in contrast to our results. The study was conducted on children aged 0.01–16 years whereas our study included parturients aged from 18 to 40 years. We did not find a significant correlation between the height of the parturients with the ultrasound-estimated epidural depth in both TP ($r = 0.17$, $p = 0.055$) and PSO ($r = 0.017$, $p = 0.053$). This finding is in accordance with the previous studies [1, 17, 18].

There was a positive correlation between weight and BMI with the skin to epidural space depth in the present study. The correlation coefficients were 0.615, and 0.566, respectively. These findings are in almost constant agreement with the results reported by Bassiakou et al. [1]. The correlation coefficients reported by their study group were 0.6 and 0.54, respectively. In Razavizadeh et al. [18] study, which was conducted on 297 male/88 female patients, aged 18–65 years, there was a stronger relationship between weight and BMI with the epidural depth than the present study. Unlike our study, that work included mostly males in the study group. Besides, the age group was very diverse.

To the best of our knowledge, this is the first study to assess the relationship between AG with the ultrasound-estimated skin to epidural space depth on parturients. The change in the distribution of body fat during pregnancy favors the deposition of fat in the abdominal region [23]. Although BMI increases with the gestational weight gain, it does not distribute evenly. We demonstrated a strong correlation between the AG with the ultrasound estimates of epidural depth in parturients (r: 0.801 in PSO and r: 0.797 in TP). The reason for this strong correlation may be the uneven distribution of gained weight around the abdominal region during pregnancy. We formulated a mathematical equation derived from the results of linear regression analysis to estimate the skin to epidural depth as [$a = 0.794 \times b - 33.7$] where a = ultrasound-estimated epidural depth in PSO in millimeters and b = AG in centimeters, or [$a = 0.809 \times b - 36.3$] where a = ultrasound-estimated epidural depth in TP in millimeters and b = AG in centimeters. For a parturient whose AG is 114.8 cm (mean AG for the current study), and actual epidural depth is 57.9 mm, ultrasound-estimated epidural depth in PSO = $0.794 \times 114.8 - 33.7 = 57.5$ and ultrasound-estimated epidural depth in TP = $0.809 \times 114.8 - 36.3 = 56.6$. Although both formulas provide reliable estimates of the epidural depth, we acknowledge the clinicians that the product of the formulas does not discard the use of loss of resistance technique while performing epidurals.

There were some limitations regarding the present study. First, we did not include weight/height ratio for the correlation analysis which was assessed in previous studies [16, 18]. Although the results of these two studies presented a positive correlation between weight/height ratio and the epidural depth, these studies were conducted on patients younger than 18 years of age. Second, we did not consider the ethnicity of the parturients which was assessed by Sharma et al. [19]. Further studies on different ethnical parturient populations are needed to validate our results.

In conclusion, preprocedural ultrasound estimates of the skin to epidural depth strongly correlate with the AG of parturients. US, either in TP or PSO view, has a crucial role to increase the success of labor epidurals and to avoid unintended dural puncture. We suggest that AG-based formula provides reliable estimates for the skin to epidural depth in parturients.

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Author contributions MC: project design, data collection, statistical analysis, and writing manuscript. FKC: data collection, supervision, writing, and final manuscript check. NK: data collection and statistical analysis. MH: data collection and final manuscript check.

Compliance with ethical standards

Conflict of interest All authors declare that they have no conflict of interest.

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