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VALIDATION OF AN ANTHROPOMETRIC FORMULA FOR PREDICTING EPIDURAL DEPTH IN OVERWEIGHT INDIAN SURGICAL PATIENTS: A PROSPECTIVE OBSERVATIONAL STUDY

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ABSTRACT

Background: Epidural catheter placement in overweight patients is difficult because of altered landmarks and increased skin-to-epidural space distance. Predictive equations may aid in planning and reducing complications. This study evaluated the accuracy of a predictive equation for estimating the skin-to-epidural space distance in overweight surgical patients (BMI: 25-29.9 kg/m²) by comparing the estimated and actual depths. **Materials and Methods:** This study involved 130 overweight patients from Chengalpattu Medical College over one year. Epidural depth was estimated using the formula 6.63- (0.07 × height in inches) +(0.02 × weight in pounds). Catheterisation was performed aseptically using the loss-of-resistance technique at T10-T11, T12-L1, or L1-L2. The actual depth was measured and compared. **Results:** Among the 130 patients, 64.6% were male and 35.4% were female. Most were aged 41-50 (34.6%), 160.1-170 cm tall (36.2%), weighed 61-70 kg (38.5%), and had a BMI of 28.1-29.0 kg/m² (32.3%). The catheter was mostly inserted in the right lateral position (87.7 %), with T10-T11 being the most common insertion site (40.0%). Bloody tap and dural puncture occurred in 6.9% and 4.6% of patients, respectively. The estimated depth was 5.1-5.5 cm (63.8%), actual 4.51-5.0 cm (46.2%). The mean estimated depth was higher than the actual depth (5.34 ± 0.22 cm vs. 4.66 ± 0.33 cm; P<0.001). Correlation analysis showed a strong association between the estimated and actual depths (R^2=0.693), with significant reliability (0.769). **Conclusion:** The predictive equation correlated with the actual depth but overestimated it in overweight Indian patients, limiting its direct clinical applicability without further validation.

INTRODUCTION

Epidural anaesthesia and analgesia are important in perioperative pain management, providing excellent nociceptive block, superior pain relief, less requirement for systemic opioids, and reduced associated adverse effects, such as sedation and respiratory depression. Other advantages include reduced stress response to surgery, improved postoperative recovery, early ambulation, and satisfaction levels.[1,2] Hence, epidurals have become common practice in major surgeries for optimal analgesia.1 Although epidurals play a key role in providing pain relief during surgeries, inserting an epidural catheter is difficult, particularly in individuals with altered anatomy. Obesity makes it difficult to perform anaesthesia procedures. Obese patients have additional layers of fat, making it difficult to feel the space between tissues, and hence, difficulty in identifying the correct location.[3,4] Similar challenges may also be encountered in overweight individuals, although this population has received comparatively less attention in the literature. These challenges lead to multiple insertion attempts, longer procedures, increased discomfort, and higher failure rates.

Difficult placements increase the risk of complications, including dural punctures and failed blocks. Although morbid obesity and neuraxial anaesthesia have been investigated, the overweight patient with a BMI of 25-29.9 kg/m² remains understudied despite procedural difficulties.[3,4] It is essential to estimate the depth of the epidural space prior to needle insertion. The distance from the skin to the epidural space depends on the patient's weight, height, body mass index, and body habitus. The loss-of-resistance method is subjectively used by anaesthesiologists and depends on the experience of the practitioner and anatomical variability. Consequently, there is an interest in objective techniques for estimating the epidural space distance prior to needle insertion in the scientific literature. Several imaging techniques have been examined for this purpose. Real-time ultrasound imaging provides information about the spinal anatomy and can estimate the skin-epidural distance.[5]

The correlation between the measurement of epidural depth and anthropometric parameters, such as body weight and BMI, has been established through MRI-based assessment techniques.[6,7] This has validated the hypothesis that patient-specific factors could help predict epidural depth. However, imaging techniques have their limitations. MRI is an expensive and time-consuming modality, whereas ultrasound requires special equipment and technical know-how, making it difficult in the case of obese patients due to poor acoustic windows and high fat content.[5] Prior studies have established the relationship between anthropometry and epidural depth in terms of body weight and BMI.[7] These findings provide a theoretical basis for using predictive equations in routine practice.

However, there are limitations to using and validating these models. Variability in anthropometry among ethnic groups and regions can influence the validity of the formulas generated for a particular population group. Regional variability in the body habitus of different populations indicates that models which are valid in Western populations are less likely to be equally valid in Asian populations.[8,9] Moreover, there is insufficient evidence regarding the applicability of anthropometric epidural depth prediction formulas in overweight Indian adults undergoing surgery. Whether these formulas accurately predict the actual epidural depth in this population remains unclear. There is also limited research comparing predicted and true epidural depths using loss-of-resistance-guided catheter insertion. Considering the common occurrence of overweight individuals and the difficulty involved in the process, the validation of simple anthropometric formulas is important. Therefore, the study aimed to evaluate the accuracy and clinical applicability of a predictive epidural depth equation for estimating the skin-to-epidural space distance before epidural catheter insertion in overweight patients (BMI: 25-29.9 kg/m²) undergoing surgery and to compare the estimated epidural depth with the actual depth during conventional epidural catheter placement.

MATERIALS AND METHODS

his prospective observational study was conducted among 130 overweight patients admitted to the Departments of Orthopaedics, General Surgery, and Obstetrics at Chengalpattu Medical College and Hospital, Chengalpattu, over a period of one year. Ethical approval was obtained from the Institutional Ethical Committee, and written informed consent was obtained from the participants before study initiation.

Inclusion and Exclusion criteria

This study included overweight patients of either sex aged 20-60 years undergoing surgeries with BMI of 25-29.9 kg/m² and ASA PS grades 1 and 2. Patients refusing consent, uncooperative patients, patients with ASA PS grade 3 and above, severe haemorrhage, shock, spine defects or post-laminectomy surgery, bleeding diathesis, and local inflammation were excluded from the study.

Sample size calculation

Sample size was calculated using the formula $N = Z^2pq/d^2$, where Z = 1.96 for 95% confidence interval, p = 92%, q = 8%, and d = 5%. The calculated sample size was 114. After adding 10% for non-response, the final sample size was rounded to 130 participants.

Materials

The study materials included a sterile tray, towel, gauze, sponge holding forceps, povidone-iodine solution, 2 ml syringe with 24 G needle for skin infiltration with 2% lignocaine, 5 ml syringe for a test dose of 3 ml of 1.5% lignocaine with 15 µg adrenaline, 16-gauge Tuohy needle, 5 ml glass syringe for identifying the epidural space via the loss of resistance method, anaesthesia machine, emergency airway equipment (laryngoscopes, blades, endotracheal tubes, LMAs, oropharyngeal airways), emergency drug tray, defibrillator, pulse oximeter, ECG, and NIBP monitor.

Methods

One hundred thirty patients were selected based on the inclusion criteria after Institutional Ethical Committee approval. Patient details were recorded confidentially and maintained throughout the study. Patients were assessed preoperatively and clinically examined with relevant investigations, including height and weight measurements. On the day of surgery, the patients were shifted to the operating theatre. The anaesthesia machine was checked along with emergency airway equipment, including laryngoscopes, blades, endotracheal tubes, LMAs, and oropharyngeal airways. Emergency drugs and defibrillators were ready. Patients were connected to monitors, including pulse oximeters, ECG, and NIBP. Intravenous cannulation was performed using an 18G venflon. Intravenous cannulation was performed using an 18G venflon, and 500 ml of isotonic intravenous fluid was administered before the procedure. Using the formula, epidural depth (cm)=6.63 − (0.07 × height in inches) +(0.02 × weight in pounds), epidural space depth was calculated before the procedure. Under aseptic precautions, patients were positioned right laterally, and epidural catheterisation was performed at the T10-T11, T12-L1, or L1-L2 level based on the surgery and dermatomal level.

Following skin infiltration with 2 ml of 2% lignocaine, a 16 G Tuohy needle with a 1 cm marking was inserted. The epidural space was identified using

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the loss of resistance method with a 5 ml glass syringe, and an epidural catheter was inserted. The point at which the epidural space was achieved was marked on the Tuohy needle with a sterile marker pen. A test dose containing 3 ml of 1.5% lignocaine with 15 µg adrenaline was administered to rule out vascular or subarachnoid placement. The catheter was secured with plaster, and drugs required for sensory or motor blockade were administered for the surgical procedure. After completion of the epidural catheter placement, the distance between the skin and epidural space was measured from the tip of the Tuohy needle to the marked point using a sterile ruler.

Statistical analysis

Data were presented as mean, standard deviation, frequency and percentage. Correlation between continuous and continuous variables were done using Pearson correlation test. One-sample t-test and intra-class correlation coefficient were used for comparison and reliability analysis. Significance was defined by P values less than 0.05 using a two-tailed test. Data analysis was performed using IBM-SPSS version 21.0 (IBM-SPSS Science Inc., Chicago, IL).

RESULTS

Among the 130 patients, 84 (64.6%) were men and 46 (35.4%) were women. The mean age was 39.68 ± 9.91 years. Most were aged 41-50 years, comprising 45 (34.6%), followed by 31-40 years 37 (28.5%), 20-30 years 31 (23.8%), and 51-60 years 17 (13.1%). The mean height and weight were 162.6 ± 9.09 cm and 73.78 ± 9.23 kg, respectively. Regarding height, 47 (36.2%) were 160.1-170 cm, 41 (31.5%) were 150.1-160 cm, 31 (23.8%) were 170.1-180 cm, 10 (7.7%) were under 150 cm, and 1 (0.8%) was over 180 cm. Regarding weight, 50 (38.5%) weighed 61-70 kg, 37 (28.5%) were 71-80 kg, 34 (26.2%) were 81-90 kg, 6 (4.6%) were under 60 kg, and 3 (2.3%) were over 90 kg. [Table 1]

Table 1: Baseline demographic and anthropometric characteristics of the patients

		N (%)
Sex	Male	84 (64.6%)
	Female	46 (35.4%)
Age (years)	20-30	31 (23.8%)
	31-40	37 (28.5%)
	41-50	45 (34.6%)
	51-60	17 (13.1%)
Height (cm)	<150	10 (7.7%)
	150.1-160	41 (31.5%)
	160.1-170	47 (36.2%)
	170.1-180	31 (23.8%)
	>180	1 (0.8%)
Weight (kg)	<60	6 (4.6%)
	61-70	50 (38.5%)
	71-80	37 (28.5%)
	81-90	34 (26.2%)
	>90	3 (2.3%)
BMI category (kg/m²)	25.1-26.0	13 (10.0%)
	26.1-27.0	28 (21.5%)
	27.1-28.0	30 (23.1%)
	28.1-29.0	42 (32.3%)
	29.1-29.9	17 (13.1%)

Most patients, 114 (87.7%) underwent epidural catheter insertion in the right lateral position, whereas 16 (12.3%) were in the sitting position. T10-T11 was the most common insertion level in 52 (40.0%) patients, followed by T12-L1 in 48 (36.9%) and L1-L2 in 30 (23.1%) patients. Complications included bloody tap in nine (6.9%) patients and accidental dural puncture in six (4.6%) patients. [Table 2]

Table 2: Procedural characteristics and complications associated with epidural catheter insertion

		N (%)
Epidural insertion position	Right lateral	114 (87.7%)
	Sitting	16 (12.3%)
Epidural insertion level	L1-L2	30 (23.1%)
	T10-T11	52 (40.0%)
	T12-L1	48 (36.9%)
Procedure-related complications	Bloody tap	9 (6.9%)
	Accidental dural puncture	6 (4.6%)

Based on the estimated epidural depth, most patients had a depth of 5.1-5.5 cm, in 83 (63.8%) patients, followed by >5.5 cm in 42 (32.4%) patients. Only five (3.8%) patients had an estimated depth of 4.51-5.0 cm, and none of the patients had a depth <4.5 cm. In contrast, the actual epidural depth was most commonly observed at 4.51-5.0 cm in 60 (46.2%) patients, followed by 5.1-5.5 cm in 51 (39.2%) patients. Epidural depth <4.5 cm occurred in 19

(14.6%) patients, whereas none had an actual depth >5.5 cm. [Table 3]

Table 3: Distribution of estimated and actual epidural depth space among patients

		Estimated EDS N (%)	Actual EDS N (%)
Epidural depth space (cm)	<4.5	0 (0.0%)	19 (14.6%)
	4.51-5.0	5 (3.8%)	60 (46.2%)
	5.1-5.5	83 (63.8%)	51 (39.2%)
	>5.5	42 (32.4%)	0 (0.0%)

The estimated epidural depth ranged from 4.80 to 5.90 cm, whereas the actual epidural depth ranged from 4.00 to 5.25 cm. The mean estimated epidural depth was 5.34 ± 0.22 cm, whereas the mean actual epidural depth was 4.66 ± 0.33 cm. The mean difference between estimated and actual epidural depth was 0.687 ± 0.19 cm, and this difference was statistically significant (P<0.001). [Table 4]

Table 4: Comparison between estimated and actual epidural depth space

	Mean ± SD	Range (cm)	P value
Estimated epidural depth space	5.34 ± 0.22	4.80–5.90	<0.001
Actual epidural depth space	4.66 ± 0.33	4.00–5.25	

Scatter plot analysis demonstrated a linear correlation between the estimated and actual epidural depths. Correlation analysis showed a positive association with an R^2 value of 0.693, indicating a significant relationship between the estimated and measured epidural depth values. The intraclass correlation for a single measure was 0.769 and was significant. [Figure 1]

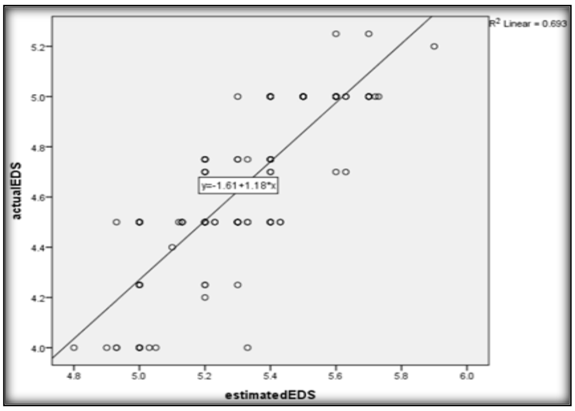

Figure 1: Correlation between estimated and actual epidural depth space

DISCUSSION

Our study determined the validity and clinical relevance of the epidural depth prediction formula among overweight patients undergoing surgery and compared the predicted epidural depth with the actual epidural depth measured during the traditional epidural catheter insertion process. The results of the current study revealed a highly statistically significant positive association between the actual and predicted epidural depths; however, the predicted value always exceeded the actual epidural depth. Male sex was the most common demographic characteristic in the present study, and the predominant age group ranged from 41 to 50 years. It was observed that most subjects had a BMI of 28.1-29.0 kg/m². Similar observations regarding the influence of anthropometric characteristics on epidural depth have been reported previously.

Adegboye et al. conducted a study among 120 Nigerian adults undergoing lumbar epidural anaesthesia and reported a mean skin-to-lumbar epidural space distance of 4.60 ± 0.83 cm with significant positive correlations between epidural depth, BMI (P=0.001), and body weight (P=0.004), while no significant correlation was observed with age, sex, or height. They further derived a regression formula based on BMI to predict epidural depth.[10] These findings are consistent with those of our study, in which body habitus significantly influenced epidural depth estimation and actual measured depth. Similarly, Alsaati et al. performed an MRI-based evaluation of lumbar epidural depth in 169 Saudi adults and reported mean skin-to-epidural space distances of 59.08 mm at L3-L4 and 63.21 mm at L4-L5. Their study demonstrated strong positive correlations between epidural depth, body weight, and BMI, whereas age and height did not show significant correlations with epidural depth measurements.[7] These studies have highlighted the importance of population-specific epidural depth assessment due to ethnic and anthropometric variations that influence epidural space depth. These observations correlate with the findings of our study, in which the predictive equation demonstrated a correlation with the actual epidural depth but showed overestimation when applied to the Indian overweight population.

In our study, epidural catheter insertion was predominantly performed in the right lateral position, and T10-T11 was the most common epidural insertion site. Procedure-related complications included bloody tap and accidental dural puncture. Difficulty in identifying the epidural space in overweight individuals due to obscured anatomical landmarks and increased soft tissue thickness has been consistently highlighted in the literature. Adegboye et al. reported that obesity significantly affects the identification of anatomical landmarks and contributes to increased epidural failure rates,

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particularly among overweight and morbidly overweight patients.[10]

Our study demonstrated that the majority of estimated epidural depth values ranged between 5.1-5.5 cm whereas the majority of actual epidural depth values ranged between 4.51-5.0 cm. The mean estimated epidural depth was 5.34 ± 0.22 cm, while the mean actual epidural depth was 4.66 ± 0.33 cm, with a significant difference between the two values (P<0.001). Scatter plot analysis demonstrated a strong positive correlation with an R^2 value of 0.693 and an intraclass correlation coefficient of 0.769, indicating substantial agreement between the estimated and actual epidural depth measurements, despite overestimation by the predictive equation.

Comparable findings were reported by Garg et al., who evaluated the effectiveness of an epidural depth equation versus preprocedural ultrasound-guided epidural block in 100 non-obstetric patients with a BMI between 18.5-29.9 kg/m² undergoing orthopaedic surgeries. This study observed a strong correlation between the epidural depth measured using ultrasound and the epidural depth equation (r^2=0.915, P=0.001). However, only a weak correlation was found between the epidural depth estimated using the epidural depth equation and the actual epidural needle depth (r^2=0.402, P=0.04).[11] These findings closely parallel the observations of our study, where a significant correlation existed despite consistent overestimation by the predictive formula.

Thomas et al. conducted an observational study evaluating the correlation between preprocedural ultrasound-estimated epidural depth and actual procedural epidural depth in 60 patients with BMI less than 30 kg/m². The study demonstrated excellent agreement between the ultrasound-derived depth and actual needle depth, with an intraclass correlation coefficient of 0.963 and a Pearson correlation coefficient of 0.960 (P=0.0001). However, subgroup analysis among patients with BMI 25-29.9 kg/m² showed only moderate agreement, with an ICC of 0.627 (P=0.008). This study concluded that an increase in BMI adversely affects the accuracy of epidural depth prediction.[12] These findings support the observations of our study, in which overweight patients demonstrated significant but imperfect agreement between estimated and actual epidural depth.

Similarly, Chauhan et al. evaluated ultrasound-derived lumbar epidural depth in 25 overweight Indian patients with BMI greater than 30 kg/m² and reported ultrasound and actual needle depth values of 4.614 ± 0.252 cm and 4.720 ± 0.271 cm, respectively. A very strong correlation was observed between ultrasound depth and actual needle depth, with Pearson's correlation coefficient r=0.953 and r^2=0.908 (P<0.001). Additionally, 92% of the patients required only a single epidural insertion attempt. This study concluded that preprocedural ultrasound significantly improves epidural insertion accuracy in overweight patients.[13] Compared with these findings, our study showed a lower agreement between the equation-derived epidural depth and actual epidural depth, further indicating that anthropometric equations may not achieve the same level of accuracy as imaging-based techniques.

Al-Ani et al. compared ultrasound-derived skin-to-posterior dura distance with BMI-based estimation in obstetric patients undergoing lumbar epidural analgesia. Ultrasound measurements matched the actual Tuohy needle depth in 76.7% of patients, whereas BMI-based estimation overestimated epidural depth in 83.3% of patients by a mean of 1.14 cm. This study concluded that ultrasound provides significantly greater accuracy than BMI-based epidural depth estimation.[14] These findings are highly comparable to those of our study, where the predictive equation significantly overestimated the actual epidural depth despite demonstrating a positive correlation.

CONCLUSION

Although the anthropometric formula showed a significant correlation with the actual epidural depth, it consistently overestimated the skin-to-epidural distance in overweight patients. These findings suggest that the formula cannot accurately predict epidural depth in its present form for the Indian overweight population. Further validation in larger and more diverse patient populations is required before its routine clinical use.

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