Section: Anaesthesiology

Original Research Article

A PROSPECTIVE OBSERVATIONAL STUDY ASSESSING THE ACCURACY OF PRE-PROCEDURAL LUMBAR ULTRASOUND IN THE PARAMEDIAN SAGITTAL VIEW FOR PREDICTING EPIDURAL SPACE DEPTH

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ABSTRACT

Background: Identification of the epidural space using conventional landmark-guided techniques may be difficult in patients with obesity, poorly palpable landmarks, and altered spinal anatomy. Pre-procedural lumbar ultrasonography has emerged as a useful tool for estimating epidural space depth and improving the success of neuraxial procedures. **Aim:** To assess the accuracy of pre-procedural lumbar ultrasound in the paramedian sagittal view for predicting epidural space depth. **Objectives:** To measure epidural space depth using pre-procedural lumbar ultrasound in the paramedian sagittal view. To compare ultrasound-estimated epidural depth with actual epidural needle depth. To determine the correlation between ultrasound-estimated depth and actual needle depth during epidural placement.

Materials and Methods: This prospective observational study was conducted in the Department of Anaesthesiology at a tertiary care teaching hospital over a period of 3 months. A total of 30 patients aged 18–75 years undergoing surgeries requiring epidural anesthesia or combined spinal epidural anesthesia were included. Pre-procedural lumbar ultrasound was performed using a low-frequency curved array probe in the paramedian sagittal view to estimate epidural space depth. Epidural placement was subsequently performed using the conventional loss-of-resistance technique, and actual needle depth was recorded. Procedural characteristics, number of attempts, needle redirections, and complications were documented. Statistical analysis included Pearson correlation coefficient and paired t-test.

Results: The mean ultrasound-estimated epidural depth was 4.72 ± 0.66 cm, while the mean actual needle depth was 4.81 ± 0.70 cm. The mean absolute difference between the two measurements was 0.23 ± 0.18 cm. There was no statistically significant difference between ultrasound-estimated and actual needle depth ($p = 0.214$). A strong positive correlation was observed between the two measurements ($r = 0.91$, $p < 0.001$). First-attempt success was achieved in 73.3% of patients, and the mean number of attempts was 1.47 ± 0.82. No accidental dural punctures were observed. Higher BMI was significantly associated with greater epidural depth and increased procedural difficulty.

Conclusion: Pre-procedural lumbar ultrasound in the paramedian sagittal view is an accurate and reliable method for predicting epidural space depth. It improves procedural success, reduces technical difficulty, and enhances safety during epidural placement, particularly in patients with difficult anatomical landmarks.

Keywords: Epidural anesthesia. Lumbar ultrasonography. Epidural space depth.

INTRODUCTION

Epidural anesthesia and analgesia are widely used techniques in anesthesiology for perioperative pain management, labor analgesia, and chronic pain interventions. Successful epidural catheter placement depends on accurate identification of the epidural space. Conventionally, the epidural space is located using surface anatomical landmarks and the loss-of-resistance technique. However, these methods are often associated with multiple needle insertion attempts, accidental dural puncture, vascular puncture, failed blocks, and patient discomfort, particularly in obese individuals, elderly patients, pregnant women, and patients with spinal deformities. The variability in anatomical landmarks and operator experience further contributes to procedural difficulty and complications.[1]

In recent years, ultrasonography has emerged as a valuable bedside tool in regional anesthesia and neuraxial procedures. Pre-procedural lumbar ultrasound allows visualization of vertebral anatomy, interspinous and interlaminar spaces, ligamentum flavum-dura mater complex, and estimation of epidural space depth. Among different sonographic approaches, the paramedian sagittal oblique view has gained popularity because it provides better visualization of spinal structures compared to the midline transverse view, especially in patients with difficult anatomy. Ultrasound-guided neuraxial assessment can assist anesthesiologists in identifying the optimal insertion point, determining the needle trajectory, and predicting the depth to the epidural space before needle insertion.[2]

Accurate prediction of epidural depth is clinically important because it may reduce the number of needle passes, improve first-attempt success rates, decrease procedure time, and minimize complications. Several studies have demonstrated a strong correlation between ultrasound-estimated epidural depth and the actual needle depth achieved during epidural placement. The use of ultrasound is particularly beneficial in obese patients, where conventional landmark-guided techniques are often challenging. Additionally, ultrasound guidance may improve patient safety and procedural confidence among trainees and less experienced practitioners.[3]

Despite increasing adoption of neuraxial ultrasonography, variations still exist regarding the optimal sonographic approach and the accuracy of ultrasound measurements in predicting epidural space depth. Limited prospective observational studies have specifically evaluated the paramedian sagittal view for pre-procedural lumbar ultrasound assessment. Therefore, the present study was undertaken to assess the accuracy of pre-procedural lumbar ultrasound in the paramedian sagittal view for predicting epidural space depth and to compare the ultrasound-estimated depth with the actual epidural needle depth obtained during the procedure. The findings of this study may help establish the usefulness of lumbar ultrasound as a reliable adjunct in routine epidural anesthesia practice.[4]

Aim

To assess the accuracy of pre-procedural lumbar ultrasound in the paramedian sagittal view for predicting epidural space depth.

Objectives

1. To measure epidural space depth using pre-procedural lumbar ultrasound in the paramedian sagittal view.
2. To compare ultrasound-estimated epidural depth with the actual epidural needle depth obtained during the procedure.
3. To determine the correlation and accuracy between sonographic and actual epidural space depth measurements.

MATERIALS AND METHODOS

Source of Data

The data for the present study were collected from patients posted for elective surgeries requiring epidural anesthesia or combined spinal epidural anesthesia in the Department of Anaesthesiology of the tertiary care teaching hospital. Eligible patients who fulfilled the inclusion criteria and provided written informed consent were included in the study.

Study Design

The present study was conducted as a hospital-based prospective observational study.

Study Location

The study was conducted in the Department of Anaesthesiology at a tertiary care teaching hospital.

Study Duration

The study was carried out over a period of 3 months from the date of approval by the Institutional Ethics Committee.

Sample Size

A total of 30 patients were included in the study.

Inclusion Criteria

1. Patients aged between 18 and 75 years.
2. Patients of either gender.
3. Patients belonging to ASA physical status I and II.
4. Patients scheduled for elective surgeries requiring epidural anesthesia or combined spinal epidural anesthesia.
5. Patients willing to provide written informed consent.

Exclusion Criteria

1. Patients with spinal deformities such as scoliosis or kyphosis.
2. Patients with local infection at the puncture site.
3. Patients with bleeding disorders or on anticoagulant therapy.
4. Patients with previous lumbar spine surgery.
5. Patients with severe obesity making ultrasound visualization difficult.
6. Patients unwilling to participate in the study.

Procedure and Methodology

After obtaining approval from the Institutional Ethics Committee and written informed consent from the patients, eligible participants were enrolled in the study. A detailed pre-anesthetic evaluation was performed including history taking, physical examination, airway assessment, and routine laboratory investigations.

In the operating room, standard monitoring including pulse oximetry, non-invasive blood pressure, and electrocardiography was established. Patients were positioned in the sitting posture for lumbar ultrasound examination and epidural procedure.

A low-frequency curved array ultrasound probe (2–5 MHz) was used for pre-procedural lumbar ultrasonography. The lumbar spine was scanned in the paramedian sagittal view. The probe was placed approximately 1–2 cm lateral to the midline in a sagittal orientation to identify the sacrum and lumbar interlaminar spaces. The ligamentum flavum-dura mater complex was visualized, and the distance from the skin to the epidural space was measured using the ultrasound machine calipers. The predicted epidural depth was recorded.

Following ultrasound assessment, epidural needle insertion was performed using standard aseptic precautions and the loss-of-resistance technique. The actual depth to the epidural space was measured from the skin to the epidural needle marking at the point of successful identification of the epidural space. Both ultrasound-estimated depth and actual needle depth were documented.

The number of attempts, needle passes, procedural difficulty, and any complications such as accidental dural puncture or vascular puncture were also noted.

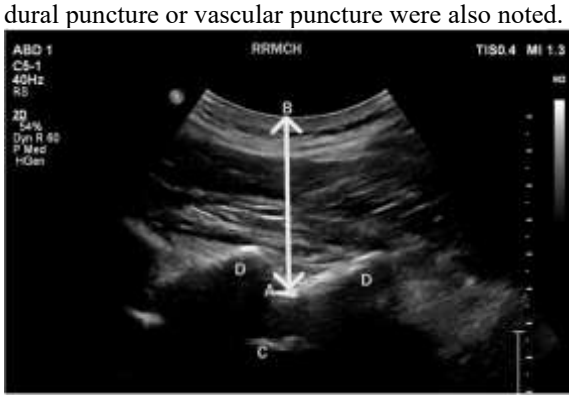

Figure 1: Ultrasonographic paramedian sagittal view of the lumbar region showing skin (B), ligamentum flavum-duramater complex (A), skin to ligamentum flavum -duramater complex distance (white solid line with double arrow connecting A to B), anterior complex (C), laminae (D) of L3 and L4 vertebral levels and lumbar spinal canal (black anechoic space between A and C).

Sample Processing

All ultrasound measurements and procedural findings were recorded immediately after the procedure in a predesigned case record form. The collected data were checked for completeness and accuracy before statistical analysis.

Statistical Methods

The collected data were entered into Microsoft Excel and analyzed using appropriate statistical software. Quantitative variables were expressed as mean and standard deviation, while qualitative variables were expressed as frequency and percentage. Correlation between ultrasound-estimated epidural depth and actual epidural needle depth was assessed using Pearson's correlation coefficient. Agreement between the two measurements was analyzed using Bland–Altman analysis where applicable. A p-value of less than 0.05 was considered statistically significant.

Data Collection

Data collected included demographic characteristics such as age, gender, height, weight, and body mass index; ultrasound-estimated epidural depth; actual epidural needle depth; number of attempts; procedural difficulty; and procedure-related complications. All observations were documented in a structured data collection proforma for further analysis.

RESULTS

Table 1 shows the demographic characteristics of the study participants included in the present study. A total of 30 patients were enrolled. The majority of participants belonged to the age group of 51–60 years, accounting for 8 patients (26.7%), followed by 20–30 years and 41–50 years age groups with 6 patients (20.0%) each. Patients aged 61–70 years constituted 4 cases (13.3%), while 31–40 years and more than 70 years age groups each included 3 patients (10.0%). The mean age of the study population was 49.8 ± 17.3 years, with an age range of 22 to 88 years, indicating inclusion of a wide adult age spectrum. Female participants predominated in the study with 17 cases (56.7%), whereas males constituted 13 cases (43.3%). [Table 1]

Table 1: Demographic Characteristics of Study Participants

Variable	n (%)
Age Group	
20–30 years	6 (20.0)
31–40 years	3 (10.0)
41–50 years	6 (20.0)
51–60 years	8 (26.7)
61–70 years	4 (13.3)
>70 years	3 (10.0)

Sex	
Female	17 (56.7)
Male	13 (43.3)
Total	**30 (100.0)**

Mean age: 49.8 ± 17.3 years; Range: 22–88 years

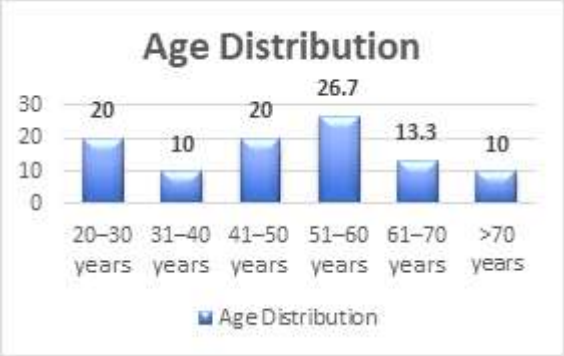

Chart 1: Age Distribution

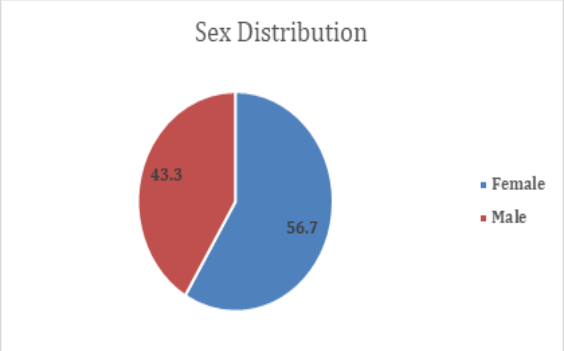

Chart 2: Sex Distribution

Table 2: Procedural Characteristics During Epidural Placement

Variable	n (%)
Anatomical Landmark Palpability	
Well felt	20 (66.7)
Not well felt	10 (33.3)
Number of Attempts	
1	21 (70.0)
2	5 (16.7)
3	3 (10.0)
4	1 (3.3)
First Attempt Success	
Yes	22 (73.3)
No	8 (26.7)
Operator	
Trainee	26 (86.7)
Staff	4 (13.3)
Total	**30 (100.0)**

Mean attempts: 1.47 ± 0.82

Table 2 describes the procedural characteristics observed during epidural placement. Anatomical landmarks were well palpable in 20 patients (66.7%), whereas landmarks were not well felt in 10 patients (33.3%). Most epidural procedures were successfully performed in a single attempt in 21 patients (70.0%), while 5 patients (16.7%) required two attempts, 3 patients (10.0%) required three attempts, and only 1 patient (3.3%) required four attempts. The mean number of attempts was 1.47 ± 0.82, indicating overall ease of epidural placement in the majority of cases. First-attempt success was achieved in 22 patients (73.3%), whereas 8 patients (26.7%) required more than one attempt. Most procedures were performed by trainee anesthesiologists, accounting for 26 cases (86.7%), while staff anesthesiologists performed 4 procedures (13.3%).

Table 3: Procedure-Related Outcomes and Complications

Variable	n (%)
Needle Redirection	
No	19 (63.3)
Yes	11 (36.7)
Accidental Dural Puncture	
Nil	30 (100.0)
Present	0 (0.0)
Change of Level	
Nil	27 (90.0)
Yes	3 (10.0)
Total	**30 (100.0)**

Table 3 summarizes the procedure-related outcomes and complications associated with epidural placement. Needle redirection was not required in the majority of patients, with 19 cases (63.3%) showing successful needle advancement without redirection, whereas 11 patients (36.7%) required needle redirection during the procedure. Importantly, no cases of accidental dural puncture were observed in the study population, indicating a favorable safety profile of the procedure. Change of epidural insertion

level was not required in 27 patients (90.0%), while only 3 patients (10.0%) required a change in the level of insertion.

Table 4: Comparison and Correlation Between Ultrasound Depth and Needle Depth

Parameter	Result
Ultrasound depth (UD) (cm)	4.72 ± 0.66
Needle depth (ND) (cm)	4.81 ± 0.70
Absolute difference |ND−UD| (cm)	0.23 ± 0.18
Paired t-test p-value	0.214
UD–ND correlation coefficient (r)	0.91
Correlation p-value	<0.001

Table 4 compares the ultrasound-estimated epidural depth with the actual epidural needle depth achieved during the procedure. The mean ultrasound-estimated depth (UD) was 4.72 ± 0.66 cm, while the mean actual needle depth (ND) was 4.81 ± 0.70 cm. The mean absolute difference between the two measurements was minimal at 0.23 ± 0.18 cm, indicating close agreement between ultrasound estimation and actual epidural depth. Statistical analysis using the paired t-test showed no significant difference between the ultrasound-estimated and actual needle depths (p = 0.214). Furthermore, a very strong positive correlation was observed between UD and ND measurements, with a correlation coefficient (r) of 0.91, which was highly statistically significant (p < 0.001).

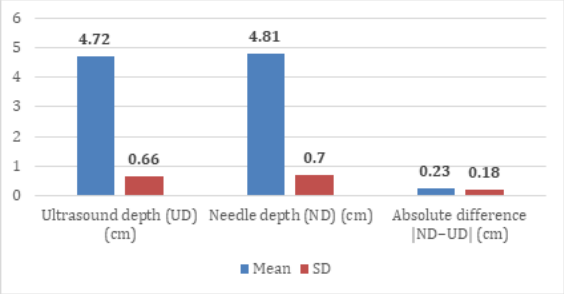

Chart 3: Comparison and Correlation Between Ultrasound Depth and Needle Depth

Table 5: Factors Associated with Epidural Needle Depth and Procedural Difficulty

Variable	Result	p-value
BMI vs ND correlation	r = 0.63	<0.001
BMI Category vs Mean ND		
Normal BMI	4.20 ± 0.42 cm	
Overweight	4.78 ± 0.51 cm	
Obese	5.49 ± 0.58 cm	<0.001
Attempts According to Landmark Palpability		
Well felt: ≥2 attempts	3 (15.0%)	
Not well felt: ≥2 attempts	6 (60.0%)	0.014
Needle Redirection According to Landmark Palpability		
Well felt: Redirection yes	4 (20.0%)	
Not well felt: Redirection yes	7 (70.0%)	0.008
First Attempt Success According to Attempts		
1 attempt	21 (100.0%)	
≥2 attempts	1 (11.1%)	<0.001

Table 5 presents factors associated with epidural needle depth and procedural difficulty. A significant positive correlation was observed between body mass index (BMI) and epidural needle depth, with a correlation coefficient of r = 0.63 (p < 0.001), indicating that higher BMI was associated with greater epidural depth. Mean needle depth progressively increased across BMI categories, being 4.20 ± 0.42 cm in patients with normal BMI, 4.78 ± 0.51 cm in overweight patients, and 5.49 ± 0.58 cm in obese patients, with the difference being statistically significant (p < 0.001). Procedural difficulty was also significantly associated with anatomical landmark palpability. Among patients with well-felt landmarks, only 3 patients (15.0%) required two or more attempts, whereas 6 patients (60.0%) with poorly palpable landmarks required multiple attempts (p = 0.014). Similarly, needle redirection was needed in only 4 patients (20.0%) with well-palpable landmarks compared to 7 patients (70.0%) with poorly palpable landmarks, showing a statistically significant association (p = 0.008). First-attempt success was strongly associated with the number of attempts, as all patients requiring only one attempt achieved first-attempt success, whereas only 1 patient (11.1%) requiring two or more attempts had first-attempt success (p < 0.001).

DISCUSSION

The demographic profile observed in the present study demonstrated a mean age of 49.8 ± 17.3 years with the majority of participants belonging to the 51–60 years age group (26.7%). Females constituted 56.7% of the study population. These findings were comparable with the observations of Choi et al.(2024),[1] who reported that neuraxial ultrasound was frequently utilized in middle-aged and elderly

patients because anatomical landmarks become progressively difficult to identify with advancing age and spinal deformities. Cantürk et al.(2019),[2] also observed a predominance of female participants in epidural ultrasound studies and emphasized that ultrasound assessment was particularly useful in patients with altered spinal anatomy and obesity. Nada et al.(2024),[4] further noted that increasing age, obesity, and degenerative spinal changes contribute significantly to difficulty in neuraxial landmark identification, supporting the demographic characteristics observed in the present study.

With regard to procedural characteristics, anatomical landmarks were well palpable in 66.7% of patients, while 33.3% had poorly palpable landmarks. Epidural placement was achieved in a single attempt in 70.0% of patients, with a mean number of attempts of 1.47 ± 0.82. First-attempt success was achieved in 73.3% of patients. These findings correlated well with the study conducted by Li et al.(2020),[3] who reported improved first-attempt success rates and reduced procedural difficulty with ultrasound-assisted lumbar epidural access compared to conventional approaches. Similarly, Elsharkawy et al.(2019),[5] demonstrated that real-time ultrasound-guided epidural techniques significantly reduced needle passes and facilitated easier epidural placement. The present study also showed that most procedures were performed by trainees (86.7%), suggesting that ultrasound guidance may improve procedural confidence and success even among less experienced operators. Kalagara et al.(2021),[9] similarly reported that spinal ultrasonography improves the learning curve for trainees and enhances procedural efficiency during central neuraxial blockade. Park et al.(2022),[12] also observed higher procedural success and easier spinal access with ultrasound-assisted paramedian approaches compared to conventional landmark techniques.

The procedure-related outcomes in the present study demonstrated favorable safety results. Needle redirection was required in only 36.7% of patients, while no cases of accidental dural puncture were observed. Change of insertion level was required in only 10.0% of cases. These findings were comparable to the results of Elsharkawy et al.(2019),[5] who demonstrated that ultrasound guidance significantly reduced traumatic needle insertions, needle redirections, and procedural complications during epidural procedures. Khemka et al.(2016),[11] also reported that ultrasound imaging in parasagittal oblique planes improved visualization of neuraxial structures and reduced procedural manipulations during thoracic epidural placement. Yoo et al.(2021),[13] further highlighted that the paramedian sagittal oblique ultrasound view provides better needle guidance and procedural success during neuraxial interventions. The absence of accidental dural puncture in the present study highlights the safety and accuracy of the paramedian sagittal ultrasound approach for predicting epidural depth and identifying the optimal insertion site.

The comparison between ultrasound-estimated depth and actual epidural needle depth in the present study demonstrated excellent agreement. The mean ultrasound depth was 4.72 ± 0.66 cm, while the actual needle depth was 4.81 ± 0.70 cm, with a minimal absolute difference of 0.23 ± 0.18 cm. There was no statistically significant difference between the two measurements ($p = 0.214$), and a strong positive correlation was observed ($r = 0.91$, $p < 0.001$). These findings strongly support the accuracy of preprocedural lumbar ultrasound in estimating epidural depth. Similar findings were reported by Canturk et al.(2019),[8] who observed a highly significant correlation between ultrasound-estimated epidural depth and actual needle depth in parturients using the paramedian sagittal oblique approach. Choi et al.(2024),[1] also demonstrated excellent correlation between sonographic measurements and actual epidural depth in children with scoliosis, concluding that ultrasound is a reliable predictor of epidural space depth even in difficult spinal anatomy. Thomas et al.(2025),[7] similarly found strong agreement between ultrasound-estimated and procedural epidural depths after accounting for BMI variations. Baglioni et al.(2021)[10] further demonstrated high accuracy of ultrasound technology in estimating epidural depth among obese pregnant patients.

The present study also evaluated factors associated with epidural needle depth and procedural difficulty. A significant positive correlation was observed between BMI and epidural needle depth ($r = 0.63$, $p < 0.001$), with obese patients demonstrating greater needle depth (5.49 ± 0.58 cm) compared to overweight and normal BMI individuals. These findings were consistent with Awasthi et al.(2021),[6] who reported that increasing BMI significantly increased the skin-to-epidural space distance and procedural epidural depth. Thomas et al.(2025),[7] also emphasized that obesity is a major factor contributing to difficult neuraxial access and increased procedural complexity. In the present study, poorly palpable anatomical landmarks were significantly associated with multiple attempts (60.0% vs 15.0%, $p = 0.014$) and increased needle redirection (70.0% vs 20.0%, $p = 0.008$). Similar observations were made by Cantürk et al.(2019),[2] who reported that patients with poorly palpable landmarks benefited most from ultrasound-assisted neuraxial procedures due to improved visualization of spinal anatomy. Furthermore, first-attempt success was significantly associated with fewer attempts ($p < 0.001$), indicating that ultrasound guidance improved procedural efficiency and reduced technical difficulty.

CONCLUSION

The present prospective observational study demonstrated that pre-procedural lumbar ultrasound performed in the paramedian sagittal view is an

accurate and reliable method for predicting epidural space depth. The ultrasound-estimated epidural depth showed excellent agreement and strong positive correlation with the actual epidural needle depth, with no statistically significant difference between the two measurements. The study also showed that ultrasound guidance facilitated high first-attempt success rates, reduced the number of needle insertion attempts, minimized needle redirections, and was associated with a low complication rate, including the absence of accidental dural puncture.

Increased body mass index and poorly palpable anatomical landmarks were significantly associated with greater epidural depth and increased procedural difficulty, highlighting the importance of ultrasound guidance in patients with difficult anatomy. Furthermore, the successful performance of most procedures by trainee anesthesiologists suggested that pre-procedural ultrasound may improve procedural confidence and learning outcomes among less experienced operators.

Overall, pre-procedural lumbar ultrasonography in the paramedian sagittal view proved to be a valuable adjunct for epidural anesthesia by improving accuracy, procedural efficiency, and patient safety. Routine incorporation of neuraxial ultrasound may enhance the success and safety of epidural procedures, especially in technically challenging patients.

Limitations of the study

1. The study was conducted with a relatively small sample size of 30 patients, which may limit the generalizability of the findings.
2. The study was performed at a single tertiary care center, and therefore the results may not represent broader populations or different clinical settings.
3. Operator-dependent variability in ultrasound image acquisition and interpretation could have influenced measurement accuracy.
4. Most procedures were performed by trainee anesthesiologists, which may have affected procedural outcomes and attempt rates.
5. The study did not include a comparison group using the conventional landmark-guided technique alone.
6. Extremely obese patients and patients with severe spinal deformities were excluded, limiting applicability in such difficult populations.
7. Interobserver variability between different ultrasound operators was not assessed.
8. Long-term patient outcomes and satisfaction related to epidural placement were not evaluated.
9. The study mainly focused on lumbar epidural procedures and findings may not be applicable to thoracic epidural techniques.

Real-time ultrasound-guided epidural insertion was not evaluated, as only pre-procedural ultrasound assessment was performed.

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