Original Article

Landmark-guided versus Real-time Ultrasound-guided Combined Spinal-epidural Anesthesia Techniques: Paramedian Sagittal Oblique and Transverse Interlaminar Approach

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Abstract

Background: There are different types of real-time ultrasound (US)-guided combined spinal epidural (CSE) anesthesia techniques. We aimed to investigate the effect of real-time US-guided paramedian sagittal oblique (PSO), transverse interlaminar (TI) approach method, and landmark-guided (LG) CSE anesthesia. **Methods:** Ninety patients who underwent CSE block were included in the study. Patients were randomized into LG ($n = 30$), PSO ($n = 30$), and TI ($n = 30$) groups. The primary outcome was number of needle manipulations. The secondary outcomes are the number of attempts, needle visibility, procedure time, procedure success rate, catheter placement difficulty, posterior complex distance, and complications. **Results:** The number of needle manipulations was statistically significantly lower in the LG technique group ($P < 0.000$). When the number of attempts, the difficulty of catheter placement, and the procedure's success rate were compared between the three groups, we did not find a statistically significant difference ($P > 0.05$). In addition, when the procedure times were compared, the time measured for the LG group was statistically significantly lower than in the PSO and TI groups ($P < 0.000$). **Conclusion:** In the results of this study, the real-time US-guided CSE anesthesia application had a similar success and complication level with LG technique. The LG method had a shorter processing time and fewer needle manipulations.

Keywords: Anesthesia, epidural, combined spinal-epidural anesthesia, landmark-guided technique, spinal, ultrasound, ultrasound-guided technique

INTRODUCTION

The popularity of the use of ultrasound (US) for regional anesthesia and pain treatment methods has increased in recent years.[1] US imaging can provide relatively inexpensive, radiation-free, and anatomical information obtained using standard palpation techniques.[1-3] In 1981, Cork *et al.* described the essential components of the US anatomy of the vertebra, such as the ligamentum flavum, spinal canal, lamina, and vertebral body.[4] Since identifying the vertebra and surrounding anatomical structures and dural imaging with the US facilitates the detection of the needle puncture site, it has had a wider usage area.[5] It has been shown that using US for visual feedback can reduce the number of needle placement attempts compared to the standard palpation technique. It has been determined that using the US for epidural needle placement in obese patients can provide 30%–60% higher success rates compared to the application method performed by detecting anatomical signs on palpation.[6] Today, the midline transverse paramedian approach, and its different variations, can be used for sonoanatomic imaging of vertebral structures.[7] Although there are studies in the literature in which neuraxial intervention is performed by imaging the sonoanatomical structures in the US before the intervention, there need to be more data on the epidural application method with real-time US. The study hypothesized that the combined spinal epidural (CSE) anesthesia method applied

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with real-time US would reduce the number of needle manipulations.

For this purpose, we compared the results of CSE anesthesia applied with real-time US-guided paramedian sagittal oblique (PSO), transverse interlaminar (TI) approach, and landmark-guided (LG) method.

MATERIALS AND METHODS

In this prospective, randomized controlled, open-label study, 90 patients due for the CSE block were evaluated within the scope of this study after institutional ethics committee (IEC) approval was received and clinical trial records were registered (IEC # 2019/12–09, Clinical Trials.gov identifier: NCT03589404). All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

American Society of Anesthesiologists I–III class patients aged between 18 and 80 years, who had undergone block, were included in this study[8] [Supplementary Table 1].

Exclusion criteria were as follows: previous spinal surgery, local anesthetic allergy, bleeding diathesis disorder, mental disorder, allergy to drugs used, refusal to participate in the study, presence of infection in the block area, and body mass index (BMI) >30. Ninety patients who met the above criteria agreed to participate in this study and provided written informed consent. Group LG ($n = 30$): CSE block with conventional LG method without using US, Group PSO ($n = 30$): CSE block with the real-time US-guided in-plane paramedian approach in PSO view technique, and Group TI ($n = 30$): patients who underwent epidural CSE block with a real-time in-plane paramedian approach in US-guided TI view technique will be grouped by randomization (using random number table) [Figure 1].

Anesthetic and analgesic management

Patients admitted to the operating room underwent routine monitoring (electrocardiogram, heart rate, noninvasive arterial pressure, and arterial oxygen saturation), and after intravenous access was provided, and auxiliary personnel put them in a sitting position. The patients in the group to be treated with LG CSE were recorded by examining the neuraxial structures with US by another researcher (DKY) before the procedure, and the posterior and anterior complex distances were measured and recorded at the Lumbar 2 to Lumbar 5 vertebral levels where intervention could be made. Sedation was provided with 1 mg of midazolam and 50 µg of fentanyl. Sterile conditions were provided, the patient was prepared, and a sterile sheath was placed on the US probe.

Paramedian sagittal oblique method

A convex US probe (2–6 MHz MyLab30; Esaote, Florence, İtaly) was held in the nondominant hand of the operator and placed in the sagittal position, 1–2 cm lateral to the spinous processes. The sacrum, which appeared as a hyperechoic band with an acoustic shadow in front, was detected by advancing the probe in the caudal direction. The space between the sacrum and the L5 lamina was defined as the L5/S1 intervertebral space. L3/L4 and L4/L5 intervertebral spaces were counted and determined by advancing the probe in the cranial direction. In the spaces between the laminae of the lumbar vertebrae displayed as curved hyperechoic lines, the hyperechoic linear structure posterior complex at the most surface (ligamentum flavum, epidural space, and posterior dura mater), a hypoechoic area of the intrathecal space under it, and the anterior complex (anterior dura, posterior longitudinal ligament, and the posterior of the vertebral body or intervertebral disc) as a single linear hyperechoic structure at the deepest were detected. The probe was placed on the L3/L4 and L4/L5 intervertebral spaces. Local anesthetic (lidocaine 1%, 3 mL) was infiltrated into the subcutaneous tissue. CSE anesthesia was initiated by the same researcher using scanning (single-operator technique) and using an 18G Tuohy needle. Tuohy needle was placed into the appropriate interlaminar space in the cranial-caudal direction with the in-plane technique [Figure 2].[9]

Transverse interlaminar method

At the level of the L4-L5 vertebrae, the convex US probe was placed in the sagittal position, 1–2 cm lateral to the midline, similar to PSO imaging. After defining the sacrum and L5 vertebrae in the caudal direction, the lumbar vertebrae were distinguished up to L2 in the cranial direction. At the level where the intervention was planned, the probe was rotated 90° transversely and positioned in the midline. In this imaging, spinous processes were detected bilaterally as a superficial hyperechoic line, and laminae were seen laterally as a hyperechoic line. With the movement of the probe in the cranial or caudal direction, the acoustic shadow of the less hyperechoic interspinous ligament compared to the spinous process, the posterior complex (ligamentum flavum/posterior dura) separated by a hypoechoic intrathecal space surrounded by erector spinae muscles on both sides, and two hyperechoic lines representing the anterior complex were detected. After infiltration with a local anesthetic, the Tuohy needle was advanced from the lateral to the medial posterior complex in the plane with real-time US guidance [Figure 2].[10]

In both approaches, after the 18G Tuohy needle was seen to have advanced into the ligamentum flavum, the transducer in the nondominant hand was left in the sterile field, which was confirmed by also testing with the loss of resistance to the saline method using the "standard Loss-of-resistance (LOR) syringe." Then, a 27G pen-tipped spinal needle was inserted through the Tuohy needle to perform the dural puncture. After the free flow of cerebrospinal fluid (CSF) was detected, the spinal needle was locked in place, and heavy bupivacaine 0.5%, 2–3 mL (10–15 mg) was injected according to the operation method. Subsequently, an epidural catheter was placed.

Landmark-guided method

The same researcher found the L4-L5 vertebral space and spinous processes using anatomical landmarks. After local anesthetic infiltration, the loss of resistance to saline was

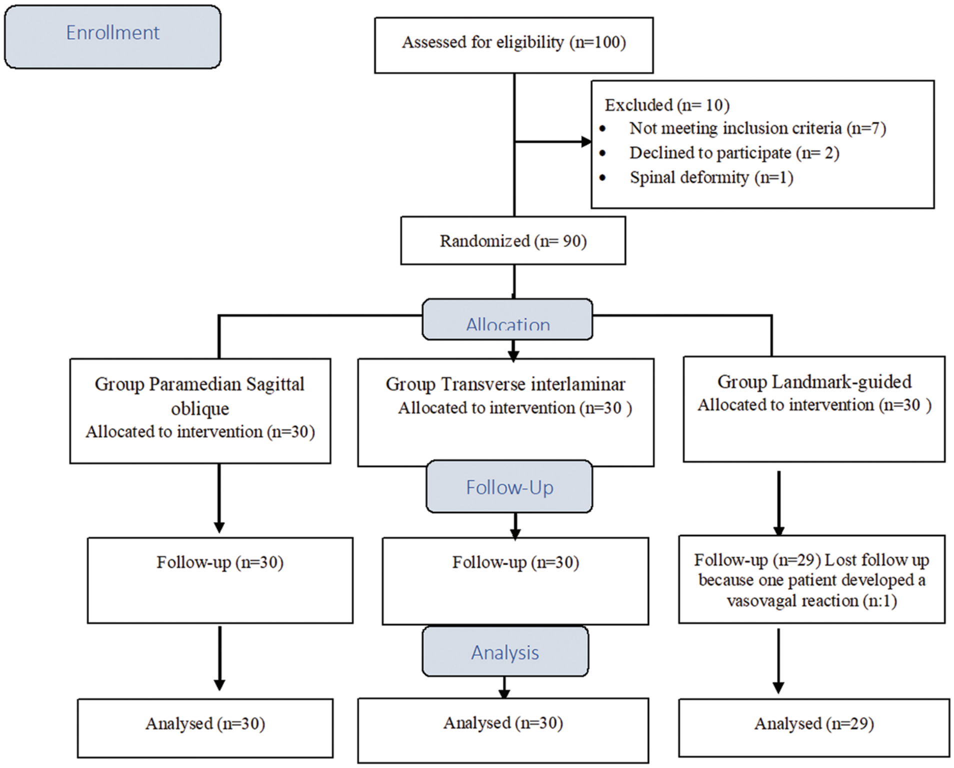

Figure 1: Flow diagram

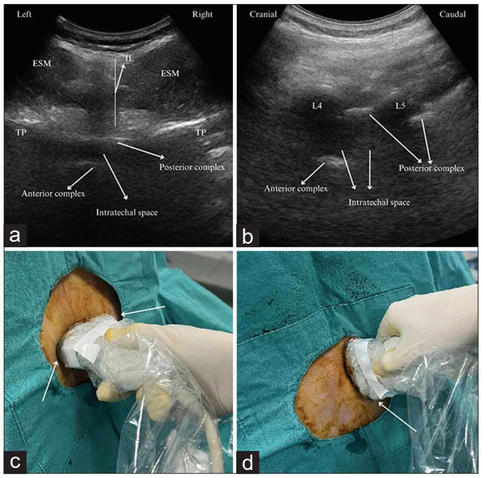

Figure 2: Ultrasound imaging findings. (a) Paramedian sagittal oblique view ultrasound image (b) Paramedian sagittal oblique view ultrasound image, (c) Transverse interlaminar view probe position, the white arrow points to the needle entry points. (d) Paramedian sagittal oblique view probe position, the white arrow points to the needle entry points. TP: Transverse process, IL: Interspinous ligament, ESM: Erector spinal muscle

tested using a standard LOR syringe from the midline, and the epidural area was confirmed. A 27G pen-tipped spinal needle was inserted through the Tuohy needle to perform the dural puncture. After the free flow of CSF was detected, the spinal needle was locked in place, and heavy bupivacaine 0.5%, 2–3 mL (10–15 mg) was injected according to the operation method. Then, an epidural catheter was placed.

CSE block procedures were performed by a regional anesthesiologist (who performed 50 CSE blocks) experienced in neuraxial block under the guidance of ultrasonography (KO). CSE with real-time US and ultrasonographic images of the neuraxial anatomy recorded before the procedure were examined, and the necessary measurements were made by the second researcher (DKY).

Outcome measures

The primary outcome was number of needle manipulations (the number of referrals made from the skin entrance to the epidural space). The secondary outcomes are number of attempts (skin entry from a different area), needle visibility (4-point Likert scale: 4 – excellent visibility, 3 – moderate visibility, 2 – poor visibility, and 1 – no visibility), procedure time, procedure success rate, catheter placement difficulty (assessed by the practitioner using a 10-point scale with 0: easiest and 10: most difficult), anterior and posterior complex distance measured during the epidural application, complications, and demographic data.

Statistical analysis

Data were analyzed using descriptive statistical methods, and Chi-square test was used. The normal distribution of the data was evaluated by Kolmogorov–Smirnov and Shapiro–Wilk test (it was determined that the data were normally distributed). A one-way analysis of variance test was used for comparisons between the groups. The Pearson correlation test was used to evaluate the correlation. Data analysis IBM SPSS 23.0 (IBM Co., Armonk, NY, USA) statistical program was used.

Power analysis

According to the results of our pilot study of 10 patients, the number of needle manipulations in the epidural application with the LG method was determined as 2.2 ± 1.1. The sample size required to detect a 40% reduction in the number of needle interventions, and this study's primary outcome was patients with 85% power ($\alpha = 0.05$). Considering patient loss during the study, 90 patients were included.

RESULTS

The study was completed with 89 patients in the LG group ($n = 29$), PSO epidural group ($n = 30$), and TI epidural group ($n = 30$) because a patient in the LG epidural group developed a vasovagal reaction during the procedure. The demographic characteristics of the patients are shown in Table 1. There was no statistically significant difference between the groups in these values ($P > 0.05$). When the characteristics of the procedure variables were evaluated, there was no statistically significant difference between the three groups when the number of attempts, the difficulty of catheter placement, and the procedure success rate were compared ($P > 0.05$) [Table 2]. The number of needle manipulations performed after skin entry was statistically significantly lower in the LG technique group than in the PSO and TI techniques ($P < 0.000$). Among the three groups, the highest number of needle manipulations was found in the PSO group (3.5 ± 1.195) [Table 2].

Needle visibility was found to be statistically significantly higher in the PSO group when compared to the TI group ($P < 0.003$) [Table 2] ($P < 0.003$) [Table 2]. When the procedure times were compared, the procedure time measured in the LG group (255.2 ± 145 s) was found to be statistically significantly lower than the PSO (403.4 ± 169.6 s) and TI groups (396.9 ± 159.1 s) ($P < 0.000$) [Figure 3]. While the

Table 1: Comparison of the demographic characteristics of the patients

	PSO (n=30), n (%)	TI (n=30), n (%)	LG (n=29), n(%)	P
Age (year)	64.2±12.8	65.3±12.8	63.8±12.19	0.659
BMI (kg/m^2)	25.6±4.14	25.3±4.2	24.6±3.75	0.453
Gender				
Male/female	13 (43.3)/17 (56.7)	16 (53.3)/14 (46.7)	11 (37.9)/18 (62.1)	0.550
ASA PS				
2	10 (33.3)	11 (36.4)	10 (34.4)	0.875
3	18 (60)	17 (55.3)	19 (65.6)	0.785
4	2 (6.7)	1 (3.3)	-	0.899
Surgery				
Tibia shaft fracture	3 (10)	4 (14)	2 (6.8)	0.675
Knee arthroscopy	1 (2)	2 (6)	3 (10)	0.334
Hip operation	10 (34)	9 (30)	11 (37.9)	0.770
Knee arthroplasty	16 (54)	15 (50)	13 (44.8)	0.567
Location				
L2–L3	1 (46.7)	-	2 (6.8)	0.345
L3–L4	10 (46.7)	12 (40)	9 (31)	0.734
L4–L5	19 (46.7)	18 (60)	18 (62)	0.603

Mean ± SD values for normal distribution. BMI: Body mass index, ASA: American Society of Anesthesiologists, PS: Physical status, PSO: Paramedian sagittal oblique, TI: Transverse interlaminar, LG: Landmark guided, SD: Standard deviation

Table 2: Properties of procedure variables

	PSO (n=30)	TI (n=30)	LG (n=29)	P	Differences
Number of needle manipulations	3.5±1.195	2.7±1.17	2.1±1.02	0.000	Between LG and TI
				0.014	Between PSO and TI
Number of attempts	1.36±0.61	1.16±0.37	1.2±0.55	0.315	
Needle visibility	2.9±0.81	2.58±0.98	-	0.003	Between PSO and TI
Catheter placement difficulty	2.56±1.9	2.5±2	2.65±2	0.953	
Dural puncture	2	1	1	0.815	
Procedure success rate, n (%)	28 (93.3)	29 (96.7)	26 (89.7)	0.853	
	2 (6.7)	1 (3.3)	3 (10.3)		
Posterior complex distance (cm)	6.6±0.89	5.99±0.97	4.92±1	0.000	Others with LG
Procedure time (s)	403.4±169	396.9±159	255.2±145	0.000	Others with LG

Mean ± SD values for normal distribution. The one-way ANOVA tests for the inter-group comparisons. PSO: Paramedian sagittal oblique, TI: Transverse interlaminar, LG: Landmark guided, SD: Standard deviation

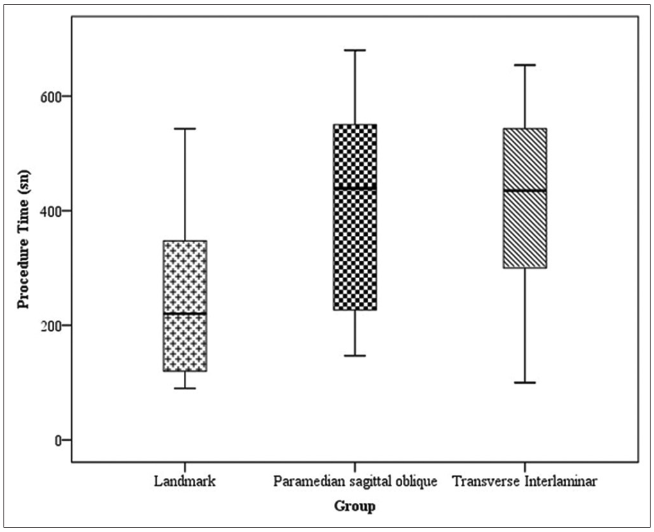

Figure 3: Box-plot chart showing the procedure time

Table 3: Correlation table with the posterior complex distance

	PSO (*n*=30)	TI (*n*=30)	LG (*n*=29)
Posterior complex distance (cm)	6.6±0.89	5.99±0.97	4.92±1
Procedure time (s)	403.4±169	396.9±159	255.2±145
Correlation coefficient	0.149	0.217	0.011
P	0.431	0.249	0.954
Number of needle manipulations	3.5±1.195	2.7±1.17	2.1±1.02
Correlation coefficient	0.031	0.083	0.058
P	0.870	0.669	0.759
Procedure success rate, *n* (%)	28 (93.3) 2 (6.7)	29 (96.7) 1 (3.3)	26 (89.7) 3 (10.3)
Correlation coefficient	−0.011	0,144	0.194
P	0.955	0.0457	0.304

Mean ± SD values for normal distribution. The Pearson correlation test was used for the correlation. PSO: Paramedian sagittal oblique, TI: Transverse interlaminar, LG: Landmark guided, SD: Standard deviation

posterior complex distance was negatively correlated with the success rate in the PSO group (*P* = 0.011, *P* = 0.955), it was found to be positively correlated with the number of needle insertions (*P* = 0.031, *P* = 0.870) [Table 3].

DISCUSSION

In this study, we compared real-time US-guided PSO and TI approach and CSE block applications with the LG method. Procedural success and complications were similar in all the three groups. In the LG method, CSE had a shorter processing time, and fewer needle manipulations were detected.

Central neuraxial block applications are accepted as the gold standard in many fields for surgical anesthesia or postoperative analgesia.[11] The widespread use of US in regional anesthesia has shifted the attention from neuraxial block applications to field blocks. The difficulties in imaging the anatomical structures of the vertebrae with US have limited its use in this area. In particular, excess bone structures, age-related calcification (facet joints), osteoproliferation, calcification, and muscle atrophy can complicate imaging.[12,13]

For this reason, applying neuraxial blocks with the LG technique by detecting anatomical landmarks by palpation is still in use. Obesity, anatomical variations, and spinal defects may cause difficulty in applying the LG technique. Experiences in these cases with significant problems about using the US in blocks that could not be involved with the LG approach were shared.[14,15]

Besides using US in central neuraxial blocks, which can be difficult to apply with the LG technique, US can be used to determine the area to be intervened in the vertebra before the procedure and to apply real-time blocks with US.[5,9,16]

The basic approach for US-guided neuraxial anesthesia is the identification of anatomical structures. The primary anatomical structures are the vertebral lamina, the posterior complex (containing the ligamentum flavum, epidural space, posterior dura mater), the intrathecal space, the anterior complex (formed by the anterior dura), and the posterior longitudinal ligament. Different scanning techniques can be used to identify these anatomical structures. Three basic orientations are paramedian sagittal, PSO, and transverse examination method.[5] Grau *et al*., in the study they conducted in 2001, visualized the vertebrae in the transverse, median, and paramedian longitudinal planes with US. They reported that the longitudinal paramedian method provides excellent imaging quality information about the epidural space in 3 imaging.[17] In another study, which used preprocedural US to determine the intervention site, it was found that the paramedian approach for the CSE technique increased the chance of first-pass success and reduced the number of multiple interventions.[18] In another study, CSE anesthesia used a paramedian longitudinal approach accompanied by real-time US. Compared to other groups using LG technique and preprocedural US, the out-of-plane method in paramedian longitudinal imaging was found to reduce puncture entries and the number of manipulations. They stated that this approach improved the quality and performance of the CSE application.[19] Tran *et al*., who applied real-time US with a paramedian approach for lumbar epidural anesthesia, were successful in 18 out of 19 patient groups and stated that it might be more suitable for elderly patients.[13] Karmakar *et al*. described the paramedian sagittal scanning method in their technical update. They demonstrated that a real-time, in-plane (caudal-cranial direction in the long axis of the probe) epidural block can be performed by a single practitioner.[9] Alternatively, studies using neuraxial anesthesia with a paramedian transverse approach are available in the literature. In the study, where the real-time US was used for spinal anesthesia, the probe position was shifted in the paramedian direction from the midline in the transverse position, the vertebral structures were defined, and the procedure was completed with the paramedian in-plane technique.[20]

On the other hand, real-time epidural catheterization was successfully performed with paramedian transverse scanning and paramedian sagittal scanning methods. This study discussed some disadvantages of the paramedian sagittal method compared to the paramedian transverse scanning application. The first of these disadvantages was the difficulty of controlling the needle in sagittal and coronal directions in the sagittal approach, and the second was the prolongation of the procedure time due to the long distance that the epidural needle would advance in sagittal scanning and practice.[21] Studies for better visualization of vertebral structures and reducing the number of practitioners are also found in the literature.[20,22]Among these, a paramedian approach to the epidural space with TI imaging was described in a prospective pilot study. In this new approach, in which epidural catheterization was successfully applied for 20 patients in a series of 21 patients, the median block application time was 4.5 min.[10]

Although real-time US and neuraxial regional anesthesia methods have achieved encouraging results in these similar studies, there are results with negative feedback about the application time and the success of the procedure. Chen *et al*. published the results of 114 patients who applied spinal anesthesia with real-time US and preprocedural US. They found that the duration of the procedure was long, and the chances of success and patient satisfaction were low in patients who underwent spinal anesthesia with real-time US. In that study, three different scans and approaches were used in real-time US procedures; they could not find any difference between approaches in the subgroup analysis.[23] In their data (level evidence IA) obtained from 14 randomized controlled trials and two meta-analyses, Perlas *et al*. found that neuraxial US reduces technical problems and the number of needle insertions in lumbar epidural or spinal anesthesia applications. In addition, they found results supporting the increase in efficiency in patients with normal anatomy and patients with difficult vertebra examinations (such as obesity, scoliosis, or previous spinal surgery) (Grade A recommendation). In the results on safety, a grade B recommendation was given at evidence level III.[24]

In the study, in which difficulty levels were defined for block applications in regional anesthesia, real-time US-guided spinal anesthesia application was classified as level III.[25]

In our study results, the duration of the procedure and the number of needle manipulations had lower values in the group using the LG method. The procedure success rate and complications were similar in all the three groups. Therefore, it was impossible to talk about the additional benefit of using real-time US in terms of efficacy and safety. There was no correlation between the distance from the epidural needle to the posterior complex and the procedure duration within the three groups. In the PSO approach, the long posterior complex distance causes an increase in the number of needle manipulations and decreases the procedure's success rate. Paravertebral muscles have been observed as a complicating factor in positioning and holding the US probe in PSO imaging. This may cause an increase in the number of needle manipulations. Performing the procedure in a sitting position may affect these results. In addition, in examining the studies in the literature that apply CSE with real-time US, it needs to be stated whether the epidural needle used during the procedure is US visible or not. As in our study, the needle types used in other studies are the standard Tuohy needle as described. Only one study stated that an echogenic needle was used.[10] This factor may change the study results.[9,12,13,17-21] Adaptation to performing LG neuraxial block procedures with US, which regional anesthesiologists have been practicing for many years and have experience with, may take time. Technical problems during the process (probe sterilization, difficulties in the application by a single person, sterility of US gel, etc.) in the application of neuraxial block with US and problems in anatomical imaging of the vertebra may cause this situation. Technological and medical developments can reduce the obstacles in applying neuraxial block with ultrasonography.[10]

Limitations

There are some limitations to this study. The patient groups included in the study did not include conditions that may cause difficulties in CSE application, such as BMI >35, old age, or pregnancy. In addition, user-related variables could not be eliminated, like other US studies. The fact that an US image needle was not used and the study could not be blinded was also a limitation.

CONCLUSION

In the results of this study, real-time CSE anesthesia application had a similar success and complication level with LG technique. The LG method had a shorter processing time and fewer needle manipulations. In the PSO approach, in which real-time US is used in the two groups, the length of the epidural distance has caused some disadvantages. The existence of aspects for improvement in the real-time CSE anesthesia method is promising for this procedure.

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Conflicts of interest

There are no conflicts of interest.

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Supplementary Material

Supplementary Table 1: American Society of Anesthesiologists Physical Status (ASA PS) classification

ASA PS classification	Definition	Adult examples, including but not limited to	Pediatric examples, including but not limited to	Obstetric examples, including but not limited to
ASA I	A normal healthy patient	Healthy, nonsmoking, no or minimal alcohol use	Healthy (no acute or chronic disease), normal BMI percentile for age	
ASA II	A patient with mild systemic disease	Mild diseases only without substantive functional limitations. Current smoker, social alcohol drinker, pregnancy, obesity (30< BMI <40), well-controlled DM/HTN, mild lung disease	Asymptomatic congenital cardiac disease, well-controlled dysrhythmias, asthma without exacerbation, well-controlled epilepsy, noninsulin-dependent DM, abnormal BMI percentile for age, mild/moderate OSA, oncologic state in remission, autism with mild limitations	Normal pregnancy*, well-controlled gestational HTN, controlled preeclampsia without severe features, diet-controlled gestational DM
ASA III	A patient with severe systemic disease	Substantive functional limitations; one or more moderate to severe diseases. Poorly controlled DM or HTN, COPD, morbid obesity (BMI ≥40), active hepatitis, alcohol dependence or abuse, implanted pacemaker, moderate reduction of EF, ESRD undergoing regularly scheduled dialysis, history (>3 months) of MI, CVA, TIA or CAD/stents	Uncorrected stable congenital cardiac abnormality, asthma with exacerbation, poorly controlled epilepsy, insulin dependent DM, morbid obesity, malnutrition, severe OSA, oncologic state, renal failure, muscular dystrophy, cystic fibrosis, history of organ transplantation, brain/spinal cord malformation, symptomatic hydrocephalus, premature infant PCA <60 weeks, autism with severe limitations, metabolic disease, difficult airway, long term parenteral nutrition. Full-term infants <6 weeks of age	Preeclampsia with severe features, gestational DM with complications or high insulin requirements, a thrombophilic disease requiring anticoagulation
ASA IV	A patient with severe systemic disease that is a constant threat to life	Recent (<3 months) MI, CVA, TIA or CAD/stents, ongoing cardiac ischemia or severe valve dysfunction, severe reduction of EF, shock, sepsis, DIC, ARD or ESRD not undergoing regularly scheduled dialysis	Symptomatic congenital cardiac abnormality, congestive heart failure, active sequelae of prematurity, acute hypoxic-ischemic encephalopathy, shock, sepsis, DIC, automatic implantable cardioverter-defibrillator, ventilator dependence, endocrinopathy, severe trauma, severe respiratory distress, advanced oncologic state	Preeclampsia with severe features complicated by HELLP or other adverse events, peripartum cardiomyopathy with EF <40, uncorrected/decompensated heart disease, acquired or congenital
ASA V	A moribund patient who is not expected to survive without the operation	Ruptured abdominal/thoracic aneurysm, massive trauma, intracranial bleed with mass effect, ischemic bowel in the face of significant cardiac pathology or multiple organ/system dysfunction	Massive trauma, intracranial hemorrhage with mass effect, patient requiring ECMO, respiratory failure or arrest, malignant HTN, decompensated congestive heart failure, hepatic encephalopathy, ischemic bowel or multiple organ/system dysfunction	Uterine rupture
ASA VI	A declared brain-dead patient whose organs are being removed for donor purposes			

*Although pregnancy is not a disease, the parturient's physiologic state is significantly altered from when the woman is not pregnant, hence the assignment of ASA 2 for a woman with uncomplicated pregnancy, **The addition of "E" denotes emergency surgery: An emergency is defined as existing when delay in treatment of the patient would lead to a significant increase in the threat to life or body part. ASA: American Society of Anesthesiologists, PS: Physical status, BMI: Body mass index, HTN: Hypertension, DIC: Disseminated intravascular coagulation, DM: Diabetes mellitus, EF: Ejection fraction, ESRD: End-stage renal disease, CAD: Coronary artery disease, MI: Myocardial infarction, CVA: Cerebrovascular accident, TIA: Transient ischemic attack, COPD: Chronic obstructive pulmonary disease, ARD: Acute renal disease, OSA: Obstructive sleep apnea, PCA: Patient-controlled analgesia, ECMO: Extracorporeal membrane oxygenation, HELLP: Hemolysis, elevated liver enzmymes, low platelet