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Original Article

Assessment of Ultrasound-Guided Modified Erector Spinae Plane Block for Clinical Anesthesia in Geriatric Spinal Surgery

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SUMMARY

Objective: To compare the clinical anesthetic effects of ultrasound-guided traditional erector spinae plane block (ESPB) with those of modified ESPB (layer-by-layer infiltration erector spinae plane block) in elderly spinal fracture surgery.
Methods: From January to December 2023, eighty patients diagnosed with geriatric spinal fractures underwent ESPB surgery at Guangzhou University of Chinese Medicine's Shenzhen Hospital (Futian). The patients were randomly divided into the ESPB layer-by-layer infiltration group (Group M) and the traditional ESPB group (Group E), with 40 participants in each. The study compared ESPB operation time and percutaneous kyphoplasty (PKP) procedure time between the groups, as well as the intraoperative administration of additional intravenous analgesic medicines and the assessment of blood oxygen, mean arterial pressure (MAP), heart rate (HR), and pain scores at before anesthesia (T0), 20 minutes after blockade (T1), skin incision (T2), and following bone cement implantation (T3).
Results: The use of additional intraoperative sufentanil in ESPB revealed significant differences between the groups ($p < 0.001$). From T0 to T3, there were statistically significant differences in HR, MAP, and numerical rating scale scores between the groups ($p < 0.05$). There were also significant differences in MAP and NRS scores between the traditional and modified ESPB groups ($p < 0.05$).
Conclusion: Modified ESPB builds upon traditional ESPB by continuing to infiltrate anesthesia layer by layer along the direction of the erector spinae fascia after the puncture needle reaches the ultrasound-guided nerve block plane. This method effectively enhances intraoperative analgesia and sedation in spinal compression surgery, improving the quality of anesthesia in senior spinal surgery.

1. Introduction

According to 2020 census data, China now has 260 million people over the age of 60, accounting for 18.7% of the overall population.[1] These individuals often experience degenerative spinal changes such as vertebral compression fractures, protrusion of the intervertebral discs, and osteoporosis.[2] Erector spinae plane block (ESPB), a nerve block technique that has evolved in recent years, is frequently used in spinal surgery to reduce the risk of infection in spinal cord injuries.[3] In the context of geriatric spine surgery, traditional ESPB primarily relies on ultrasound guidance. This technique uses the transverse process of the thoracolumbar region as a landmark for clear visualization of the transverse process, erector spinae muscle, and other anatomical structures. Using the ultrasound image as a guide, a needle is inserted at the transverse process of the puncture site to block the nerves of the erector spinae muscle. In traditional ESPB, the diffusion of the anesthetic drug may be limited because the erector spinae muscle is divided into three longitudinal bundles separated by fascial barriers. Consequently, this study proposes using layer-by-layer infiltration to enhance the efficacy of traditional ESPB anesthesia. It also aims to compare changes in vital signs, pain scores numerical rating scale (NRS), and postoperative adverse reactions between the modified and traditional ESPB at different time intervals in geriatric spinal surgeries. This will provide a reference for clinical anesthesia methods in such surgeries.

2. Information and techniques

2.1. General information

From January to December 2023, 80 patients diagnosed with elderly spinal fractures at the Guangzhou University of Traditional Chinese Medicine Shenzhen Hospital (Futian) who underwent orthopedic spinal fracture surgery under ESPB were included in this study. This study was a clinical prospective randomized controlled trial (RCT), based on literature related to similar RCTs,[4] utilizing literature related to the Visual Analogue Scale (VAS), with parameters $\delta = 0.641$, $\sigma = 0.61$, $\alpha = 0.05$, $\beta = 0.10$, and $t0.05 = 1.645$, $t0.1 = 1.282$, the sample size was calculated using the formula: $N = (2 + 2) \times [(1.645 + 1.282) \times 0.61/0.641]^{\wedge 2} = 32$. Considering uncontrollable factors that might cause patient dropout, a 20% (7 additional participants) increase in the sample size was factored in, resulting in a total

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requirement of 40 participants for this project. Despite initially estimating the sample size to be 80 based on prior studies, this number was maintained to account for potential attrition affecting the trial outcomes. Randomization Method for Eligible Subjects: A simple randomization method was employed using Excel's = INT(RAND()*3) function to generate a random numerical table, which facilitated the design and arrangement of random codes for the control and test groups, subsequently producing randomized allocation cards (with number 0 denoting test group M, and 1 for control group E). These cards were sealed in opaque envelopes numbered sequentially. During the enrolment, envelopes with matching numbers were opened according to each patient's entry sequence, and subjects were assigned to their respective groups as per the randomization card instructions and treated according to the predetermined plans. The patients were divided into two groups using the randomized numerical method: the ESPB layer-by-layer infiltration group (Group M) and the ESPB traditional treatment group (Group E), each consisting of 40 cases. The study comprised 37 males and 43 females, all over the age of 65, with surgical sites located in the chest in 23 cases and the waist in 57 cases. There were no statistically significant differences in age, gender, or surgical location between the groups ($p > 0.05$), indicating comparability. Blinding Method: Throughout the grouping process, neither the patients nor the researchers were aware of the allocated treatment plans.

2.2. Inclusion criteria

(1) Diagnosed with primary osteoporosis according to the Diagnostic Guidelines for Primary Osteoporosis;[5] (2) History of minor trauma or thoracolumbar exertion; (3) Diagnosed with a spinal compression fracture on imaging, qualifying for surgical intervention; (4) No restrictions on gender, age over 65; (5) Body mass index (BMI) < 30 kg/m^2; (6) Preserved mental health and cognitive abilities postoperation; (7) American Society of Anesthesiologists (ASA) grade II to III; (8) Patient has signed an informed consent form after fully understanding the study.

2.3. Exclusion criteria

(1) Concomitant pyramidal injuries and fractures in other body parts; (2) Pathologic fractures due to metastases; (3) Severe medical conditions; (4) Prolonged use of hormonal medications; (5) Contraindications to regional anesthesia; (6) Allergy to local anesthetics or opioids; (7) Extended use of analgesic and sedative drugs or substance abuse; (8) History of mental disorders or poor communicative ability.[6]

2.4. Removal criteria

Change in anesthesia method, loss during postoperative follow-up, etc. The study was approved by the Ethics Committee of the Shenzhen Hospital of Guangzhou University of Chinese Medicine (Futian), and all participants or their family members provided signed informed consent. This study (Trial Registration Identifier: ChiCTR 2200057505), conducted from January to December 2023, received approval from the institutional review boards at Shenzhen Hospital of Guangzhou University of Chinese Medicine (Futian). Consent was also obtained from all subjects involved.

2.5. Grouping therapy

Using a simple randomization procedure, patients were divided into two groups: ESPB layer-by-layer infiltration (Group M = 40) and ESPB conventional treatment (Group E = 40), both undergoing ultrasound-guided ESPB.

In the conventional treatment group (Group E), patients were positioned prone. Adhering to aseptic principles, the puncture site on the erector spinae muscle at the fracture segment was selected as the central point. The area surrounding the site was disinfected three times within a 15–20 cm radius using 1% vital iodine, followed by the placement of a sterile cavity towel. A convex array ultrasound transducer (APLIO500 color doppler ultrasound equipment) was used.[7] The anesthetic, a saline-diluted 0.375% ropivacaine injection, was applied. The ultrasound probe was covered with a sterile film, and placement was aided by an X-ray 3D imaging system (C-arm) (ZiehmVisionFDVario3D). The high-frequency ultrasound probe was positioned sagittally at the patient's spinous process level, then moved 2–3 cm laterally to the puncture site, allowing visualization of the trapezius muscle, erector spinae muscle, transverse process, ribs, and pleura in a thoracic spine image from superficial to deep layers. The ribs and transverse processes appeared as highly echogenic structures. A 0.7*80 mm nerve block needle (TWLB; KDL) was used for puncturing using the in-plane needle technique. The needle was inserted at the center of the probe, the needle tip angle adjusted, and advanced until it reached the transverse process surface, followed by slow injection of 20 mL of 0.375% ropivacaine. The formation of a "shuttle" shape in the hypoechoic area indicated successful injection. The procedure on the opposite side mirrored this approach.[8] After the local anesthetic injection, patients were monitored for twenty minutes. The anesthesiologist used ice cube and needle tests to assess the plane of anesthesia; the absence of complications or unusual reactions indicated successful anesthesia. Each side of the ESPB was administered a total of 40 ml of 0.375% ropivacaine. Patients with NRS scores of 4 or higher at any time during the procedure were deemed to have inadequate analgesia and received an additional 5 ug of sufentanil, 0.5 mg of fentanyl, or 1 mg of buprenorphine intravenously. This dosage adjustment was based on standardized opioid equivalency, serving as a statistical measure in this study. Patients with scores below 4 demonstrated sufficient analgesia, eliminating the need for further analgesic intervention.

In the layer-by-layer infiltration group (Group M), building on the traditional ESPB group, once the puncture needle reached the target plane under ultrasound guidance, 10 ml of 0.375% ropivacaine was injected between the erector spinae muscle and the transverse process at the puncture site. The remaining 10 ml of 0.375% ropivacaine was then administered via layer-by-layer infiltration following the distribution of the erector spinae muscle. The efficacy and extent of the block were evaluated 20 minutes post-procedure, excluding any patients where the block was ineffective.[9]

2.6. Anesthesia techniques

Before surgery, all patients were required to fast for eight hours and abstain from liquids for four hours. Upon entering the operating room, non-invasive blood pressure (NIBP), electrocardiogram (ECG), respiration rate, and pulse oximetry (SpO_2) were measured, and an intravenous (IV) line was established. Patients received three liters per minute of oxygen via traditional nasal tubing. For the procedure, Group E underwent conventional ESPB at the fracture site under ultrasound guidance, while Group M received layer-by-layer infiltration anesthesia along the muscle bundles at various levels of the erector spinae muscle, based on the nerve block technique used in Group E. Intraoperative heart rate was maintained between 50 and 90 beats per minute using atropine or esmolol, and blood pressure fluctuations were controlled within 20% of the preoperative range

using m-hydroxylamine or nitroglycerin. Additional analgesia was provided with an IV injection of 5 ug sufentanil, 0.5 mg fentanyl, or 1 mg buprenorphine if the patient's pain became unbearable.[10] One anesthesiologist performed the ESPB and managed intraoperative anesthesia, while a separate physician, uninvolved in the anesthesia procedures, conducted postoperative follow-up without knowledge of the specific interventions applied.

2.7. Observational indicators

(1) Assess the differences in operating times for ESPB and percutaneous kyphoplasty (PKP) between the two groups, as well as the volume of additional IV analgesic medication administered during the procedures. (2) Evaluate blood oxygen levels, mean arterial blood pressure, and heart rate at various time points: before anesthesia (T0), 20 minutes post-block (T1), during the skin incision (T2), and after implantation of bone cement (T3). Analyze changes in these vital signs and pain scores between the two groups, using the NRS to assess pain at each time point.[11] (3) Investigate the incidence of postoperative complications such as nausea, vomiting, dizziness, and skin irritation. (4) Document severe outcomes including death, pulmonary embolism, deep vein thrombosis, and cardiac complications.

2.8. Statistical analysis

Quantitative data were expressed as mean ± standard deviation ($x \pm s$); categorical data were reported in numbers or percentages. An independent sample T-test was used for comparison between the two groups, and repeated measures ANOVA was employed to analyze data across multiple time points. If $p < 0.05$, the difference was considered statistically significant.

3. Results

This study involved 80 participants, all of whom completed the ESPB experiment.

3.1. Comparison of general statistics between the two patient groups

There was no statistically significant difference ($p > 0.05$) between the two groups in terms of age, gender, height, weight, ASA classification, total operation duration, and duration of the ESPB procedure (Table 1).

3.2. Comparison of ESPB procedure duration, total operation time, and additional intraoperative analgesics between the two groups

There was a marked difference in the use of additional intraoperative analgesics between the two groups during the ESPB procedure ($p < 0.001$) (Table 2).

3.3. Comparison of vital indicators (MAP (mmHg), HR, SpO_2, and pain scores (NRS)) at various ESPB periods between two groups

The difference in MAP between ESPB T0, T2, and T3 was not statistically significant ($p > 0.05$), except for a significant difference at T2 ($p < 0.05$). There was no significant difference in HR between the ESPB T0 and T2 groups ($p > 0.05$), but significant differences were noted between T1 and T3 ($p < 0.05$). The variations in SpO_2 between the two groups at various ESPB stages were not statistically significant ($p > 0.05$). However, differences in pain scores (NRS) at various ESPB periods were significant between the two groups.

Further pairwise comparisons were conducted: Within groups, from T0 to T3, no significant difference was observed in SpO_2 ($p > 0.05$). However, significant differences were noted in HR, MAP, and NRS scores between the two groups ($p < 0.05$). When comparing the traditional ESPB group with the modified ESPB group, no significant differences were found in HR and SpO_2 ($p > 0.05$), but significant differences in MAP and NRS scores were noted ($p < 0.05$). In interactive comparisons, no significant difference was found in SpO_2 scores ($p > 0.05$). However, HR, MAP, and NRS showed statistically significant differences (Table 3; Figure 1).

3.4. Comparison of postoperative adverse effects following ESPB in the two groups

The incidence of adverse events, including deep vein thrombosis, pulmonary embolism, nausea, vomiting, itchy skin, and death, as well as the overall incidence of postoperative complications, did not differ statistically significantly between the two patient groups ($p > 0.05$) (Table 4).

4. Conclusion

Originally used in 2016 to treat neuropathic pain, the ESPB is a regional nerve block technique that employs ultrasound guidance to inject local anesthetic between the patient's erector spinae muscles and the transverse processes of the vertebral body.[12] Since its introduction, ESPB has evolved and is now utilized for spinal surgery and postoperative analgesia in cardiac, thoracic, and abdominal surgeries.[13] ESPB poses a lower risk of side effects compared to traditional

Table 2
Comparison of ESPB operation time, operation time, and additional intraoperative analgesic medicines in the two groups ($\bar{x} \pm s$).

Group	Number	Additional sufentanil (ug)
E group	40	1.88 ± 2.70
M group	40	0.88 ± 1.92
t value		1.907
p value		< 0.001

NOTE: ESPB, erector spinae plane block.

Table 1
Comparison of the two groups patients' general data.

Group	Number	Gender (male/female)	ASA (II/III)	Age (years)	Height (cm)	Weight (kg)	Surgery time (min)	ESPB operating time (min)
E group	40	18/22	2.38 ± 0.49	72.52 ± 6.47	163.13 ± 7.30	61.84 ± 9.37	51.28 ± 10.22	8.05 ± 1.95
M group	40	19/21	2.38 ± 0.49	72.67 ± 6.81	163.08 ± 6.94	61.70 ± 8.49	51.98 ± 8.78	8.03 ± 2.21
χ^2/t value		0.221	1.000	-0.101	0.032	0.067	-0.329	0.054
p value		0.675	0.000	0.467	0.905	0.884	0.372	0.233

NOTE: ASA, American Society of Anesthesiologists; ESPB, erector spinae plane block.

Table 3
Comparison of vital indicators (MAP (mmHg), HR, SpO2 and pain scores (NRS)) at various ESPB periods between two groups.

Group	Number	MAP (mmHg)	HR (beats/min)	SpO2 (%)	NRS
E group	40				
T0		102.1 ± 13.62^{2}	69.43 ± 10.50^{2}	98.08 ± 1.38^{2}	6.48 ± 1.54^{2}
T1		89.05 ± 11.46^{2}	69.53 ± 9.40^{2}	98.30 ± 1.22^{2}	2.85 ± 1.07^{2}
T2		94.63 ± 17.02^{2}	64.85 ± 8.02^{2}	96.98 ± 1.86^{2}	2.85 ± 1.33^{2}
T3		93.1 ± 14.29^{2}	63.65 ± 11.12^{2}	93.90 ± 14.54^{2}	3.50 ± 1.21^{2}
M group	40				
T0		102.25 ± 10.85^{2}	69.50 ± 8.12^{2a}	98.05 ± 1.08^{2}	6.48 ± 1.40^{2}
T1		97.35 ± 9.57^{2}	66.80 ± 6.35^{2}	98.13 ± 1.11^{2}	2.02 ± 0.95^{2}
T2		102.43 ± 12.77^{2a}	68.3 ± 7.27^{2}	97.62 ± 1.48^{2a}	1.82 ± 0.81^{2a}
T3		94.63 ± 10.02^{2}	67.63 ± 7.01^{2a}	97.68 ± 1.35^{2a}	1.98 ± 0.77^{2a}
F_{time}, P_{time}		15.04, < 0.0001	5.092, 0.0040	3.680, 0.0549	238.9, < 0.0001
$F_{interblock}$, $P_{interblock}$		4.414, 0.0389	0.7033, 0.4042	2.782, 0.0993	39.38, < 0.0001
$F_{interactive}$, $P_{interactive}$		3.740, 0.0118	4.353, 0.0052	2.550, 0.0565	6.064, 0.0005

NOTE: T0: measured on admission; T1: measured 20 min after block; T2: measured at the time of skin cutting; T3: measured after cement implantation.
[a] Compared with the conventional group (E group) at that moment, $p < 0.05$.
NOTE: MAP, mean arterial pressure; HR, heart rate; NRS, numerical rating scale; SpO2, pulse oximetry.

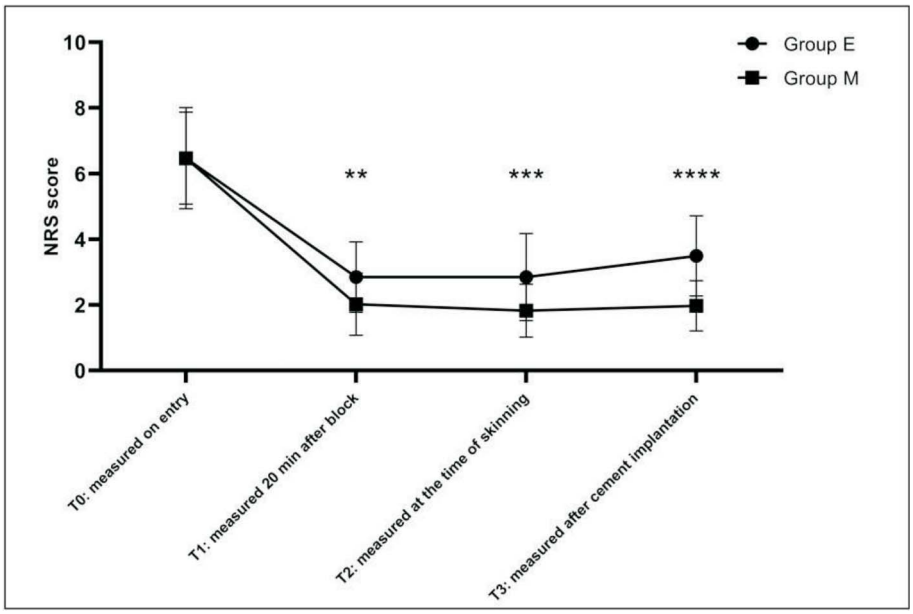

Figure 1. Intraoperative pain numerical rating scale (NRS) scores at various time points.

Table 4
Comparing the two groups' postoperative adverse responses following ESPB.

Group	Number	Nausea	Sleepiness	Pruritus	Heart rate decrease	Deep vein thrombosis (DVO)	Pulmonary embolism	Death	Total incidence
E group	40	2 (5%)	1 (2.5%)	0	1 (2.5%)	0	0	0	7 (20%)
M group	40	2 (5%)	1 (2.5%)	0	0	0	0	0	2 (5%)
χ^2/t value									0.674
p value									0.174

NOTE: ESPB, erector spinae plane block.

epidural block anesthesia.[14] With traditional ESPB, it has been found that injecting anesthetics deep into the erector spinae muscle allows the anesthetic fluid to spread into the paravertebral space, effectively blocking the sympathetic nervous system's traffic branches as well as the corresponding ventral and dorsal branches of the spinal nerves. Its benefits include safety, ease of use, minimal impact on coagulation function, strong analgesic effects, a broad range of blocking, and a low risk of complications.[15]

Osteoporosis is a gradual, systemic skeletal disease that progressively affects the body with age, characterized by a reduction in bone mass, structural changes, and decreased bone density, all of which can lead to fractures.[16] It is estimated that over 200 million individuals worldwide suffer from osteoporosis, with more than 90 million patients in China alone.[17] The large population base and the aging demographic have also led to an annual increase in the number of spinal fracture procedures performed on the elderly. ESPB relies on the concept of physically diffusing and spreading local anesthetic to the neural structures deep within the fascial plane of the erector spinal muscle and the surrounding tissues.[18] Research has indicated that[19] in perioperative analgesia, preoperative bilateral ultrasound-guided ESPB blocks provides more effective postoperative pain control in the lumbar spine than traditional postoperative analgesia methods.[20]

This study analyzes the anesthetic effects of modified ESPB compared to regular ESPB in clinical anesthesia, with the goal of opti-

mizing clinical anesthesia outcomes. For the local anesthetic, this study utilized 0.375% ropivacaine in a 20 ml volume to perform the erector spinae muscle block. Ropivacaine, a long-acting amide local anesthetic, acts quickly and maintains a stable duration of action with reduced cardiac toxicity, thereby lowering the risks associated with local anesthetics.[21] According to the study results, there were no significant differences between the two groups in terms of gender, age, ASA score, height, overall operation time, and ESPB operation duration. However, there was a significant difference in the use of additional anesthetic drugs during surgery between the modified and traditional ESPB groups. This difference was attributed to the modified ESPB's wider infiltration range within the erector spinae muscle, enhancing intraoperative analgesia.[15] Due to the structural characteristics of the erector spinae muscle, the enhanced ESPB provides more comprehensive coverage of all levels of the erector spinae muscle bundles at the anesthetic level, thus offering superior intraoperative analgesia. Additionally, the presence of fascia overlying the muscle bundles allows the modified ESPB to more effectively envelop the various layers of the erector spinae muscle, further facilitating intraoperative analgesia. Regarding the differences between the two groups, significant variations were observed in HR, MAP, NRS scores, and postoperative complications ($p > 0.05$), while differences in SpO_2 scores were not statistically significant ($p > 0.05$). These findings suggest that the overall effectiveness of the modified ESPB surpasses that of the traditional method.[3] Regarding adverse reaction incidence, the modified group had only a 5% occurrence, less than the traditional group. However, there was no statistical significance between the two, likely due to the small sample size in this study. This study has limitations: (1) It has so far analyzed only 80 cases, which is a relatively small sample that will need to be expanded in subsequent research. (2) Further investigation is required to determine the appropriate dosages of ropivacaine at various levels within the modified ESPB. (3) Given the variable tissue responses to ESPB across different segments, a comprehensive statistical analysis of these segments is planned for future studies.

In conclusion, analgesia and sedation following thoracolumbar fracture vertebroplasty in elderly patients can be effectively enhanced by both conventional ESPB and ultrasound-guided layer-by-layer infiltration bilateral ESPB. However, the anesthetic efficacy of the modified ESPB surpassed the traditional method in terms of quality, perioperative analgesia, sedation, and vital signs stabilization. This improvement may be attributed to the modified ESPB's broader coverage of nerve branches within the intermuscular fascia, which facilitates the diffusion of local anesthetics more effectively than the targeting of the posterior branch of spinal nerves at the deep part of the erector spinae muscle during puncture. ESPB is superior to traditional anesthesia methods in reducing perioperative aberrant reactions, enhancing anesthesia quality and operation safety in elderly patients, and promoting rapid postoperative recovery, among other benefits. Thus, it demonstrates significant clinical value for broader adoption.

Conflict of interest declaration

All authors declare no personal or professional conflicts of interest relating to any aspect of this study.

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