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Original Article

Clinical Anesthesia of Geriatric Percutaneous Kyphoplasty: A Comparative Study of Different Injection Levels for Erector Spinae Plane Block

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SUMMARY

Objective: To compare the clinical anesthesia outcomes of different segmental erector spinae plane block (ESPB) under ultrasound guidance in elderly patients undergoing percutaneous kyphoplasty (PKP).
Methods: From January to December 2022, patients who underwent ESPB-guided PKP at Shenzhen Hospital (Fu Tian) of Guangzhou University of Chinese Medicine were randomly divided into two groups: M group (ESPB anesthesia shifted 1–2 segments, 40 cases) and E group (ESPB anesthesia at the level of the fractured segment, 40 cases). The operation time for ESPB, PKP, additional intravenous analgesic dose during surgery, vital sign changes, and pain scores at various time points were compared between the two groups. SpO_2, MAP, and HR were assessed before anesthesia (T0), 20 minutes after blockade (T1), at skin incision (T2), and after bone cement implantation (T3). The Numerical Rating Scale (NRS) was used to evaluate pain scores at each interval. Postoperative complications, including nausea, vomiting, itching, cardiopulmonary complications, deep vein thrombosis, pulmonary embolism, and mortality, were documented.
Results: No statistically significant differences were observed in operative time, surgery duration, and intraoperative additional analgesic use between the groups. HR, MAP, SpO_2, and NRS pain scores also showed no significant differences ($p > 0.05$) between the groups. For intragroup comparisons, from T1 to T3, Group E had significantly lower HR, MAP, SpO_2, and NRS scores than at T0 ($p < 0.05$). There was no statistically significant difference in the overall incidence rate of adverse reactions between the two groups.
Conclusion: While variations in needle segments for ESPB, as guided by ultrasound, did not significantly alter the anesthetic effect, they effectively improved analgesia and sedation in elderly patients with thoracolumbar vertebral compression fractures undergoing PKP. This method also reduces perioperative stress reactions and adverse events, enhancing the quality and safety of anesthesia.

1. Introduction

Due to the increasing aging of the population year by year, geriatric vertebral compression fractures (VCF) have gradually become one of the diseases that cannot be ignored on an international scale.[1] Globally, about 20% of those older than 70 years have experienced VCF, with approximately 16% of postmenopausal women having suffered VCF.[2] Percutaneous kyphoplasty (PKP) is an effective and precise intervention technology for VCF and has been extensively used in their treatment.[3–7] Various anesthesia methods, including general, local, spinal anesthesia, and nerve blocks, are applicable to PKP. However, general anesthesia carries greater risks for elderly patients, and local anesthesia may cause severe pain. In this context, nerve blocks, specifically erector spinae plane blocks (ESPB), emerge as a more suitable anesthesia technique for geriatric PKP. ESPB, a novel interfascial plane block developed in recent years, encompasses the dorsal, abdominal, and intercostal branches of the spinal nerve, and influences the paravertebral space. Compared to traditional intraspinal and thoracic paravertebral blocks, ESPB reduces risks of spinal cord injury and infection, offering significant advantages in efficacy, ease of operation, and safety.[8,9] Forero et al.[10] first used ESPB for treating chest and back pathological pain in 2016. However, there are limited reports on the specific segments for ESPB application. This study, therefore, compared the effectiveness and postoperative complications of ESPB in geriatric PKP under different segments to provide references for anesthesia practice.

2. Materials and methods

2.1. General

Patients undergoing orthopedic PKP under ESPB at Shenzhen Hospital (Fu Tian) of Guangzhou University of Chinese Medicine from January 2022 to December 2022 were selected. Inclusion crite-

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ria: (1) Unrestricted gender, age over 65, BMI < 30 kg/m^2; (2) Meeting the indications for PKP surgery according to the guidelines for the treatment of osteoporotic vertebral compression fractures;[11] (3) American Society of Anesthesiologists (ASA) classification: II~IIII. Exclusion criteria: (1) Allergy to local anesthetics or opioids; (2) Contraindications to regional anesthesia; (3) A long-term history of using analgesic and sedative drugs or drug abuse; (4) History of mental illness or poor communication. Additional exclusion criteria: change in anesthesia method, loss during postoperative follow-up, etc. This study was approved by the ethics committee of Shenzhen Hospital (Fu Tian) of Guangzhou University of Chinese Medicine, and all patients or their family members provided advance signed informed consent.

2.2. Grouping and intervention

Patients were divided into two groups using simple random method: ESPB up 1–2 segments group (group M, n = 40) and ESPB fracture segment group (Group E, n = 40). Both groups underwent ESPB with ultrasound guidance. With the assistance of the operating room nurse and other colleagues, the patient was positioned prone. Ropivacaine injection (10 ml: 100 mg/tube; Jiabo pharmaceutical) was diluted to 0.375% concentration using normal saline. Following surgical sterility principles, the affected vertebra was taken as the central point. The area around it was disinfected three times with 1% vital iodine, covering a 15–20 cm radius, and then sterile hole towels were placed. A convex array ultrasonic transducer (Aplio 500 color Doppler ultrasonic instrument) was selected. A suitable amount of coupling agent was applied to the ultrasonic probe, which was then securely wrapped with sterile film. Before the procedure, the intraoperative X-ray three-dimensional imaging system (C-arm) (Ziehm vision FD vario 3D) was used for positioning. Once positioned correctly, the anesthesiologist stood beside the bed, placed the ultrasound probe parallel to the spine's long axis, and scanned in a parasagittal direction. The probe was moved slowly from the anterolateral side to the medial side until the vertebral body's transverse process plane was visible. Both ribs and transverse processes appeared as hyperechoic masses. However, in comparison to the ribs, the transverse process was deeper and more square-shaped.[12] The nerve block needle's angle (0.7 * 80 mm, twlb; KDL) was adjusted until its tip touched the transverse process's surface. To determine the optimal position, 2 ml of normal saline was injected. The "fusiform" appearance of the dark liquid area could be seen in the "water separation" technique (Figure 1). After ensuring the absence of blood, gas, and cerebrospinal fluid on aspiration, 20 ml of 0.375% ropivacaine injection was administered. The procedure for the ESPB on the opposite side was identical, with a total of 40 ml liquid (0.375% ropivacaine injection 150 mg) used for both sides. After 20 minutes, the anesthesiologist used both the ice block and acupuncture methods to identify the anesthesia plane, which could block three segments of the ipsilateral upper and lower spinal nerve innervation areas. This procedure aims to avoid mistakenly puncturing the intervertebral foramen or spinal canal; thus, we opted for ESPB over annulus fibrosus anesthesia. Patients with an NRS score of 4 or higher at any given time during surgery indicated inadequate analgesia. These patients received either intravenous sufentanil 5 ug, fentanyl 0.5 mg, or butorphanol 1 mg. For the purpose of this study, the total amount of standardized opioids replaced the initial analgesic drugs based on an equivalent dose conversion. An NRS score below 4 indicated satisfactory analgesia, and no supplementary analgesics were administered. Group E's ESPB at the fracture segment followed the same procedure as Group M.

2.3. Anesthesia method

Patients were instructed to fast and refrain from drinking before surgery. Upon entering the pre-anesthesia room, nurses established peripheral venous access. No medication was administered prior to anesthesia. Noninvasive blood pressure (NIBP), pulse oxygen saturation (SpO_2), and electrocardiogram (EEG) are monitored immediately upon entering the room. Oxygen was administered at a rate of 3l/min through a conventional nasal tube. After preparations, Group E underwent ESPB at the fracture stage using ultrasound guidance, while Group M underwent ESPB 1–2 segments above. Atropine or esmolol was administered to maintain the intraoperative heart rate within the range of 50–90 beats/minute. M-hydroxylamine or nitroglycerin was used to stabilize blood pressure fluctuations, keeping it within 20% of the preoperative measure. If the patient experienced pain, 5 ug of sufentanil, 0.05 mg of fentanyl, or 1.33 mg of butorphanol was administered intravenously. Given the variety and complexity of opioid drugs utilized in anesthesia, the original data were standardized using an equivalent dose conversion table for opioid drugs (Table 2-2). One anesthesiologist documented the ESPB and intraoperative anesthesia, while a separate physician, not involved in the anesthesia procedure, conducted postoperative follow-up. This follow-up physician was not informed of the patient's intervention measures.

2.4. Outcome measures

(1) The ESPB operation time and PKP operation time were compared between the two groups. The equivalent dosages of intravenously administered analgesics used during the operation were also compared. (2) Changes in vital signs and pain scores at different time points were compared between the groups. Specifically, blood oxygen, mean arterial pressure, and heart rate were assessed at various intervals: before anesthesia (T0), 20 minutes post-block (T1), during skin incision (T2), and after bone cement implantation (T3). The pain scores at each of these time points were evaluated using the numerical rating scale (NRS).[13] (3) The incidences of postoperative complications, such as dizziness, nausea, vomiting, and skin itching, were compared between the groups. (4) Records of cardiopulmonary complications, deep vein thrombosis, pulmonary embolism, and any deaths were maintained.

2.5. Statistic analysis

Data was analyzed using SPSS 24.0 software. Measurement data was presented as mean ± standard deviation (x ± s). Data from multiple time points were compared using repeated measures analysis of variance, and comparisons between the two groups were made using the independent samples t-test. Count data were expressed as the number of cases or percentage, and the compari-

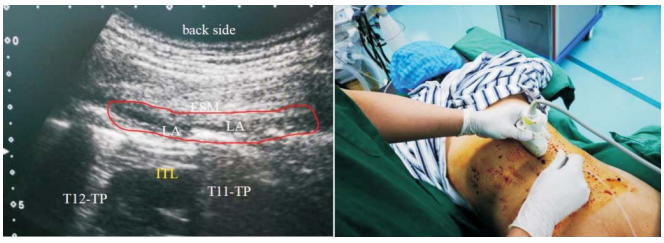

Figure 1. Ultrasound imaging of ESPB and image of ESPB operation. ESM: erector spinae muscle; ESPB: erector spinae plane blocks; ITL: intercostal ligament; LA: local anesthetic; T11-TP: Thoracic 11 Transverse Process; T12-TP: Thoracic 12 Transverse Process.

son between the two groups was performed using χ^2 inspection. $p < 0.05$ was considered indicative of a statistically significant difference.

3. Results

A total of 80 subjects participated in the study, all of whom completed the entire ESPB experiment.

3.1. Comparison of general data between the two groups

There was no significant difference in age, gender, height, weight, ASA grade, and other general data between the two groups ($p > 0.05$) (Table 1).

3.2. Comparison of ESPB operation time, operation duration, and intraoperative addition of equivalent analgesic drugs between the two groups

No significant differences were observed in ESPB operation time, operation duration, and the intraoperative addition of equivalent analgesic drugs between the groups ($p > 0.05$) (Table 2).

3.3. Comparison of vital signs changes and NRS scores between the two groups at different time points

There was no significant difference in vital signs, HR, MAP, SpO_2 and NRS scores between the two groups at each corresponding time point ($p > 0.05$). Upon further pairwise comparison, within Group E: from T1 to T3, HR, MAP, and NRS scores were lower than at T0, showing a statistically significant difference ($p < 0.05$). However, when comparing SpO_2 values from T1 to T3 with T0, no significant difference was found ($p > 0.05$). Between groups, from T1 to T4, there were no significant differences in HR, MAP, SpO_2, and NRS scores between Group M and Group E ($p > 0.05$). Repeated measures analysis of variance confirmed these findings, showing no significant differences in HR, MAP, SpO_2, and NRS scores between the groups at each respective time point ($p > 0.05$) (Table 3).

3.4. Comparison of adverse reactions between the two groups

No significant differences were observed in the total incidence of postoperative dizziness, nausea, vomiting, skin itching, and other complications, or in cardiopulmonary complications, deep vein thrombosis, pulmonary embolism, and death between the two groups ($p > 0.05$) (Table 4).

4. Conclusions

In recent years, the incidence of traumatic, pathological, and

Table 2-1
Comparison of ESPB operation time, surgical time, and intraoperative additional analgesics between two groups ($x \pm s$)

Group	ESPB time (min)	Operative time	Additional analgesics
E group	9.80 ± 3.11	47.75 ± 15.69	0.5 ± 0.59
M group	9.65 ± 3.99	47.15 ± 13.92	0.25 ± 0.43
t value	0.126	2.172	1.134
p value	0.901	0.223	0.204

ESPB: erector spinae plane blocks.

Table 2-2
Equivalent dose of analgesics.

Analgesics	Sufentanil	Fentanyl	Butorphanol	Statistic
Equivalent dose	0.005 mg	0.05 mg	1.33 mg	1

Table 1
Comparison of general information between two groups of patients.

Group	Number	Gender (male/female)	ASA (II/III)	Age (years)	Height (m)	Weight (kg)
E group	40	5/15	2/18	77.9 ± 8.78	157.19 ± 7.44	56.85 ± 10.22
M group	40	7/13	3/17	77.6 ± 8.00	157.82 ± 7.31	56.47 ± 10.25
χ^2/t value		0.305	0.228	0.112	0.286	0.118
p value		0.503	0.572	0.904	0.778	0.907

ASA: American Society of Anesthesiologists classification.

Table 3
Comparison of changes in vital signs and NRS scores between two groups at different time points ($x \pm s$)

Group	Number	HR (beats/min)	MAP (mmHg)	SO_2 (%)	NRS
E group	40				
T0		80.2 ± 14.3	100.9 ± 16.4	97.5 ± 1.7	6.1 ± 1.7
T1		75.4 ± 13.6^{a}	95.5 ± 15.7^{a}	97.9 ± 1.5	3.0 ± 1.2^{a}
T2		79.1 ± 14.8^{a}	101.6 ± 16.0^{a}	97.9 ± 2.2	3.5 ± 1.4^{a}
T3		79.8 ± 15.7^{a}	101.9 ± 16.5^{a}	97.0 ± 3.2	3.2 ± 1.3^{a}
M group	40				
T0		79.8 ± 13.2	101.0 ± 20.5	96.8 ± 1.8	6.0 ± 2.2
T1		$76.6 \pm 11.8^{a,b}$	$90.9 \pm 15.8^{a,b}$	$97.4 \pm 1.6^{a,b}$	$2.9 \pm 1.1^{a,b}$
T2		$79.3 \pm 20.0^{a,b}$	$98.0 \pm 17.5^{a,b}$	$97.3 \pm 1.4^{a,b}$	$3.0 \pm 1.1^{a,b}$
T3		$74.3 \pm 14.1^{a,b}$	$92.9 \pm 15.0^{a,b}$	$97.3 \pm 1.5^{a,b}$	$2.9 \pm 1.1^{a,b}$
F-time		0.59	1.6	0.68	40.17
P-time		< 0.001*	< 0.001*	0.37	< 0.001*
F-interblock		0.2	2.46	1.4	1.15
P-interblock		0.65	< 0.12	0.24	0.29
F-interactive		0.38	0.47	0.51	0.24
P-interactive		0.77	< 0.7	0.68	0.87

Note: Compared with T0 in this group, [a] $p < 0.05$; Compared with the control group during the same period, [b] $p > 0.05$; HR: heart rate; MAP: mean arterial pressure; SO_2: blood oxygen saturation; 1 mmHg = 0.133 kPa.

Table 4
Comparison of adverse reactions between two groups (cases (%)).

Group	Number	Nausea	Vomiting	Pruritus	Cardiopulmonary complications	Deep vein thrombosis	Pulmonary embolism	Death	Total incidence
E group	40	3 (50%)	2 (33%)	1 (17%)	0	0	0	0	6
Mgroup	40	2 (40%)	2 (40%)	1 (20%)	0	0	0	0	5
χ^2 value									0.826
p value									0.572

osteoporotic spinal and vertebral fractures has risen significantly compared to previous years, leading to an increase in posterior vertebral fracture reduction surgeries.[4] General anesthesia or local anesthesia can affect the efficiency of the surgery and extend postoperative recovery time.[15,16] ESPB, a newer regional anesthesia technique, has gained wide acceptance. Beyond providing analgesia for the lower back, ESPB has recently been employed for intraoperative anesthesia. ESPB involves the injection of local anesthetics between the transverse process and the deep part of the erector spinae muscle to achieve analgesic blockage. Since the pleura is positioned outside the transverse process, it acts as an anatomical barrier, substantially reducing the risk of pleural puncture under ultrasound guidance.[17] Forero et al.[10] posited that ESPB can produce an expansive cutaneous sensory block, suggesting that both the anterior and posterior branches of the spinal cord are impacted.[18] Concurrently, post-ESPB local anesthetics can affect visceral analgesia by blocking the communicating branch and sympathetic nerve.[19,20] Elsharkawy et al. discovered in their anatomical studies on adult human cadavers that the erector spinalis muscle encompasses the entire back. They noted that the ESPB extensively covers the dorsal and ventral branches of the spinal nerve, the intercostal nerve, and other components, including the sensory areas of multiple skin ganglia.[21] Ueshima et al.[22] also determined that ESPB adequately provides the necessary analgesic plane for patients with spinal fractures, offering effective pain relief, reducing bodily stress responses and sympathetic nerve reflexes, limiting harmful stimuli during surgery, and ensuring stability of vital signs during the procedure.[23–25]

This study primarily examines the dispersion mechanism and block segment of ESPB action, offering insights for clinical trial research. Building on prior clinical experiences and literature,[26,27] the local anesthetic chosen for this study was low-concentration ropivacaine (0.5% for each side during bilateral block; 20 ml of 0.375% ropivacaine) for blockage. Being a relatively long-lasting amide, ropivacaine diminishes the toxicity risk of local anesthetics, while maintaining consistent injection speed. The precise mechanism of ESPB remains uncertain, with its pain-relieving effects varying widely among individuals. Research indicates that the analgesic effect of ESPB is influenced by factors like drug volume, injection segment, procedure type, and injection speed.[25] Kose et al.[28] noted differences in ESPB application at the thoracic and lumbar levels. The erector spinae muscle showcases both anatomical and ultrasonic disparities at these levels. Thus, ESPB application varies, with the thoracic level being simpler and more practiced than the lumbar level.

In this study, patients in group E, who received ESPB at the fractured segment, experienced block plane spread across 2–3 thoracic segments and 2–4 lumbar segments. This distribution was comparable to Group M, where ESPB was administered 2 segments above the fracture segment, showing no significant difference in block plane extent. Consequently, there was no significant difference in NRS pain scores and intraoperative vital signs fluctuations (Figure 2). Neither group exhibited adverse reactions, such as significant vital sign fluctuations, local anesthetic toxicity, drowsiness, nausea, or vomiting during ESPB. This technique is suitable for anesthesia and pain management during vertebral fracture PKP in elderly patients and enhances patient comfort and satisfaction during surgery.

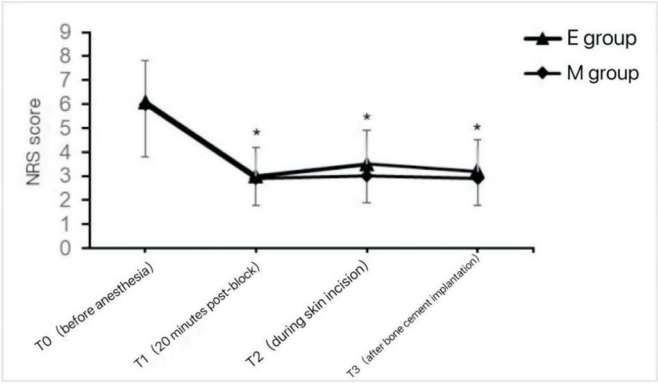

Figure 2. Pain NRS score at various time points during surgery (* $p < 0.05$ compared with the T0). NRS: numerical rating scale.

However, this study does have some limitations: (1) Currently, the study only comprises 80 samples, with 40 cases in each group. Being a small, single-center clinical study, there's a need to expand the sample size to enhance the study's quality; (2) Determining the lowest effective concentration of ropivacaine, ensuring satisfactory analgesic effects during ESPB while minimizing adverse reactions, remains a pressing concern for future research; (3) Differences exist between the effects of thoracic and lumbar blocks. This study did not categorize the thoracic and lumbar segments for analysis and statistics. Segregating and studying these segments separately will be pursued in future research.

In conclusion, although variations in needle segments for ESPB, guided by ultrasound, did not significantly alter the anesthesia effect, they effectively enhanced analgesia and sedation in elderly patients with thoracolumbar VCF undergoing PKP. This can mitigate perioperative stress responses and reduce postoperative adverse events, elevating the quality of anesthesia and surgery safety in elderly patients. Such advancements are crucial for the swift postoperative recovery of this demographic, bearing notable clinical significance.

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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