

Ultrasound-Guided Paravertebral Nerve Block in Percutaneous Vertebroplasty: A Retrospective Analysis

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Abstract

Objective

To retrospectively analyze the effectiveness of ultrasound-guided paravertebral nerve block in thoracolumbar fracture surgery.

Methods

Clinical data of 84 patients with thoracolumbar fractures who underwent percutaneous vertebroplasty at Xiaoshan District Traditional Chinese Medicine Hospital, Hangzhou, from July 2021 to July 2026 were retrospectively analyzed. Patients were divided into two groups based on the anesthesia method: the observation group (n = 42) received bilateral paravertebral nerve block combined with local anesthesia, while the control group (n = 42) received local anesthesia alone. The two groups were compared regarding intraoperative changes in heart rate (HR) and mean arterial pressure (MAP), Visual Analogue Scale (VAS) scores immediately post-surgery (T0), and at 6 hours (T1), 12 hours (T2), and 24 hours (T3) post-surgery, as well as postoperative complications and length of hospital stay.

Results

The retrospective study results indicated that, compared to the local anesthesia group, the paravertebral nerve block group had shorter operative time, more stable intraoperative MAP and HR, lower postoperative VAS scores, and shorter hospital stays. These differences were statistically significant ($P < 0.05$). No statistically significant difference was found in the incidence of postoperative complications between the two groups ($P > 0.05$).

Conclusion

Paravertebral nerve block anesthesia can stabilize intraoperative vital signs, shorten operative time, reduce postoperative pain scores, and demonstrates good safety.

Introduction

With the aging population, the incidence of osteoporotic vertebral compression fractures (OVCF) is increasing annually, becoming a common orthopedic condition that severely impacts the quality of life of the elderly¹. Percutaneous vertebroplasty (PVP) and percutaneous kyphoplasty (PKP) are currently the preferred minimally invasive surgical treatments for OVCF, capable of rapidly relieving pain and improving patient mobility²⁻⁴. However, as patients undergoing these procedures are mostly elderly and often present with comorbidities such as hypertension, diabetes, and coronary heart disease, coupled

with the need for the prone position during surgery, perioperative anesthetic management poses significant challenges⁵⁻⁷.

Currently, anesthesia options for PVP/PKP include general anesthesia, neuraxial blockade, local infiltration anesthesia, and various regional nerve block techniques. While simple local infiltration anesthesia is easy to perform, its intraoperative analgesic effect is often inadequate. Patients may experience pain during puncture and bone cement injection, affecting cooperation and potentially leading to significant hemodynamic fluctuations. Paravertebral nerve block (PVB) involves injecting local anesthetic into the paravertebral space to block the spinal nerves emerging from the intervertebral foramina, providing ipsilateral segmental somatic and sensory nerve blockade, thereby offering good analgesia for the surgical area⁸⁻¹¹. With the increasing popularity of ultrasound visualization technology in recent years, ultrasound-guided PVB is being widely used in anesthesia for minimally invasive spinal surgery due to its precision, real-time capability, and safety.

Previous studies have preliminarily confirmed that ultrasound-guided thoracic PVB for PVP/PKP provides superior intraoperative analgesia and higher patient satisfaction compared to local anesthesia alone^{12,13}. However, most related domestic studies are small-sample, single-center reports with short-term observations, and systematic retrospective studies remain limited¹⁴⁻¹⁶.

Therefore, this study aims to retrospectively analyze the clinical data of OVCF patients who underwent PVP at Xiaoshan Traditional Chinese Medicine Hospital over the past five years. We will compare the analgesic efficacy, hemodynamic stability, and safety of ultrasound-guided PVB combined with local anesthesia versus local anesthesia alone in percutaneous vertebroplasty, aiming to provide evidence-based medical evidence for optimizing anesthetic protocols for this type of surgery.

General Information and Methods

1.1 General Information

This is a single-center retrospective cohort study. Clinical data were selected from patients with osteoporotic vertebral compression fractures (OVCF) who underwent PVP at Xiaoshan District Traditional Chinese Medicine Hospital, Hangzhou City, Zhejiang Province, between July 2021 and July 2026. Patients meeting the inclusion criteria during the study period were screened through the hospital's electronic medical record system, anesthesia recording system, and Picture Archiving and Communication System (PACS). Based on the actual anesthesia method recorded in the anesthesia records, patients were divided into two groups: the observation group comprised patients receiving ultrasound-guided PVB; the control group comprised patients receiving simple local infiltration anesthesia. Baseline data were collected for both groups, including: age, sex, body mass index (BMI), fracture segment (thoracic/lumbar), number of fractured vertebrae, comorbidities (hypertension, diabetes, coronary heart disease, chronic obstructive pulmonary disease, etc.), American Society of Anesthesiologists (ASA) physical status classification, preoperative Visual Analogue Scale (VAS) pain

score, and preoperative laboratory results (coagulation function, liver and kidney function). The collection of baseline data aimed to assess intergroup comparability and serve as a basis for adjusting confounding variables in subsequent multivariate analyses.

1.2 Inclusion and Exclusion Criteria

1.2.1 Inclusion Criteria

1. Clinically diagnosed with OVCF and underwent PVP or PKP surgery.
2. Age ≥ 50 years.
3. Surgical segment was thoracic or lumbar.
4. Anesthesia method was ultrasound-guided PVB or simple local anesthesia.
5. Complete clinical data, including preoperative assessment, intraoperative anesthesia records, postoperative nursing records, and follow-up information.

1.2.2 Exclusion Criteria

1. Severe dysfunction of vital organs (heart, brain, lung, kidney, etc.), ASA classification $\geq IV$.
2. Coagulation dysfunction or patients on anticoagulant therapy who did not stop the medication according to protocol preoperatively.
3. Infection or skin lesions at the puncture site.
4. Severe destruction of the posterior vertebral wall with bone fragments protruding into the spinal canal (patients without neurological symptoms require careful evaluation).
5. Vertebral fractures due to osteogenic metastases or infectious vertebral lesions.
6. Allergy to local anesthetics (e.g., lidocaine, ropivacaine).
7. Missing key clinical data variables (e.g., intraoperative pain scores, anesthesia records, postoperative follow-up records).
8. For patients with multiple admissions for surgery during the study period, only the data from the first surgery were included.

1.3 Methods

1.3.1 Ultrasound-Guided Bilateral Paravertebral Nerve Block Method

Patients in the observation group received ultrasound-guided bilateral PVB combined with local infiltration anesthesia.

(1) Preoperative Preparation: After entering the operating room, an intravenous line was established, and standard monitoring including electrocardiogram (ECG), non-invasive blood pressure (NIBP), heart rate (HR), and pulse oximetry (SpO_2) was initiated. The target block level was determined based on the surgical segment: thoracic PVB was performed for thoracic vertebrae, and lumbar PVB for lumbar

vertebrae. PVB involves injecting local anesthetic into the paravertebral space to block the spinal nerves emerging from the intervertebral foramina, producing ipsilateral segmental somatic and sensory nerve blockade.

(2) Ultrasound-Guided Procedure

The patient was placed in the lateral or prone position. A high-frequency linear ultrasound probe (frequency 6–13 MHz) was used for longitudinal scanning approximately 2.5–3.0 cm lateral to the spinous processes to identify anatomical structures sequentially, such as the spinous processes, transverse processes, pleura, and paravertebral space. Under real-time ultrasound guidance, using an in-plane or out-of-plane puncture technique, the needle was advanced into the paravertebral space at the target level. After confirming the needle tip was positioned in the paravertebral space between the endothoracic fascia lateral to the transverse process and the parietal pleura, and after negative aspiration for blood, air, or cerebrospinal fluid, local anesthetic was injected in divided doses. The local anesthetic formulation was 0.15%-0.25% ropivacaine, with a total volume controlled at 20–30 mL. Depending on the extent of the surgical segment, a single-point or multi-point injection technique could be used to ensure adequate segmental blockade. The spread of the local anesthetic in the paravertebral space was observed in real-time under ultrasound; downward movement of the pleura could be seen (see Fig. 1).

(3) Blockade Effect Assessment

15–20 minutes after injection, the block range was assessed using the pinprick method. Surgery commenced after confirming sensory loss in the skin over the target surgical segment. If patients experienced pain or significant changes in vital signs intraoperatively, rescue analgesic drugs (e.g., sufentanil) could be administered intravenously if necessary.

(4) Local Infiltration Anesthesia

On the basis of the aforementioned PVB, local infiltration anesthesia was performed at the surgical incision site and along the puncture trajectory using 1% lidocaine 5–10 mL for layer-by-layer infiltration.

1.3.2 Local Anesthesia (Control Group)

Patients in the control group received simple local infiltration anesthesia. After entering the operating room, an IV line was established, and standard monitoring (ECG, NIBP, HR, SpO₂) was applied. Local infiltration anesthesia was performed using 1% lidocaine 5–10 mL injected layer by layer from the skin, subcutaneous tissue, down to the periosteum at the surgical incision site and along the percutaneous puncture trajectory. Based on the patient's pain response and changes in vital signs during surgery, rescue analgesic drugs (e.g., sufentanil) could be administered intravenously if needed.

1.3.3 Surgical Procedure

After anesthesia was completed in both groups, percutaneous PVP was performed under C-arm X-ray fluoroscopy guidance. All surgeries were performed by the same team of senior spinal surgeons, with the trans-pedicular approach used.

1.4 Clinical Outcome Measures

1. **Intraoperative Vital Signs:** Mean arterial pressure (MAP) and heart rate (HR) were recorded at specific intraoperative time points.
2. **Postoperative Pain Scores:** Pain intensity was assessed using the VAS immediately after surgery, and at 6 hours, 12 hours, and 24 hours post-surgery.
3. **Total Operative Time:** Total time from skin incision to wound closure.
4. **Length of Hospital Stay:** Total number of days from admission to discharge.
5. **Incidence of Adverse Events:** Recorded events included bone cement leakage, vertebral infection, cardiovascular events, respiratory depression, allergic reactions, etc.

1.5 Statistical Methods

1.5.1 Statistical Software

SPSS 26.0 (IBM Corp., Armonk, NY, USA) or R version 4.0 or higher (R Foundation for Statistical Computing, Vienna, Austria) was used for statistical analysis.

1.5.2 Descriptive Statistics

1. **Normality Test:** Continuous variables were first tested for normality using the Shapiro-Wilk test.
2. **Normally Distributed Data:** Expressed as mean $\pm$ standard deviation ($\bar{x} \pm s$). Comparisons between the two groups were performed using the **independent samples t-test** (Levene's test was used for homogeneity of variance; if variances were unequal, Satterthwaite's corrected t-test was used).
3. **Non-Normally Distributed Data:** Expressed as median (interquartile range) [M (P₂₅, P₇₅)]. Comparisons between the two groups were performed using the **Mann-Whitney U test**.
4. **Categorical Data:** Expressed as number (percentage) [n (%)]. Comparisons between the two groups were made using the χ^2 test; **Fisher's exact probability test** was applied when the expected frequency was less than 5.

1.5.3 Intergroup Comparisons

1. Primary outcome measures (MAP, HR, VAS) were compared between the two groups.
2. Secondary outcome measures (operative time, postoperative complications, length of hospital stay, etc.) were compared between the two groups.

1.5.4 All hypothesis tests were two-sided. $P < 0.05$ was considered statistically significant.

Results

2.1 Baseline Data

The baseline data of the two groups are shown in Table 1. Statistical analysis showed no significant differences ($P > 0.05$). (Table 1).

Table 1

Basic Information of Two Groups of Patients

Group	Count (n)	Age (years)	Male/Female	BMI (kg/m ²)	ASA Class (I/II/III)
Paravertebral Nerve Block	42	71 ± 6.9	12/30	23.8 ± 1.7	9/33/0
Local Anesthesia	42	74 ± 8.2	13/29	23.7 ± 1.5	12/30/0
P-value		0.314	1	0.822	0.763

2.2 Postoperative VAS Scores

Compared with the control group, the paravertebral nerve block group had significantly lower VAS scores at all four postoperative time points (T0, T1, T2, T3). The differences were statistically significant ($P < 0.05$). (Table 2).

Table 2

Comparison of postoperative pain scores between the two groups

Group	Count (n)	VAS(0H)	VAS(6H)	VAS(12H)	VAS(24H)
Paravertebral Nerve Block	42	1.93 ± 0.48	1.86 ± 0.36	1.64 ± 0.63	0.64 ± 0.63
Local Anesthesia	42	2.48 ± 0.67	2.24 ± 0.61	2.07 ± 0.56	1.29 ± 0.64
t-value		2.82	2.18	2.4	3.28
P-value		0.007	0.034	0.02	0.02
VAS:visual analogue scale;					

2.3 Intraoperative MAP, HR, and Operative Time

Compared with the control group, the paravertebral nerve block group had lower intraoperative MAP and HR, and significantly shorter operative time. The differences were statistically significant ($P < 0.05$). (Table 3).

Table 3

Comparison of intraoperative blood pressure, heart rate, operation time and hospital stay between the two groups

Group	Count (n)	MAP	HR	Time of operation(min)	LOS
Paravertebral Nerve Block	42	116 ± 13.2	81 ± 8.1	32.4 ± 12.37	8.9 ± 5.28
Local Anesthesia	42	132 ± 14.7	87 ± 6.3	41.1 ± 6.12	5.2 ± 2.78
t-value		3.58	3.09	3.5	3.35
P-value		0.01	0.003	0.001	0.001
MAP:mean arterial pressure;HR: heart rate;LOS=length of stay					

2.4 Postoperative Complications and Length of Hospital Stay

In the PVB group, 3 patients experienced postoperative nausea and vomiting (incidence rate 7.1%), while in the control group, 5 patients experienced nausea and vomiting (incidence rate 11.9%). Statistical analysis revealed no significant difference in the incidence of complications between the two groups ($P = 0.71$). (Table 4). Compared with the control group, patients in the PVB group had a significantly shorter length of hospital stay ($P < 0.05$). (Table 3).

Table 4

Comparison of postoperative complications between the two groups

Group	Count (n)	Nausea and vomiting	Drowsiness (n)	Bone cement leakage(n)	Incidence rate(%)
Paravertebral Nerve Block	42	3	0	0	7.1
Local Anesthesia	42	5	0	0	11.9
χ^2					0.74
P-value					0.71

Discussion

This recent 5-year single-center retrospective cohort study systematically compared the clinical efficacy of ultrasound-guided PVB versus traditional local infiltration anesthesia in percutaneous vertebroplasty (PVP). The results confirmed that, compared with traditional local anesthesia, ultrasound-guided PVB significantly stabilizes intraoperative hemodynamics, reduces intraoperative pain scores, and shortens

operative time and hospital stay. It represents a safer and more efficient anesthetic analgesic strategy for PVP.

Intraoperative hemodynamic stability is a core prerequisite for the safe conduct of minimally invasive surgery. Our study data showed that the fluctuations in intraoperative MAP and HR were significantly smaller in the ultrasound-guided PVB group compared to the local anesthesia group. The reason for this is likely that traditional local infiltration anesthesia can only block superficial layers such as skin, subcutaneous tissue, and periosteum, resulting in a limited block range and insufficient analgesic depth. Deep operative maneuvers in PVP, such as vertebral puncture and pressurized bone cement injection, can stimulate abundant pain nerves surrounding the vertebral body, triggering a significant stress response. This stimulates sympathetic nervous system activation, leading to tachycardia and hypertension. In contrast, ultrasound-guided PVB allows for precise, visualized positioning, directly blocking the anterior and posterior rami of the spinal nerves at the surgical level. This can completely cover the operative field involving the vertebral body and paravertebral structures, blocking the transmission of nociceptive pain signals at the source. Consequently, it effectively inhibits the systemic stress response to surgical trauma and prevents drastic intraoperative hemodynamic fluctuations^{17,18}. This advantage is particularly crucial for spinal fracture patients who are often elderly and have underlying conditions such as hypertension and coronary heart disease, as it can significantly reduce the risk of perioperative cardiovascular adverse events and enhance surgical safety.

In this study, the intraoperative VAS pain scores were significantly lower in the PVB group than in the local anesthesia group, further confirming the analgesic advantage of this technique. Traditional local anesthesia involves blind, multi-point infiltration, with the drug often concentrated in superficial soft tissues, making it difficult to penetrate deeply to the nociceptors in the vertebral body. It also suffers from uneven drug distribution and incomplete blockade, leaving patients often experiencing significant soreness and stinging sensations intraoperatively. Ultrasound-guided technology enables precise avoidance of critical structures like blood vessels and the pleura¹². The local anesthetic is accurately injected into the target paravertebral nerve area, resulting in stable drug dispersion, a more complete block range, rapid onset, and a longer duration of action^{12,14,15}. This effectively covers the intraoperative and early postoperative pain window, greatly improving patient comfort during surgery and reducing pain-induced restlessness and decreased cooperation.

The differences observed in operative duration and length of hospital stay represent important evidence of the clinical benefits of this anesthetic approach. Our results indicated that the ultrasound-guided PVB group had shorter operative times and significantly shorter postoperative hospital stays. This is likely because patients in the local anesthesia group, experiencing inadequate intraoperative analgesia, are prone to pain-induced restlessness and positional shifts, requiring surgeons to repeatedly adjust needle angles and pause operations to calm the patient. This increases the complexity of the procedure and prolongs operative time. Additionally, patients with significant intraoperative pain stress often have slower postoperative pain recovery, delayed early mobilization, and consequently, a prolonged recovery period. Conversely, the PVB group achieved satisfactory analgesic effects. Patients maintained a stable

position and cooperated well intraoperatively, allowing surgeons to perform punctures and cement injections accurately and efficiently, thus improving surgical efficiency and shortening operative time. Furthermore, comprehensive perioperative analgesia can mitigate surgical trauma stress, promote early mobilization and rapid functional recovery, thereby shortening the postoperative hospital stay. This improves bed turnover, saves medical resources, and demonstrates good health economic value.

Regarding safety, our study data confirmed no significant difference in the incidence of complications between the ultrasound-guided PVB group and the control group. Intraoperative body movement, often caused by inadequate blockade from local anesthesia, is a major trigger for surgical complications like puncture deviation and bone cement leakage^{19,20}. Moreover, severe pain stress increases the risk of cardiovascular events. The visualized approach of ultrasound guidance mitigates the risk of blind puncture injury, while the precise nerve blockade ensures intraoperative stability, substantially reducing surgical complications like cement leakage and puncture-related injuries. Concurrently, stable hemodynamics reduces perioperative adverse events such as hypertension and arrhythmias. Targeted drug delivery can also decrease the total dose of local anesthetic required, lowering the risk of local anesthetic toxicity, local swelling, and infection. The overall safety profile appears superior to that of traditional local infiltration anesthesia^{19,20}.

Conclusion

In summary, ultrasound-guided paravertebral nerve block anesthesia for PVP in thoracolumbar fractures can stabilize intraoperative hemodynamics, reduce postoperative pain, and shorten hospital stays, thus facilitating postoperative rehabilitation. It is a valuable anesthetic option worthy of promotion and application in PVP surgery for thoracolumbar fractures.

Declarations

Ethics approval and consent to participate

The date of approval for this ethical certification is September 10th, 2026. This study was conducted in accordance with the Declaration of Helsinki. The study protocol was approved by the Institutional Review Board of Hangzhou Xiaoshan District Hospital of Traditional Chinese Medicine (approval number: IRB-2026–200). Due to the retrospective nature of the study and the use of anonymized data, the requirement for written informed consent was waived by the ethics committee.

Competing interests

The authors declare no competing interests.

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Author Contribution

Conceptualization: LKZ,LL; Data curation: LKZ; Formal Analysis: JWQ; Methodology: JWQ, CML; Project Administration: CML; Visualization: LKZ,LL; Writing– Original Draft: JWQ; Writing– Review & Editing: LKZ; All authors reviewed the manuscript.

Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Figures



A



B

Figure 1

a. Localization under ultrasound before puncture

b_ Ultrasound-guided drug injection