Retrospective Study

Effect of Paravertebral Blocks Combined with Percutaneous Kyphoplasty on Thoracic Vertebral Fractures Complicated with Costal Pain

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Background: Vertebral augmentation surgery has shown good results for treating osteoporotic vertebral compression fractures, but its effect on relieving costal pain is not satisfactory.

Objective: To study the clinical efficacy of combining thoracic paravertebral nerve blocks (TPVNBs) with percutaneous kyphoplasty (PKP) in the treatment of thoracic vertebral fractures with costal pain, providing a reference for clinical diagnosis and management.

Study Design: A retrospective study.

Setting: A single medical center in China.

Methods: This was a retrospective cohort study. Patients who underwent PKP for thoracic fractures with costal pain at Quzhou People's Hospital from March 1, 2021, to March 1, 2023, were included. They were divided into a paravertebral block group (PVB group) and a control group. Pain intensity was measured using the Visual Analog Scale (VAS) before surgery and at multiple postoperative intervals. Physical function was evaluated using the Patient-Reported Outcomes Measurement Information System Physical Function (PROMIS PF) tool, and treatment satisfaction was recorded using the Modified Macnab Criteria.

Results: A total of 73 patients met the inclusion criteria, with 35 in the PVB group and 38 in the control group. Preoperative VAS scores for back pain and costal pain were similar between the 2 groups. Postoperatively, both groups experienced significant pain reduction, but the PVB group had better costal pain relief in the early follow-up period (within the first 3 months) and greater early functional recovery. At 12 months, the satisfaction rate was higher in the PVB group (94.3%) than in the control group (76.3%).

Limitations: The study's retrospective design, small sample size, short follow-up period, and incomplete understanding of pathogenesis limit the generalizability and long-term assessment of its findings.

Conclusion: A combination of PKP and PVB can significantly improve the pain relief rate and the quality of life in the early postoperative period of patients with thoracic vertebral fractures and costal pain.

Key words: percutaneous kyphoplasty, paravertebral block, vertebral fracture

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As patients age, their incidence of osteoporosis-related diseases increases year by year (1). According to statistics, the incidence of osteoporotic vertebral compression fractures (OVCFs) has been widely reported to cause non-midline pain in the chest, the lower back and near the iliac crest, groin, and trochanteric areas (2-4). Statistical data indicate that the occurrence of costal

pain in patients with OVCFs can reach 20%-28.6% (2,5).

There have been numerous studies investigating the causes of thoracic vertebral fractures accompanied by chest pain (4-6). Most scholars believe that the phenomenon is related to the loss of foraminal height caused by vertebral compression after the fracture (4-6). However, we have observed that some patients with chest pain do not exhibit intervertebral foramen stenosis after the fracture, leading us to consider other potential pathogenic mechanisms, such as post-fracture neural edema or hematoma irritation.

In clinical practice, some patients experience relief from costal pain after vertebral augmentation, while others show little to no improvement (2,3). Against this backdrop, this study was designed to investigate the clinical efficacy of combining thoracic paravertebral nerve blocks (TPVNBs) with percutaneous kyphoplasty (PKP) to treat thoracic vertebral fractures complicated by costal pain. The findings of this research are expected to offer valuable insights and references for clinical diagnosis and management strategies regarding this condition.

Methods

Study Design

This retrospective cohort study analyzed patients who underwent PKP for thoracic fractures with costal pain at Quzhou People's Hospital between March 1, 2021, and March 1, 2023. Costal pain refers to radiating pain of both sides or one side along the intercostal space (4). The patients were divided into 2 groups based on whether they were to receive PVBs: the PVB group and the control group. All patients provided written informed consent prior to inclusion. The study received approval from the local medical ethics committee before patient enrollment.

Selection Criteria

The inclusion criteria were as follows: 1) Age ≥ 55 years. 2) Acute vertebral compression fracture with costal pain (within 2 weeks). 3) Single segmental fracture. Exclusion criteria included pathological fractures due to bone tumors or infection and bone metabolic disease (including Cushing's disease, hyperthyroidism, and hyperparathyroidism). Patients for whom the medical files for at least one year after surgery were not available were also excluded.

Surgical Procedure

Patients in the control group were positioned prone on the operating table with chest support from a pillow, receiving local anesthesia. Two experienced orthopedic surgeons performed the procedures under C-arm guidance. The bone puncture trocars were inserted via the lateral pedicle margins (10 o'clock for left approaches, 2 o'clock for right approaches), advancing through the pedicle into the anterior third of the fractured vertebral body. Balloons were then inserted into each working channel, inflated with contrast agent under fluoroscopy for 2 minutes and 30 seconds, then deflated and removed. Polymethyl methacrylate (3–5 mL per segment) was injected cautiously, with termination if the cement approached the vertebral cortex, extraosseous structures, or venous channels.

Post-PKP, patients remained prone for the PVBs. Using an 18G Tuohy needle (B. Braun), the insertion point was marked 2.5–3 cm lateral to the superior edge of the target-level spinous process. The needle was advanced perpendicularly until contacting the transverse process (depth: 2–4 cm, adjusted for body habitus) then redirected cephalad to pass the superior costotransverse ligament (advancement: one–1.5 cm beyond the edge of the transverse process) (Fig.1). Loss of resistance to saline confirmed proper placement. After negative aspiration, a mixture of 0.5 mL triamcinolone and 1.5 mL bupivacaine was administered.

Clinical Data Collection

All relevant data, including demographic information (age, gender), clinical and radiographic findings, diagnosis, and surgical details, were collected from standardized electronic medical records, and telephone follow-up was further supplemented.

Pain intensity was measured using the Visual Analog Scale (VAS) before surgery and at several postoperative intervals: one day, one week, one month, 3 months, 6 months, and 12 months after percutaneous kyphoplasty (PKP).

Physical function, assessed as a secondary outcome, was evaluated at each follow-up using the Patient-Reported Outcomes Measurement Information System Physical Function (PROMIS PF) tool (7). Treatment satisfaction was recorded at the final follow-up using the Modified Macnab Criteria.

Demographic and clinical characteristics collected at baseline included age, gender, body mass index (BMI), bone mineral density (BMD), and diabetes mellitus status. Postoperative monitoring tracked serious

adverse events such as cement leakage, surgical site infections, new vertebral compression fractures, and other procedure-related complications. The vertebral height restoration rate was calculated using the following formula:

estimated intact height = (height of upper adjacent vertebra + height of lower adjacent vertebra) / 2

restoration rate (%) = [(postoperative height - preoperative height) / (estimated intact height - preoperative height)] × 100%

Statistical Analysis

For all measured parameters, we computed both mean values and corresponding standard deviations to characterize central tendency and data dispersion. Continuous variables underwent comparative analysis using Student's t-tests, while categorical variables (including both ordinal and nominal data types) were evaluated with chi-squared tests. A predetermined threshold of $P \leq 0.05$ established statistical significance for all inferential analyses. All statistical computations were executed using IBM SPSS Statistics software 28.0 (IBM Corporation), ensuring rigorous analytical methodology throughout our investigation.

Results

Patient Enrollment and Follow-Up

Among the 375 thoracic OVCF patients initially screened, a total of 73 patients met the inclusion criteria. Of these, 35 patients received PVBs and were assigned to the PVB group, while the remaining 38 patients were allocated to the control group. The demographic characteristics of the 2 groups were summarized in Table 1, the distribution of fractured vertebral segments between the groups was presented in Table 2, and the vertebral height restoration rates were presented in Table 3. The mean injected cement volumes was 3.6 ± 1.2 mL in the PVB group and 3.5 ± 0.9 mL in the control group, with no statistically significant difference between the 2 groups ($P = 0.68$). Notably, during the follow-up period, no serious complications, such as cement leakage, infection, or new fractures, occurred in either group.

Primary Outcome: Pain Relief (VAS Scores)

The 2 group's preoperative VAS scores for back pain and costal pain showed no significant differences ($P > 0.05$). Postoperatively, both groups showed significant pain reduction compared to baseline (Table 4,

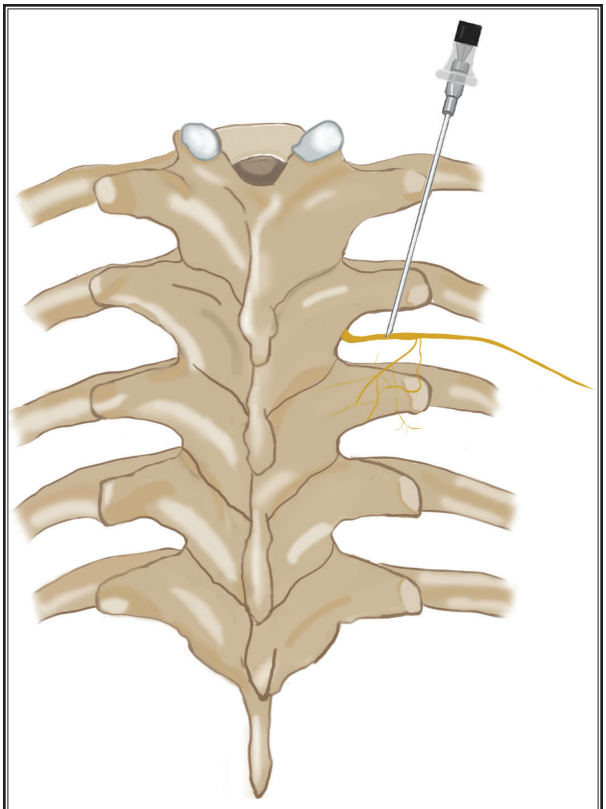


Fig. 1. *The schematic picture of a paravertebral block (PVB).*

Table 1. *Summary of demographic characteristics of both groups.*

	PVB Group	Control Group	*P*-value
Age	68.7 ± 4.1	69.3 ± 4.5	0.622
BMD	-3.1 ± 0.3	-3.3 ± 0.5	0.107
BMI	24.3 ± 2.7	23.9 ± 2.5	0.311
Female Gender (%)	23 (65.7%)	27 (71.1%)	0.680
Diabetes (%)	11 (31.4%)	15 (39.5%)	0.470

Abbreviations: PVB, paravertebral block; BMD, bone mineral density; BMI, body mass index.
Data are presented as number or mean ± SD.

Table 2. *Comparison of fractured vertebral segments between the 2 groups.*

	Fractured Vertebral Segment							
	T5	T6	T7	T8	T9	T10	T11	T12
PVB Group	1	3	2	2	4	9	6	8
Control Group	2	1	3	6	5	11	4	6

Abbreviation: PVB, paravertebral block.

Fig. 2, Fig. 3). However, the PVB group demonstrated superior costal pain relief at early follow-ups (within the first 3 months).

No statistically significant differences were found between the groups at the 6-month and 12-month follow-ups ($P > 0.05$).

Secondary Outcomes

Preoperative PROMIS PF scores were similar between the groups ($P > 0.05$). Both groups improved postoperatively, but the PVB group showed greater early functional recovery. Differences were not sustained beyond 3 months ($P > 0.05$; Table 5, Fig. 4).

At the 12-month follow-up, the satisfaction rates, as evaluated by the Modified Macnab Criteria (rated as excellent or good), were higher in the PVB group (94.3% [33/35]) than in the control group (76.3% [29/38]).

Discussion

Thoracic vertebral fractures are a prevalent condition in clinical practice, accounting for approximately 20% of all spinal fractures (8). When accompanied by costal pain, patients often experience stabbing pain, burning pain, or sensory abnormalities along the distribution area of the intercostal nerves (3,4). Choi et al (3) conducted a retrospective observational study involving 35 patients who received surgical treatment for thoracic OVCFs and found that the incidence of postoperative intercostal pain was 28.6%. Tang et al (9) conducted a retrospective observational study including 188 patients with osteoporotic fractures, and the study showed a slightly lower incidence of intercostal pain at 20.20%. Chen et al (5) and colleagues, in a study involving 205 patients with thoracic OVCFs, found that 39 of those patients (19.02%) had intercostal pain. In this study, the most common segment for intercostal pain after thoracic OVCFs was T10 (27.4%), while the study by Chen Runsen (6) suggested that the most common location for fracture segments was in the middle thoracic vertebrae. Clearly, further large-sample studies are required to clarify this discrepancy.

This neuropathic pain has a profound impact on patients' quality of life. It not only severely affects their respiratory function and daily living abilities but is also closely associated with psychological disorders such as depression and anxiety. Therefore, understanding the pathogenesis of intercostal pain and developing appropriate treatment strategies for it are of utmost importance.

Consistent with Tae-Hoon Doo et al (10), who demonstrated a diminished response to vertebral augmentation in OVCF patients presenting with costal pain, our data further support the notion that costal pain may represent a distinct mechanistic subset that warrants separate evaluation. Despite extensive research, the pathogenesis and causes of osteoporotic thoracic compression fractures with nonaxial pain remain incompletely understood. The current mainstream anatomical view is that after thoracic vertebral fractures, the loss of vertebral body height, narrowing of the intervertebral foramen, deformation and edema of the ligaments outside the intervertebral foramen, and traction on the nerve roots can cause costal pain (4-6). Jun Xin (4) et al found that the occurrence of costal pain is related to changes in vertebral body width, and lateral expansion of the vertebral body may compress the sympathetic nerves, leading to costal pain. Runsen Chen (5) pointed out that the reduction ratio of the area of the thoracic vertebrae and intervertebral foramen may play a

Table 3. *Comparison of vertebral height restoration rate between the 2 groups.*

	PVB Group	Control Group	*P*-value
AVH (%)	51.3 ± 18.7	49.2 ± 19.5	0.640
MVH (%)	63.2 ± 19.3	60.3 ± 17.1	0.498
PVH (%)	10.5 ± 9.7	11.3 ± 11.5	0.749

Abbreviations: AVH, anterior vertebral height; MVH, middle vertebral height; PVH, posterior vertebral height.
Data are presented as number or mean ± SD.

Table 4. *VAS score for back pain and costal pain.*

	VAS—Back Pain (PVB Group vs. Control Group)	*P*-value	VAS—Costal Pain (PVB Group vs. Control Group)	*P*-value
Preoperative	6.58 ± 1.22 vs 6.72 ± 1.17	0.547	6.96 ± 1.13 vs 7.01 ± 1.20	0.853
One Day	3.37 ± 1.06 vs 3.42 ± 1.11	0.823	2.19 ± 0.85 vs 4.51 ± 1.66	< 0.001
One Week	3.06 ± 0.98 vs 3.14 ± 1.03	0.725	2.04 ± 0.73 vs 4.35 ± 1.59	< 0.001
One Month	2.73 ± 0.82 vs 2.70 ± 0.77	0.866	1.95 ± 0.63 vs 3.96 ± 1.25	< 0.001
3 Months	2.13 ± 0.74 vs 2.22 ± 0.70	0.571	1.84 ± 0.56 vs 2.98 ± 1.16	0.001
6 Months	2.05 ± 0.66 vs 2.13 ± 0.59	0.558	1.72 ± 0.51 vs 1.85 ± 0.72	0.357
12 Months	1.57 ± 0.51 vs 1.49 ± 0.43	0.454	1.33 ± 0.41 vs 1.42 ± 0.48	0.376

Abbreviations: VAS, visual analog scale; PVB, paravertebral block.
Data are presented as mean ± SD.

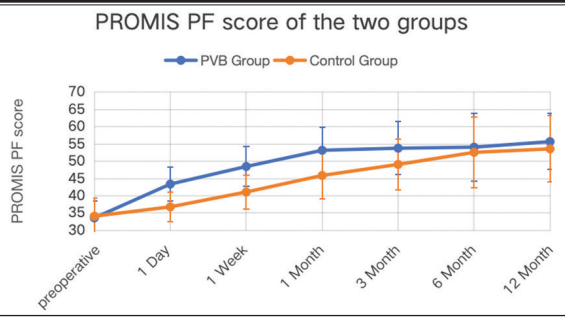


Fig. 2. *Back pain of PVB group and control group described as visual analog scale (VAS) score. PVB, paravertebral block; VAS, Visual Analog Scale.*

Table 5. *PROMIS PF score of the 2 groups.*

	PVB Group	Control Group	*P*-value
Preoperative	33.6 ± 4.8	34.1 ± 5.3	0.661
One Day	43.4 ± 4.9	36.8 ± 4.3	< 0.001
One Week	48.5 ± 5.7	41.1 ± 4.9	< 0.001
One Month	53.2 ± 6.7	45.9 ± 6.8	0.001
3 Months	53.8 ± 7.7	49.1 ± 7.3	0.007
6 Months	54.1 ± 9.8	52.6 ± 10.3	0.522
12 Months	55.7 ± 8.1	53.6 ± 9.6	0.301

Abbreviations: PROMIS PF, Patient-Reported Outcomes Measurement Information System Physical Function; PVB, paravertebral block.
Data are presented as mean ± SD.

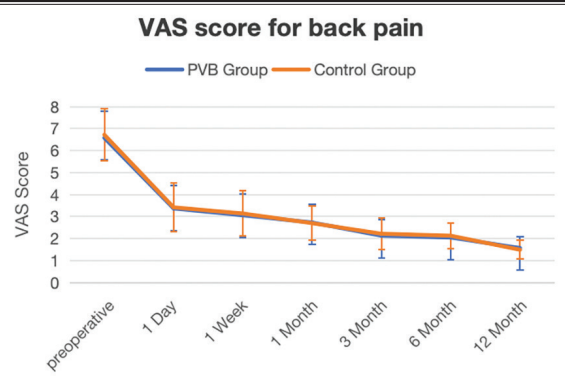


Fig. 3. *Costal pain of PVB group and control group described as VAS score.*
PVB, paravertebral block; VAS, Visual Analog Scale.

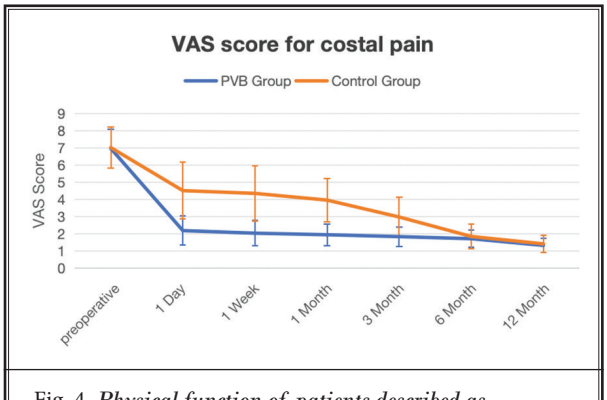


Fig. 4. *Physical function of patients described as PROMIS PF score.*
PVB, paravertebral block; PROMIS PF, Patient-Reported Outcomes Measurement Information System Physical Function.

key role in the occurrence of costal pain. Furthermore, overloading of the facet joint after the fracture is also considered an important factor (11). While the current mainstream anatomical view provides some explanations, some patients with costal pain do not have intervertebral foramen stenosis, indicating the likely existence of other contributing factors. Zhen-Gang Liu (12) et al found that an increase in the proportion of fat infiltration in the thoracic back muscles are associated with thoracic vertebral fractures. We infer that bleeding and edema around the injured vertebra, increased local pressure, and irritation of the paravertebral nerve fibers of the injured vertebra can also cause pain.

Regarding the treatment of OVCFs, vertebral augmentation surgery has shown certain advantages (13,14). However, when it comes to treating thoracic fractures accompanied by costal pain, there is still no unified approach. Studies have shown that PKP restores the stability of the fractured vertebrae, reduces micromotion at the fracture site, restores vertebral body height, and enlarges the intervertebral foramen, thereby reducing irritation to the nerve roots (3,12). In addition, the cytotoxic effect of the polymethyl methacrylate (PMMA) monomer can lead to necrosis of peripheral nerve endings, thereby reducing costal pain (15). Although PKP has some positive effects on reducing nerve root irritation, its ability to relieve costal pain is not entirely satisfactory. Hyun-Jun Choi et al found that 50% of patients still complained of costal pain (3). In contrast, the results of this study suggest that combining vertebroplasty with paravertebral blocks can significantly improve the pain relief rate and the quality of life in the early postoperative period of patients. This finding offers new perspectives and potential treatment options for clinicians dealing with such patients.

Limitations

This study has several limitations. First, the sample size was relatively small, with only 73 patients meet-

ing the inclusion criteria. A larger multicenter cohort is required to enhance the reliability and generalizability of the findings. Second, the retrospective design could have introduced selection bias, and some confounding factors (e.g., baseline pain severity or comorbidities) might not have been fully adjusted due to reliance on existing medical records. Furthermore, the maximum follow-up period was limited to 12 months, which precludes evaluation of the long-term efficacy of PVBs combined with PKP or potential late complications. Finally, the exact mechanisms remain unclear. Critical factors such as localized inflammatory responses or sympathetic nerve modulation were not investigated thoroughly, limiting the optimization of treatment strategies. Future studies should integrate prospective multicenter trials and molecular mechanistic analyses to address these gaps.

Conclusion

PKP, when combined with PVBs, can significantly improve the pain relief rate and the quality of life during the early postoperative period experienced by patients with thoracic vertebral fractures and costal pain. However, considering the limitations of this study, further research, particularly large-scale prospective studies with longer follow-up periods, is warranted to confirm these findings and develop more refined treatment protocols.

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