Retrospective Study

Percutaneous Kyphoplasty to Relieve the Rib Region Pain in Osteoporotic Thoracic Vertebral Fracture Patients Without Local Pain of Fractured Vertebra

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Background: Osteoporotic vertebral compression fractures (OVCF) are common. A few patients with thoracic vertebral fracture show pain in the bilateral rib region but not at the fracture site. The point of specific tenderness in the rib region cannot be located. It is not clear whether percutaneous kyphoplasty (PKP) can relieve the pain in the bilateral rib region in these patients.

Objective: To check whether PKP can alleviate the rib region pain in thoracic vertebral fracture patients without local pain at the fractured vertebra.

Study Design: Retrospective study.

Setting: The study was carried out at a university hospital.

Methods: We performed a retrospective analysis of thoracic vertebral fracture patients admitted to our hospital for PKP surgery between January 2018 and June 2022. The main clinical manifestations of these patients were pain in the bilateral rib region but no local tenderness and percussion pain at the fractured vertebra. CT and MRI examinations of the thoracic vertebrae were performed after admission. PKP was performed under general anesthesia after no surgical contraindication. Visual analog scale (VAS) scores and heights of the anterior, middle, and posterior edges of the fractured vertebra before the surgery, one day after surgery, and one month after surgery were compared. Also, the Cobb angles formed by the upper and lower endplate of the fractured vertebra before the surgery, one day after surgery, and one month after surgery were compared.

Results: A total of 50 patients were included in this study (3 men and 47 women, with an average age of 72.46 ± 8.15 years), of which 7 patients had 2 segmental fractures, so a total of 57 vertebrae were included. The VAS scores on day one and one month after the surgery were significantly lower than that before the surgery. The heights of the anterior, middle, and posterior edges of the fractured vertebra on day one after the surgery were significantly higher than those before the surgery. The Cobb angle of the fractured vertebra on day one after the surgery was lower than that before the surgery. The vertebrae of 23 patients were examined using x-ray one month after the surgery. The heights of the anterior, middle, and posterior edges of the fractured vertebra one month after the surgery were also significantly higher than those before the surgery but significantly lower than those one day after the surgery. Also, the Cobb angle of the fractured vertebra one month after the surgery was significantly lower than that before the surgery.

Limitations: This was a retrospective study, which may be prone to selection and recall bias. Single-center non-controlled studies may also introduce bias.

Conclusion: The exact location of the pain in the rib region caused by thoracic fracture cannot be identified usually. PKP can alleviate the rib region pain caused by the thoracic fracture.

Key words: Percutaneous kyphoplasty, rib region pain, osteoporosis, thoracic vertebra, compression fractures, local pain

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Osteoporotic vertebral compression fractures (OVCFs) are common. Most of them are caused by minor accidents such as falling on the ground and sprain. The typical manifestation is focal pain at the injured vertebra, which is aggravated when the patient changes position, and bed rest can alleviate or even eliminate the pain (1-3). The main purpose of the treatment of OVCFs is to reduce back pain, stabilize the vertebra, and restore spinal activity. The treatment methods can be conservative, such as bed rest, analgesic drugs, support, and nerve block (4,5). However, long-term bed rest might lead to subsequent aggravation of osteoporosis, bedsores, pneumonia, and deep vein thrombosis. Therefore, in clinical practice, patients with OVCFs, who suffer from local pain that significantly affects their daily activities, are often treated with surgery. The main surgical method is percutaneous vertebroplasty (PVP) or percutaneous kyphoplasty (PKP) (6-9). Most patients have immediate pain relief at the fracture site, recover early, and report an improvement in their quality of life after the surgery.

However, a few patients with thoracolumbar fractures report local pain at the fracture site as well as pain far away from the fracture area, such as iliac spine pain, costal pain, and hip joint pain (10-14). We found that a few patients were definitely diagnosed as having a thoracic vertebral fracture using computed tomography (CT) and magnetic resonance (MRI). The clinical manifestation included bilateral rib region pain, but there was no pain at the fracture site. Also, the specific tenderness in the rib region could not be located. Whether PKP surgery can alleviate the pain in the rib region far away from the fracture site is not clear. The purpose of this study was to investigate the clinical efficacy and x-ray imaging results before and after PKP in the treatment of bilateral rib region pain in patients with thoracic OVCFs and to explore the mechanism underlying the pathogenesis of bilateral rib region pain caused by thoracic OVCFs.

Methods

Patient Population

This was a retrospective study and did not disclose patient identity; therefore, it did not require the approval of the hospital ethics committee. The study population was thoracic spine fracture patients admitted to our hospital for PKP surgery between January 2018 and June 2022. The inclusion criteria were as follows: 1. The clinical manifestation was bilateral rib region pain, and the specific tenderness point could not be located in the rib region; 2. MRI confirmed the fracture in the thoracic region, and CT of the chest ruled out the pain caused by any possible fracture involving the posterior aspect of the ribs, especially any involvement of the posterior elements or costovertebral junction; 3. the x-ray, MRI, and CT data of the thoracic spine region within one week before the surgery was available; 4. the patient had obvious bilateral rib region pain, which affected day-to-day activities; 5. no symptoms of the nerve root and spinal cord compression were observed; 6. the bone mineral density was -2.5 or lower. The exclusion criteria were as follows: 1. Presence of other pathological fractures, such as hemangioma, multiple myeloma, bone tuberculosis, etc.; 2. local pain in fracture area; and 3. visual analog scale (VAS) < 5.

Surgical Techniques

The patient was laid prone on the operating table. Under the guidance of C-arm fluoroscopy, a guide needle was inserted from each pedicle projection point to the appropriate position. After replacing the working cannula and screw tap, a balloon dilation system was placed, and the pressure in the balloon was gradually increased. When the height of the vertebral body reached the appropriate level, the expansion was stopped, and the balloon was removed. The bone cement was pushed into the vertebral body when it reached the late stage of wire drawing. The bilateral working cannulas were then removed, and each incision site was surgically dressed.

Postoperative Management and Follow-Up

X-ray was obtained to evaluate the dispersion of bone cement one day after the surgery. All patients received regular anti-osteoporosis treatment after the surgery. VAS scores of patients before and one day after the surgery were collected, and VAS scores one month after the surgery were obtained over a telephone call. The heights of the anterior, middle and posterior edges of the fractured vertebra were collected. The Cobb angles were measured by the upper and lower vertebral endplate of the fractured vertebra (Fig. 1A). X-ray imaging data parameters were measured using radiology software (Neusoft PACS/RIS) to reduce errors. The measurements were performed independently by 3 spine surgeons with 5 years of experience, and their average values were considered.

Data Analysis

All statistical tests were conducted using SPSS ver-

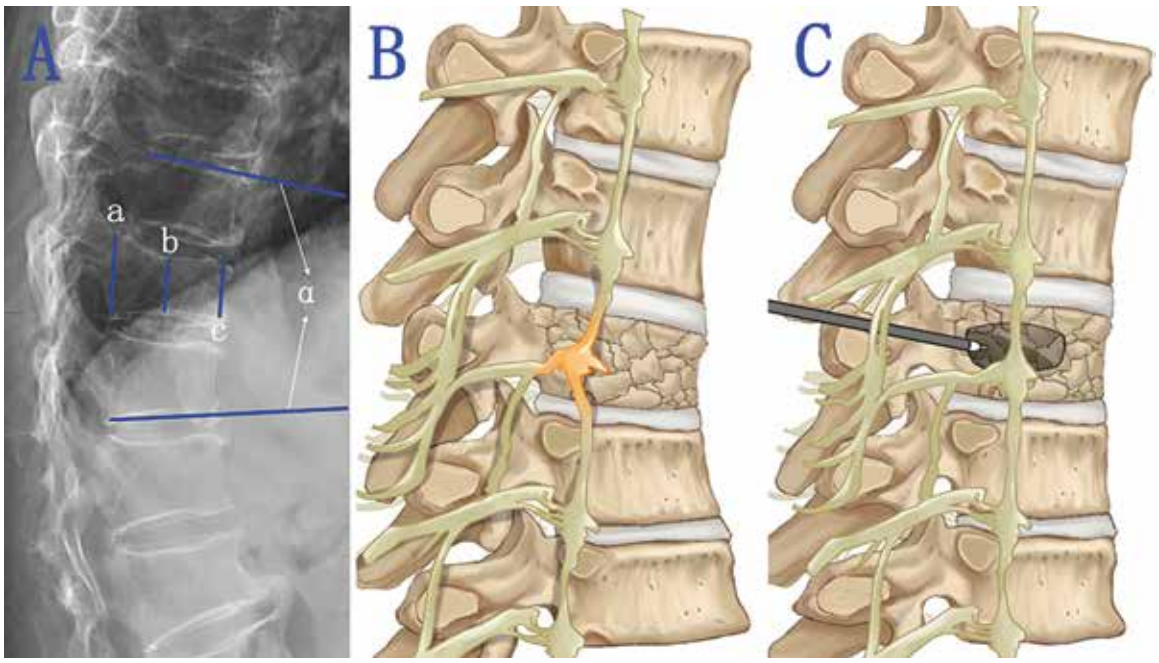

Fig. 1. *A: Measurement used in the study. The heights of the anterior, middle, and posterior edges of the fractured vertebra were c, b, and a. The Cobb angles were measured by the upper and lower vertebral endplate of the fractured vertebra (α). Thoracic vertebral fractures may compress the ventral rami of the thoracic spine and sympathetic ganglion (B). PKP surgery can restore the height of the fractured vertebral body to a certain extent, rebuild the stability of the spine, and alleviate the compression on the ventral rami of the thoracic spine and sympathetic ganglion (C).*

sion 20.0 (IBM Corporation, Armonk, NY). Continuous variables are presented as mean ± standard deviation. If it does not conform to the normal distribution, the Friedman test is expressed by 50% percentile (25%, 75%). If the data were normally distributed, paired sample t-test was used. If the data were normally distributed, and the variance was homogeneous, repeated measurement ANOVA was used. A *P*-value < 0.05 was considered significant.

Results

A total of 50 patients were included in this study (3 men and 47 women, with an average age of 72.46 ± 8.15 years), of which 7 patients had 2 segmental fractures, so a total of 57 vertebrae were included. All the surgeries were successful, and none of the patients had deep venous thrombosis, pulmonary embolism, or spinal cord nerve injury. The patient's age, gender, body mass index (BMI), duration of pain, and fracture segments are shown in Table 1. Among them, thoracic 7 to thoracic 10 vertebral fractures accounted for 77.2% of

Table 1. *Summary of demographic characteristics and surgical-related information.*

Characteristic	Possible values
Mean age (yrs) (x ± s)	72.46 ± 8.15
Female gender (%)	47 (94)
BMI	23.34 ± 2.88
Duration of pain	2.40 ± 1.92
Surgical level (%)	
T8	16 (28.1)
T7	10 (17.5)
T10	10 (17.5)
T9	8 (14.0)
T6	6 (10.5)
T11	4 (7.0)
T12	2 (3.5)
T4	1 (1.8)
Fracture pattern (%)	
Single segmental fracture	43 (86)
Double segmental fracture	7 (14)

BMI: body mass index

the total number of fractured vertebrae. Patients with single segment fractures accounted for 86% of the total patients. The VAS score of patients with pain in the bilateral rib region before the surgery was 7 (6,7), the VAS score one day after the surgery was 1 (1,2), and the VAS score one month after the surgery was 0 (0,1). The differences across the 3 were statistically significant ($P < 0.05$, Table 2).

The heights of the anterior, middle, and posterior edges of the fractured vertebra one day after the surgery were significantly higher than those before the surgery (17.33 mm ± 3.46 mm vs 14.28 mm ± 4.03 mm, 16.76 mm ± 3.01 mm vs 12.56 mm ± 3.58 mm, and 20.88 mm ± 3.51 mm vs 18.51 mm ± 4.01 mm, $P < 0.05$, Table 2). The Cobb angle of the fractured vertebra one day after the surgery was significantly lower than that before the surgery (8.75° ± 5.12° vs 12.51° ± 7.10°, $P < 0.05$, Table 2).

The vertebrae of 23 patients were examined using x-ray one month after the surgery. The heights of the anterior, middle, and posterior edges of the vertebrae one month after the surgery were significantly higher than those before the surgery (16.55 mm ± 3.64 mm vs 14.45 mm ± 4.47 mm, 16.07 mm ± 3.35 mm vs 13.29 mm ± 4.00 mm, and 20.43 mm ± 4.02 mm vs 19.26 mm ± 4.17 mm, $P < 0.05$, Table 2); however, they were significantly lower than those one day after the surgery (16.55 mm ± 3.64 mm vs 17.12 mm ± 3.59 mm, 16.07 mm ± 3.35 mm vs 16.72 mm ± 3.34 mm, and 20.43 mm ± 4.02 mm vs 21.01 mm ± 4.02 mm, $P < 0.05$, Table 2). Also, the Cobb angle of the fractured vertebra one month after the surgery was significantly lower than that before the surgery and higher than that one day after the surgery (9.22° ± 6.07° vs 12.43° ± 8.06° vs 8.78° ± 5.80°, $P < 0.05$, Table 2).

The images of patients aged 50-59 years showed thoracic vertebral compression fracture (Fig. 2). The heights of the anterior, middle, and posterior edges of the vertebrae one day after the surgery (Fig. 2D) were higher than those before the surgery (Fig. 2C) (13.99 mm vs 12.48 mm, 15.67 mm vs 13.01 mm, and 25.18 mm vs 22.98 mm). The Cobb angle of the fractured vertebra one day after the surgery (Fig. 2D) was lower than that before the surgery (Fig. 2C) (22° vs 29°). The heights of the anterior, middle, and posterior edges of the vertebrae one month after the surgery (Fig. 2E) were lower than those one day after the surgery (Fig. 2D) (13.42 mm vs 13.99 mm, 14.82 mm vs 15.67 mm, and 24.97 mm vs 25.18 mm). The Cobb angle of the fractured vertebra one month after the surgery (Fig. 2E) was higher than that one day after the surgery (Fig. 2D) (24° vs 22°).

Discussion

This study showed that thoracic osteoporotic compression fractures might cause bilateral rib region pain without local pain at the fractured vertebra. The imaging characteristics of these patients were as follows: 1. x-ray showed wedge-shaped degeneration of the vertebral body. There were no signs of new vertebral fractures such as cortical bone interruption and trabecular bone interruption; 2. CT showed that there was no interruption in the vertebral cortex, or although there was an interruption in the vertebral cortex, there were old fracture manifestations such as bone cortex absorption at the interruption site. The trabecular structure of the vertebral body was disordered, and old

Table 2. *VAS score of pain in the bilateral rib region and the heights of the fractured vertebra pre- and postoperative.*

	Preoperative	1 Day Postoperative	1 Month Postoperative	*P*
VAS	7 (6, 7) [a]	1 (1, 2) [b]	0 (0, 1) [c]	< 0.001
The heights of the fractured vertebra				
anterior	14.28 ± 4.03	17.33 ± 3.46		< 0.001
middle	12.56 ± 3.58	16.76 ± 3.01		< 0.001
posterior	18.51 ± 4.01	20.88 ± 3.51		< 0.001
Cobb angle	12.51 ± 7.10	8.75 ± 5.12		< 0.001
The heights of the fractured vertebra				
anterior	14.45 ± 4.47a	17.12 ± 3.59[b]	16.55 ± 3.64[c]	< 0.001
middle	13.29 ± 4.00[a]	16.72 ± 3.34[b]	16.07 ± 3.35[c]	< 0.001
posterior	19.26 ± 4.17[a]	21.01 ± 4.02[b]	20.43 ± 4.02[c]	< 0.001
Cobb angle	12.43 ± 8.06[a]	8.78 ± 5.80[b]	9.22 ± 6.07[c]	< 0.001

VAS, visual analog scale; a, b, c means the differences across the three were statistically significant

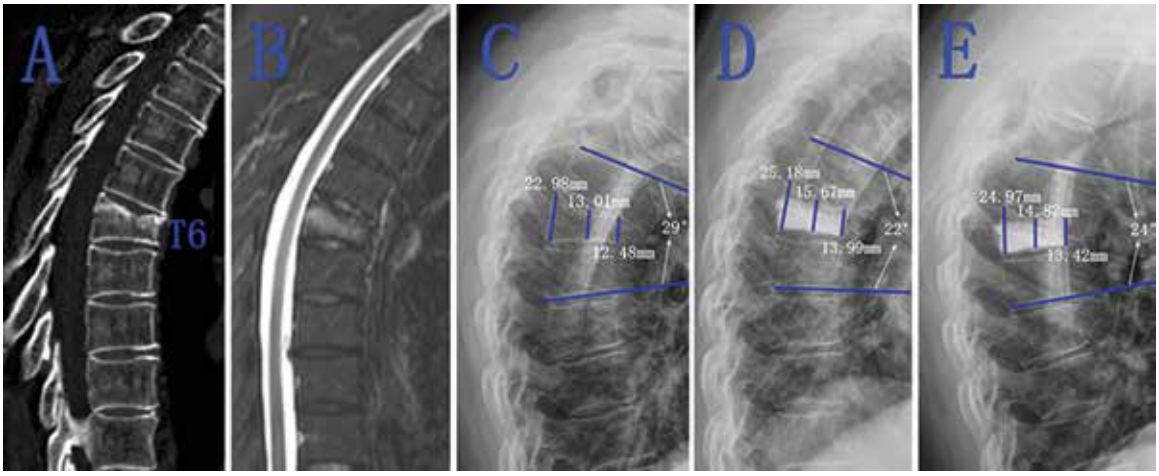

Fig. 2. *The CT and MRI images of patients aged 50-59 years showed thoracic vertebral compression fracture (T6, A, and B). The heights of the anterior, middle, and posterior edges of the vertebrae one day after the surgery (D) were higher than those before the surgery (C) (13.99 mm vs 12.48 mm, 15.67 mm vs 13.01 mm, and 25.18 mm vs 22.98 mm). The Cobb angle of the fractured vertebra one day after the surgery (D) was lower than that before the surgery (C) (22° vs 29°). The heights of the anterior, middle, and posterior edges of the vertebrae one month after the surgery (E) were lower than those one day after the surgery (D) (13.42 mm vs 13.99 mm, 14.82 mm vs 15.67 mm, and 24.97 mm vs 25.18 mm). The Cobb angle of the fractured vertebra one month after the surgery (E) was higher than that one day after the surgery (D) (24° vs 22°).*

fractures, such as the sclerotic bone, were observed; 3. MRI showed bone marrow edema, suggesting a new vertebral fracture. The clinical characteristics of these patients were as follows: 1. Bilateral rib region pain was persistent, lasting for a long time, generally 2-8 weeks. The nature of pain was a dull pain, and specific tenderness points could not be located; 2. there was no tenderness or percussion pain in the fractured vertebra.

It was observed that in some cases, the pain caused by OVCF was not limited to the vertebral fracture but referred to areas away from the injured vertebrae, such as the lower back, peri iliac, bilateral rib region, and hip joint. PVP and PKP can partially alleviate the pain in these areas, but a few patients still experience pain in regions far away from the fracture area. PKP and PVP can immediately relieve pain caused by the fractured vertebra. However, a few patients still experience postoperative residual lumbar pain, which can hamper their quality of life. Therefore, other treatments, such as facet joint block and local steroid injection, are administered (10,15-19). Rib region pain caused by thoracic OVCF is rare (20). Patients may be first triaged to respiratory medicine or thoracic surgery to check the ribs and lungs. The orthopedic clinic might also first check whether the problems pertain to the ribs and lungs. Only when there is no abnormality in the chest CT and other relevant examinations will the examination of thoracic spine MRI be considered. MRI of the thoracic vertebrae clearly shows if there is a new fracture. However, its treatment plan is not clear. There is no report of PKP treatment for bilateral rib region pain caused by thoracic fractures in the literature. Whether PKP surgery for fractured vertebrae can alleviate the pain of the bilateral rib region is not known. Also, the trauma of the surgery to the patient and the large surgical cost are other things to consider.

In the current study, 50 patients with thoracic vertebral fractures, who showed bilateral rib region pain and no local pain, were treated with PKP. The surgical indications of these patients should be strictly controlled. Only when the diagnosis of thoracic vertebral fracture is clear, pain in the bilateral rib region is obvious, which seriously affects daily life, can surgery be performed. At the same time, we researched the CT of the chest carefully before the surgery to rule out pain caused by any possible fracture involving the posterior aspect of the ribs, especially any involvement of the posterior elements or costovertebral junction. After the surgery, the pain in the bilateral rib region was relieved immediately. In elderly patients with osteoporosis,

minor accidents may cause fractures. If the fracture involves the thoracic vertebra, the early pain may not be very obvious because the thoracic vertebra has ribs and a sternum to maintain stability. If the patient does not get it treated in the early stage, the injury may aggravate. The processes of fracture healing and re-fracture coexist. Therefore, old fractures will be observed on CT and new fractures on MRI. Thoracic vertebral fractures may compress the ventral rami of the thoracic spine and sympathetic ganglion. The ventral rami of the thoracic spine run anterolaterally between the ribs to innervate the chest and abdominal wall. This may contribute to the band-like distribution of thoracic radiculopathy to the anterior thorax, chest, and abdominal areas. Sympathetic ganglion compression can cause referred pain. Referred pain is a segmental component of nociceptive pain perceived at a location remote from the original injury site. The convergent-projection theory suggests that afferent fibers from different tissues converge into a common second-order neuron in the spinal cord. Therefore, nociception is misinterpreted centrally as originating from other structures. These may be the main causes of bilateral rib region pain due to thoracic vertebral fractures without local pain (21,22).

The main treatment options of OVCFs are PKP and PVP, which have their advantages and disadvantages (23,24). PKP surgery can partially restore the height of the fractured vertebral body to a certain extent, rebuild the stability of the spine, and alleviate the compression on the ventral rami of the thoracic spine and sympathetic ganglion. Also, the high temperature of the bone cement burns the nerves in the vertebral body. This may be the reason why PKP can alleviate the bilateral rib region pain caused by the thoracic fracture (Figs. 1B and 1C). The overall surgical cost of PVP is low, but the reduction of the compressed vertebral body is not as satisfactory as that of PKP. Especially for the cases in this study, there have been bone trabecular blur and osteosclerosis, and PVP cannot achieve satisfactory vertebral body reduction by relying on body position reduction alone. Therefore, PVP was not suitable for the cases in this study.

The main manifestations of Kümmell disease are delayed vertebral collapse and progressive kyphosis, which cause long-term lower back pain. The imaging manifestations were delayed vertebral collapse and characteristic vacuum fissure (25-27). There was no characteristic intravertebral vacuum cleft in the current study. However, the clinical manifestations and imaging results were consistent with delayed vertebral collapse. Part of it is in line with the characteristics of Kümmell disease. However, since this is a retrospective study and lacks relevant examinations, a prospective study will be carried out in the later stage to determine whether the cases in this study are a special type of Kümmell disease or a separate disease. Also, various improved methods for the treatment of Kümmell disease exist (28-30). Whether these methods are suitable for the cases from the current study needs further research.

The current study also has certain limitations: 1. It is a retrospective study with selection and memory bias and few evaluation indicators. In the later prospective study, functional evaluation criteria, such as the Oswestry Disability Index score (ODI), can be incorporated in the evaluation and calibration; 2. the overall sample size was small and relevant cases would continue to be incorporated and evaluated; 3. at present, the mechanism underlying bilateral rib region pain and the pain relief mechanism of PKP are only speculative. In the follow-up studies, we intend to propose a thoracic fracture model to observe the mechanism underlying bilateral rib region pain caused by repeated movement of the fractured vertebra.

Conclusion

Bilateral rib region pain may be caused by the thoracic vertebral fracture. These patients may not experience local pain in the fracture area. MRI can be used to make a definite diagnosis. PKP can alleviate the bilateral rib region pain caused by the thoracic vertebral fracture.

Contributors

All authors contributed significantly to the planning, conduct, and reporting of the work described in the paper. Fanguo Lin, Yuye Zhang, and Xiaomei Song contributed equally to this paper. Fanguo Lin, Yuye Zhang, and Xiaomei Song are joint first authors.

Patient Consent for Publication

Not required.

Ethics Approval

Ethics Committee of Second Affiliated Hospital of Soochow University.

Data Availability Statement

Our data have not been deposited in a repository but are available upon reasonable request to the corresponding author.

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