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Clinical effect analysis of unilateral percutaneous vertebral cement distribution in the repair of osteoporotic thoracolumbar vertebral compression fractures

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Abstract

Background Osteoporotic vertebral fractures and their complications pose increasing risks to the elderly. The purpose of this study was to evaluate the clinical efficacy of unilateral percutaneous vertebroplasty in patients with osteoporotic vertebral compression fractures (OVCF) by assessing postoperative cement distribution.

Objective This study aimed to investigate the impact of cement distribution on the efficacy of vertebral compression fracture repair to provide effective preventive and therapeutic measures, prevent postoperative vertebral re-fracture, and improve surgical outcomes.

Methods A total of 170 patients who underwent unilateral percutaneous vertebroplasty at our hospital from January 2020 to December 2022 were selected. Based on the postoperative X-ray cement distribution morphology, they were divided into the good distribution group ($n = 87$) and the poor dispersion group ($n = 83$). The basic information of patients, surgery-related indicators including operation time, total hospitalization costs, postoperative hospitalization time, cement injection volume, visual analog scale (VAS) for back pain, Oswestry Disability Index (ODI) for back pain, vertebral height restoration rate, local kyphotic angle of the vertebra, and incidence of re-fracture of injured and adjacent vertebrae were compared between the two groups, and the follow-up results of all patients were recorded.

Results There were no significant differences in age, gender, body mass index, fracture days, menopausal age of female patients, bone density T value, medical history, smoking history, alcohol history, and surgical segments between the two groups ($P > 0.05$). The VAS scores for back pain at 1 month and 1 year postoperatively were significantly lower in the good distribution group than in the poor dispersion group, with statistical significance ($P < 0.05$). The good distribution group had a significantly lower incidence of re-fracture of injured vertebrae and overall fracture incidence than the poor dispersion group ($P < 0.05$). There were no statistically significant differences in operation time, cement dosage, cement leakage, postoperative hospitalization time, adjacent vertebral fractures,

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postoperative vertebral height restoration rate, VAS scores for back pain at preoperative and 1 week postoperative, and ODI at preoperative, 1 week, 1 month, and 1 year postoperative between the two groups ($P > 0.05$).

Conclusion Compared with the poor dispersion group, patients in the cement distribution group achieved better short-term clinical efficacy, and long-term prognosis effects are still under observation. Moreover, the cement good distribution group significantly reduced the incidence of re-fracture of injured vertebrae and overall fracture incidence, thereby achieving better surgical outcomes.

Keywords Osteoporotic vertebral compression fracture, Percutaneous vertebroplasty, Bone cement, Cement distribution

Introduction

Thoracolumbar vertebral compression fractures are a common spinal injury, which can be caused by external forces (such as falls, accidents, or high impact) or internal factors (such as osteoporosis) [1]. In vertebral compression fractures, the vertebral bone structure undergoes compression, leading to a decrease in vertebral height or collapse [2]. This type of fracture may result in symptoms such as back pain, changes in posture, loss of height, and neurological damage. Osteoporotic vertebral compression fractures (OVCFs) are the most common type of vertebral compression fracture [3, 4]. It is estimated that globally, 1.4 million patients suffer from OVCFs each year [5]. Patients are generally older, and due to slow fracture healing, poor quality of life, and other reasons, various complications may occur, increasing the risk of disability and death, and imposing a heavy economic burden on patients' families [6, 7]. With the continuous advancement of medical technology, its treatment has always been a focus of clinical attention. Percutaneous vertebroplasty (PVP) has become a commonly used method for treating OVCFs due to its high safety and efficacy. In this procedure, physicians inject special bone cement (usually polymethylmethacrylate, PMMA) into the damaged vertebrae through small skin incisions [8]. This bone cement fills the cavities of the vertebrae, increasing their stability and strength, thereby alleviating pain and restoring vertebral height [9]. The distribution of bone cement may play an important role in the efficacy of the surgery [10–12]. Even distribution of bone cement can provide balanced support, reduce vertebral pressure, and thus alleviate pain and stabilize the vertebrae [13]. However, uneven distribution may lead to vertebral instability or localized high pressure, increasing the risk of cement loosening or vertebral re-collapse [14]. Therefore, ensuring uniform distribution of bone cement and correct injection technique are crucial for the success of the surgery and the recovery of patients [15]. This study aims to investigate the impact of bone cement distribution on the efficacy of vertebral compression fracture repair, to provide effective preventive and therapeutic measures, prevent postoperative vertebral re-fracture, and improve surgical outcomes.

Subjects and methods

Design

Retrospective comparative trial. T-tests and chi-square tests were conducted to assess the impact of bone cement distribution on the efficacy of unilateral percutaneous vertebroplasty.

Time and location

The trial was conducted from January 2020 to December 2022 at the Minimally Invasive Spine Surgery Department of the Sixth Affiliated Hospital of Xinjiang Medical University.

Participants

A total of 170 cases of patients who underwent unilateral percutaneous vertebroplasty for the first time and were hospitalized at the Sixth Affiliated Hospital of Xinjiang Medical University from January 2020 to December 2022 were selected for retrospective study. Among them, there were 44 males and 126 females, with mean ages of 73.76 ± 8.37 and 72.39 ± 9.78, respectively. The study was reviewed and approved by the Ethics Committee of the Sixth Affiliated Hospital of Xinjiang Medical University, Approval No.: LFYLLSC20230510-01. Informed consent was obtained from all study participants.

Inclusion criteria ① Patients who underwent unilateral percutaneous vertebroplasty for the first time. ② Diagnosis of newly developed fractures confirmed by bone density and magnetic resonance imaging, with concomitant osteoporotic changes and bone density T values <-2.5 standard deviations. ③ Number of fractured vertebrae ≤ 2. ④ Follow-up duration greater than 12 months.

Exclusion criteria ① Patients with symptoms of nerve root injury. ② Patients allergic to bone cement. ③ Patients with pathological fractures caused by tuberculosis or infection. ④ Patients with severe underlying diseases (tumors, immune system diseases, etc.) or other conditions incompatible with surgery. ⑤ Patients with a history of spinal surgery. ⑥ Patients with a body mass index exceeding 35 kg/m^2.

According to the distribution morphology of bone cement on the vertebral X-ray film, the anterior, middle, and posterior regions were divided into a total of nine small areas labeled as ①, ②, ③, ④, ⑤, ⑥, ⑦, ⑧, ⑨, etc. When the bone cement dispersed to more than half of a small grid, it was considered completely filled, and vice versa. Patients were categorized into the poor dispersion group ($n = 87$) and the good dispersion group ($n = 83$).

Distribution of vertebrae. Figure 1A.

Poor dispersion groupa When the complete filling of bone cement was ≤ 6 small grids, it was classified as poor dispersion, as shown in Fig. 1B.

Good dispersion group When the complete filling of bone cement was > 6 small grids, it was classified as good dispersion, as shown in Fig. 1C.

Materials

Methods

Preoperative preparation

Upon admission, all patients underwent X-ray and magnetic resonance imaging to assess vertebral compression, routine blood tests including C-reactive protein, liver and kidney function tests, serum bone metabolism tests to evaluate the patients' baseline conditions, and bone density tests to assess bone quality.

PVP surgical procedure

Patients were placed in the prone position, and under C-arm fluoroscopy guidance, the target responsible vertebra was identified. Routine disinfection and draping were performed, followed by local infiltration anesthesia with 2% lidocaine injection solution (Tianjin Jinyao Group Hubei Tianyao Pharmaceutical Co., Ltd., specifications: 5mL:0.1 mg, National Drug Approval Number: H20133209). Unilateral puncture positioning was used, and a bone cement puncture needle was inserted with adjustment of its position under C-arm assistance. The needle was gently tapped with a bone hammer to enter the vertebral arch, and the needle position was rechecked under C-arm assistance. The needle was advanced to the anterior 1/3 of the midline of the vertebral body. After confirming the correct position, the needle core was withdrawn, and polymethylmethacrylate bone cement was prepared and injected into the vertebral body using a cement pusher. Under C-arm monitoring, 1-7mL of bone cement was injected into the vertebral body using the pusher. The direction and distribution of bone cement were observed at all times. After the cement injection was completed, the cement puncture needle was removed after the cement hardened, and the puncture site was covered with sterile dressing. X-rays taken during the operation were retained. The patient was transferred back to the ward. Six to eight hours after surgery, the patient could move freely with the assistance of a lumbar protector [10]. (For details of the material characteristics of bone cement and the complete set of instruments for vertebral molding surgery, refer to Tables 1, 2 and 3).

Postoperative management

At 24 h after the operation, the spinal X-ray was reviewed 7 d after the operation, and anti-osteoporosis treatment was routinely given after discharge. The bone cement used during the procedure was all produced by the same company. All operations were completed by two associate senior doctors or above. X-ray and CT review were given 7 days after surgery to clarify the distribution of bone cement and the recovery of surgical vertebral height.

Observational indicators

Primary outcome measures

Preoperative and postoperative (at 1 week, 1 month, and 1 year) Visual Analog Scale (VAS) scores for back pain

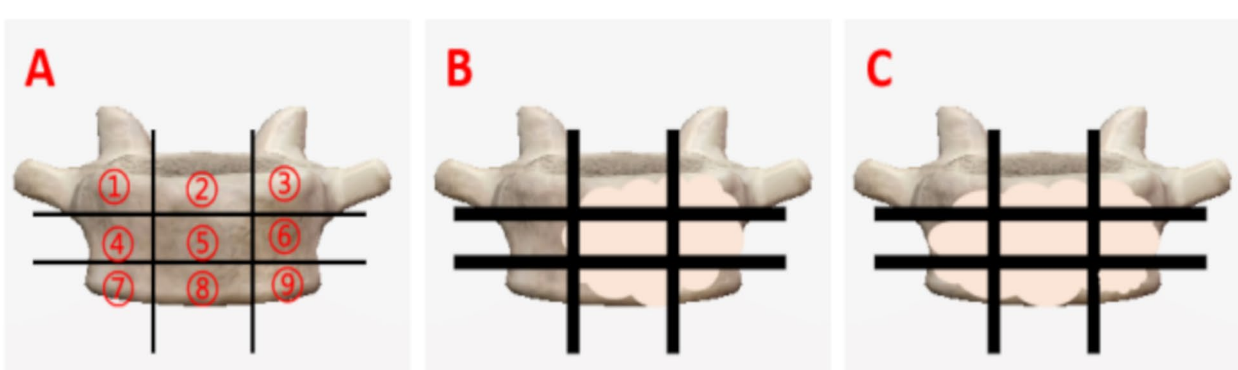

Fig. 1 Vertebral body classification method and bone cement distribution type. **A**: Distribution of vertebrae. **B**, represents the poor dispersion group: when the complete filling of bone cement is ≤ 6 small grids, it is classified as poor dispersion. **C**, represents the good dispersion group: when the complete filling of bone cement is > 6 small grids, it is classified as good dispersion

Table 1 Material characteristics of the implant

Product Name	Bone Cement Bone Cement (REF66055104)
Manufacturers	Heraeus Medical GmbH (Heraeus Medical)
Specification Model	OSTEOPAL V
Approval Number	LOT 61,185,327
Structure and composition/main constituents	Osteopal V is a fast setting, radiation-impermeable bone cement for filling and stabilizing vertebrae. The product contains a powder and a liquid. The powder consists of methyl acrylate-methyl methacrylate polymer, zirconium dioxide, benzoyl peroxide, and copper chlorophyll (E141).The liquid consists of methyl methacrylate, N,N-dimethyl-p-toluidine, hydroquinone, and copper chlorophyllin (E141).
Scope of application/intended use	Osteopal V is indicated for filling and stabilization of the vertebral body: relief and elimination of pain in vertebral compression fractures, relief and elimination of pain in vertebral tumors (metastatic or bone marrow cancer), symptomatic vertebral hemangiomas.
Biocompatibility	Good
Adverse reactions	May cause adverse effects such as hypotension, hypoxemia, arrhythmia, cardiac arrest, cardiopulmonary dysfunction, and even death

Table 2 Complete set of surgical instruments for vertebroplasty

Device name	Spiral Propeller
Specification	20 ml
Model	Type 201
Registration certificate number	National Machinery Note approved 20,153,040,284
Production companies	Shandong Guanlong Medical Supplies Co.

Table 3 Puncture needle

Device name	Puncture Needle
Specification	2.5 × 130
Model	GC-01
Registration certificate number	RuMechanicsNotePermission20142140147
Production companies	Shandong Guanlong Medical Supplies Co.

and Oswestry Disability Index (ODI) scores, preoperative and postoperative (at 1 week) vertebral height restoration rate, preoperative and postoperative (at 1 week) local kyphotic angle (LKA), incidence of adjacent vertebral fracture, and occurrence of recurrent fractures in the injured and adjacent vertebrae (Fig. 2).

(1) Local Kyphotic Angle (LKA), Line A is parallel to the upper endplate of the fractured vertebra, and line B is parallel to the lower endplate of the fractured vertebra. LKA is the angle between lines A and B. LKA = local kyphotic angle, as shown in Fig. 3①.

(2) Postoperative Imaging Parameter Measurements, Estimated original vertebral height (EOH), preoperative

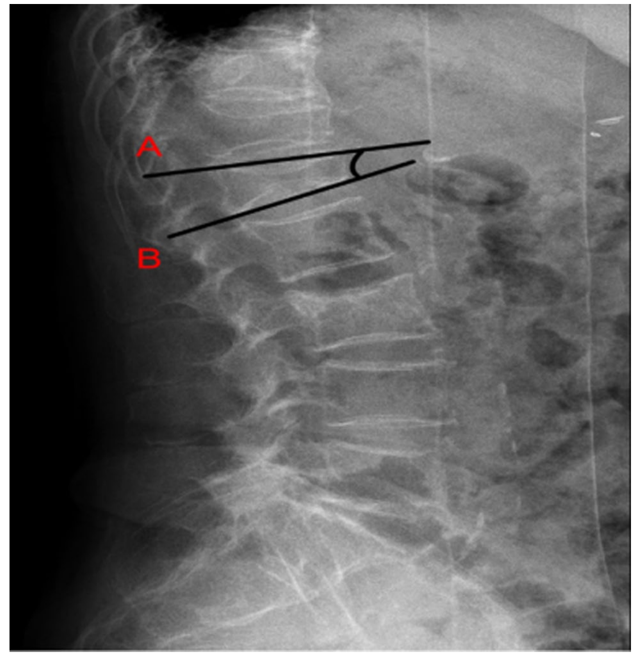

Fig. 2 Method of local spinal kyphosis angle measurement. **A** is the parallel line to the upper endplate of the fractured vertebra; **B** is the parallel line to the lower endplate of the fractured vertebra. Figure ②: B1 is the posterior edge of the postoperative vertebra; Figure ①:B2 is the restored height of the postoperative vertebra; B3 is the anterior edge of the postoperative vertebra

fractured vertebral height (PFH), postoperative restored vertebral height (PRH), height restoration rate (HRR), and preoperative vertebral height (LKA) were measured using X-ray plain film evaluation. EOH was considered as the average height of the normal vertebral body above and below the fractured vertebra. PFH (A2) and PRH (B2) were the averages of the posterior (A1/B1) and anterior (A3/B3) edges of the vertebrae (Fig. 3). HRR represents the percentage of height restored from the preoperative state [11] and can be calculated as: HRR = (PRH-PFH) / EOH. Vertebral height measurement formulas: ①A2 = (A1 + A3) / 2; ②B2 = (B1 + B3) / 2; ③HRR = (PRH-PFH) / EOH × 100%. See Fig. 3 ②③.

(3) Adjacent Vertebral Fracture, New fractures occurring in the upper and lower adjacent thoracolumbar vertebrae of the original injured vertebra.

(4) Assessment of Recurrent Fracture in the Injured Vertebra, Patients experienced recurrent lower back pain or discomfort after percutaneous vertebral augmentation, with physical examination indicating positive tenderness of the spine or spinous process. The patient's medical history, clinical manifestations, and lumbar spine X-ray examination suggested compression fractures of the adjacent vertebrae, confirmed by magnetic resonance imaging.

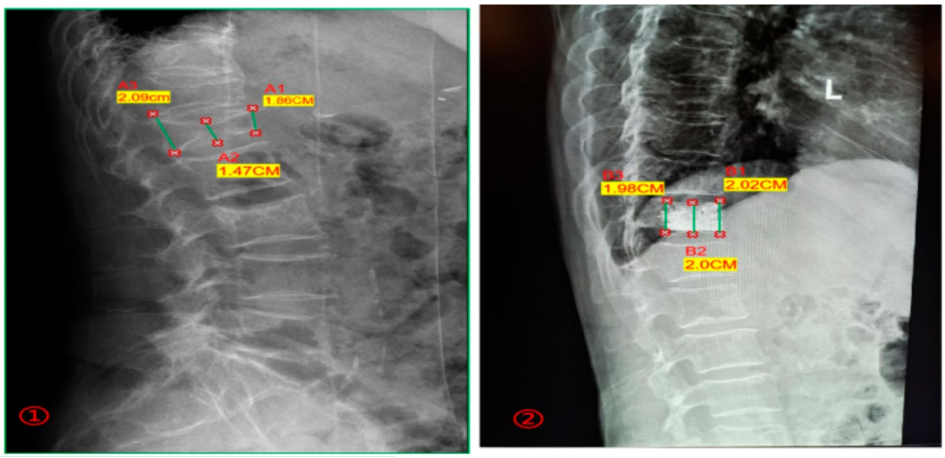

Fig. 3 Methods for preoperative and postoperative vertebral height measurement. Figure ①: A1 is the posterior edge of the preoperative vertebra; A2 is the height of the preoperative fractured vertebra; A3 is the anterior edge of the preoperative vertebra

(5) Bone Cement Leakage, Excessive bone cement beyond the vertebral range during PVP, leading to its presence in other tissues.

(6) Visual Analog Scale (VAS) for Back Pain, Evaluates the degree of focal back pain (0 = no pain, 10 = worst pain).

(7) Oswestry Disability Index (ODI) for Back Pain, Scores used to assess improvement in daily functional capacity, evaluating aspects including pain intensity, lifting, walking, sleep, and social life, where 0% represents minimal disability and 100% represents extreme disability, where the patient may be bedridden or have significant symptoms.

Secondary outcome measures

Surgical time, amount of bone cement used, postoperative length of hospital stay, and total hospitalization costs.

General information

From January 2020 to December 2022, medical records of patients who underwent unilateral percutaneous vertebroplasty in our hospital were collected, totaling 170 cases, including 44 males and 126 females. A retrospective study was conducted with the diffusion distribution group and the poor diffusion group having average ages of 73.76 ± 8.37 and 72.39 ± 9.78, respectively. Patients were divided into two groups based on the morphology of bone cement distribution: (1) the diffusion distribution group ($n = 87$) and (2) the poor diffusion group ($n = 83$). The influence of bone cement distribution on the efficacy of unilateral percutaneous vertebroplasty was statistically analyzed. General data for the two groups included patient gender, age, body mass index (BMI), bone density T value, PVP stage, and medical history.

Statistical methods

Statistical analysis was performed using SPSS 22.0 statistical software package. Measurement data were expressed as mean ± standard error. One-way analysis of variance (ANOVA) was used for comparison of measurement data between different groups. Independent sample t-test or chi-square test was used for comparison of preoperative and postoperative 7-day, 1-month, and 12-month VAS scores and ODI scores, as well as vertebral height within the same group. Chi-square test was used for comparison of count data between groups. A significance level of $P < 0.05$ was considered statistically significant. All statistical methods and results of this study have been reviewed by a statistical expert from the Sixth Affiliated Hospital of Xinjiang Medical University.

Results

Participant number analysis

A total of 170 patients who underwent unilateral percutaneous vertebroplasty were included in the study. They were divided into two groups based on the different morphologies of bone cement distribution: the diffusion distribution group ($n = 87$) and the poor diffusion group ($n = 83$). All patients were included in the outcome analysis, with no missing data.

Experimental flowchart

The flowchart depicting the grouping process of the two groups is shown in Fig. 4.

Comparison of preoperative data between two groups

There were no statistically significant differences in age, sex, body mass index (BMI), duration of fracture, menopausal time in female patients, bone mineral density T value, injured vertebral segment, medical history (cardiovascular diseases, neurological diseases, respiratory

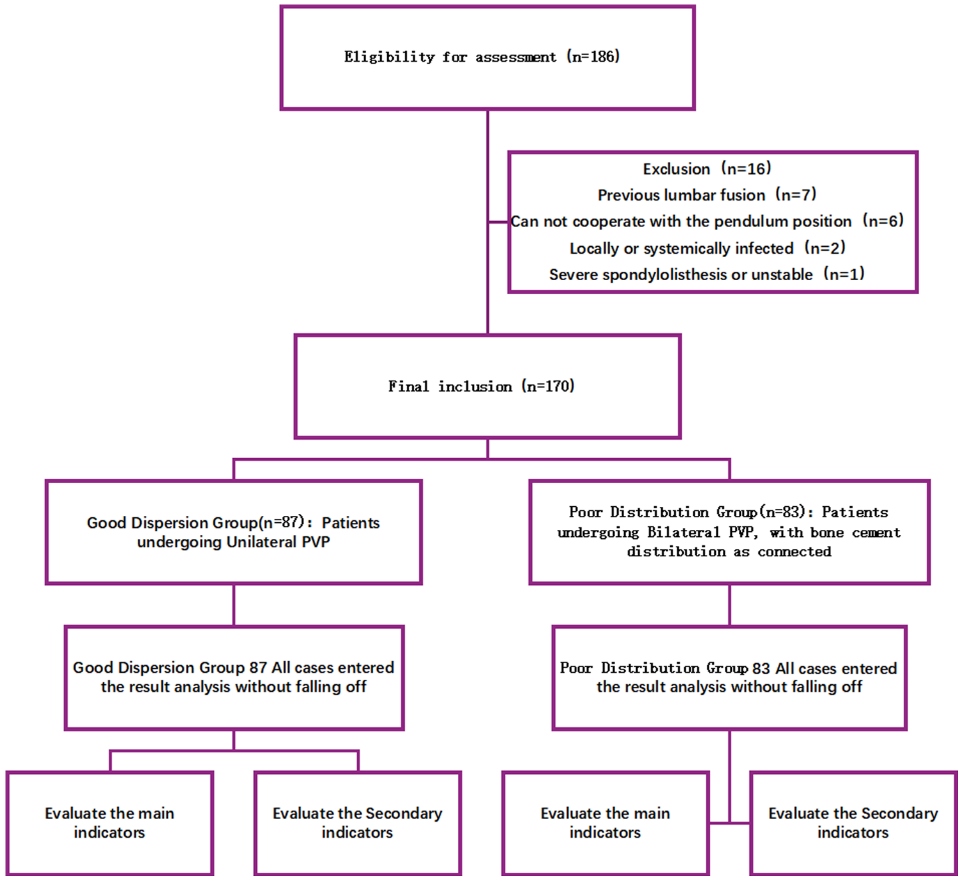

Fig. 4 Flow chart of patient assignment

diseases, endocrine diseases, metabolic diseases), smoking history, and alcohol consumption history between the two groups ($P > 0.05$) shown in Table 4.

Comparison of preoperative and postoperative lumbago VAS and ODI scores between two groups

There were no significant differences in preoperative lumbago VAS and ODI scores between patients in the good distribution group and the poor distribution group ($P > 0.05$). Similarly, there were no significant differences in lumbago VAS scores at 1 week postoperatively and lumbago ODI scores at 1 week, 1 month, and 1 year postoperatively between the good distribution group and the poor distribution group ($P > 0.05$), indicating no statistical differences. However, there were significant differences in lumbago VAS scores at 1 month and 1 year postoperatively between the two groups (t_1 month = 3.285, t_1 year = 5.490, $P < 0.05$), indicating statistical differences, as shown in Table 5. The above data suggest that the good distribution group may have better clinical outcomes.

Comparison of pre- and postoperative vertebral height restoration rate and local vertebral kyphosis angle between the two groups

As shown in Table 6, there was no significant difference in vertebral height restoration rate and local vertebral kyphosis angle between the two groups at pre-operation and postoperative 1 week ($P > 0.05$).

Comparison of secondary outcome measures

There were no significant differences between the two groups in terms of surgical time, bone cement volume, cement leakage, total hospitalization expenses, postoperative hospital stay, and adjacent vertebral fractures ($P > 0.05$). However, there were significant differences in the incidence of re-fracture of the injured vertebra and the overall fracture rate (t_re-fracture of injured vertebra = 8.337, t_overall fracture rate = 5.116, $P < 0.05$). The data above suggest that the fracture rate (re-fracture of injured vertebra and overall fracture rate) in the good distribution group was significantly lower than that in the poor distribution group, as shown in Table 7.

Table 4 Comparison of the preoperative general data between the two groups

Factor	Good Dispersion Group ($n=87$)	Poor Distribution Group ($n=83$)	t/X^2	*p*
Age (x̄±s, years)	73.76 ± 8.37	72.39 ± 9.78	2.165	0.326
Gender Male/Female (n/%)	23/64	21/62	0.029	0.866
BMI (x̄±s, kg/m^2)	25.08 ± 4.91	24.22 ± 4.92	0.011	0.254
Fracture Days (x̄±s, d)	4.98 ± 1.87	5.04 ± 1.61	2.249	0.824
Menopausal Time for Female Patients (x̄±s, d)	49.18 ± 2.20	19.61 ± 2.77	1.904	0.313
Bone Density T Value (x̄±s)	-3.23 ± 1.07	-3.45 ± 0.70	10.401	0.111
Injured Vertebral Segments (n/%)	9/10.3	7/8.4	7.121	0.416
T10	10/11.5	5/6.0		
T11	14/16.1	14/16.9		
T12	19/21.8	18/21.7		
L1	6/6.9	16/19.3		
L2	18/20.7	14/16.9		
L3	10/11.5	8/9.6		
L4	1/1.1	1/1.2		
L5				
Cardiovascular Disease (n/%)	35/40.2	45/54.2	3.336	0.068
Neurological Disease (n/%)	18/20.7	28/33.7	3.662	0.056
Respiratory System Disease (n/%)	22/25.3	18/21.7	0.306	0.580
Endocrine System Disease (n/%)	34/39.1	59/28.9	1.953	0.162
Metabolic Disease (n/%)	39/44.8	40/48.2	0.193	0.660
Smoking History (n/%)	12/13.8	19/22.9	2.358	0.125
Alcohol Consumption History (n/%)	14/16.1	19/22.9	1.255	0.263

Table 5 Comparison of VAS and ODI scores before and postoperative in the two groups

Outcome indicators	Follow-up time	Good distribution group($n=87$)	Poor distribution group($n=83$)	t	*p*
Lumbar pain VAS score (x̄±s, points)	Pre-operation	7.28 ± 1.34	7.46 ± 1.31	0.198	0.374
	Post-operation 1 week	4.21 ± 1.58[a]	4.06 ± 1.71[a]	0.064	0.563
	Post-operation 1 month	2.99 ± 2.03[a]	3.86 ± 2.20[a]	3.285	**0.009**
	Post-operation 1 year	1.76 ± 1.15[a]	2.40 ± 1.64[a]	5.490	**0.004**
Lumbar pain ODI score (x̄±s, %)	Pre-operation	68.67 ± 10.64	69.55 ± 9.02	0.082	0.558
	Post-operation 1 week	36.72 ± 12.36[a]	36.87 ± 11.18[a]	2.327	0.937
	Post-operation 1 month	25.99 ± 10.84[a]	26.31 ± 9.74[a]	0.147	0.837
	Post-operation 1 year	21.83 ± 7.61[a]	23.37 ± 8.47[a]	0.825	0.214

Note: Compared to pre-treatment within the group, [a]$P < 0.05$

Table 6 Comparison of preoperative and postoperative vertebral height recovery rate and vertebral local kyphosis angle in the two groups

Outcome indicators	Follow-up time	Good distribution group($n=87$)	Poor distribution group($n=83$)	t	*p*
Vertebral height restoration rate (x̄±s, cm)	Pre-operation	2.18 ± 0.27	2.14 ± 0.20	7.692	0.305
	Post-operation 1 week	2.49 ± 0.37[a]	2.49 ± 0.17[a]	16.207	0.962
Local vertebral kyphosis angle (x̄±s,°)	Pre-operation	15.05 ± 1.33	15.23 ± 0.93	4.432	0.308
	Post-operation 1 week	6.96 ± 0.50[a]	7.06 ± 0.51[a]	0.499	0.204

Note: Compared to pre-treatment within the group, [a]$P < 0.05$

Typical cases

(A) Female, 63 years old, postoperative compression fracture of the L3 vertebra. Bone cement showed good distribution on anteroposterior X-ray images (regions ①, ②, ③, ④, ⑤, ⑦, ⑧), as shown in Fig. 5A; bone cement showed good distribution on lateral X-ray images, as shown in Fig. 5C. (B) Female, 69 years old, postoperative compression fracture of the L3 vertebra. Bone cement showed poor distribution on anteroposterior X-ray images (regions ②, ④, ⑥), as shown in Fig. 5B; bone cement showed good distribution on lateral X-ray images, as shown in Fig. 5D. Figures E, F, G, H depict vertebral re-fractures and other vertebral fractures caused by uneven distribution, as shown in Fig. 6.

Table 7 Comparison of the secondary outcome measures

Factor	Good distribution group($n=87$)	Poor distribution group($n=83$)	t/x^2	*p*
Operation time ($\bar{x}$±s, min)	39.24 ± 8.93	41.12 ± 6.23	11.679	0.112
Bone cement dose ($\bar{x}$±s, ml)	5.46 ± 1.06	5.81 ± 1.47	7.156	0.079
Cement leakage (n/%)	32/36.8	25/30.1	0.846	0.358
△Expenses ($\bar{x}$±s, RMB)	13143.35 ± 10969.49	12262.46 ± 4675.82	1.614	0.500
Postoperative hospital stay ($\bar{x}$±s, d)	5.57 ± 2.86	5.23 ± 2.47	0.541	0.407
Overall fracture incidence rate (n/%)	8/9.2	18/21.3	5.116	**0.024**
The adjacent vertebral body fracture (n/%)	7/8.0	8/9.6	0.134	0.714
The injured vertebral body was fractured again (n/%)	1/1.1	10/12.0	8.337	**0.004**

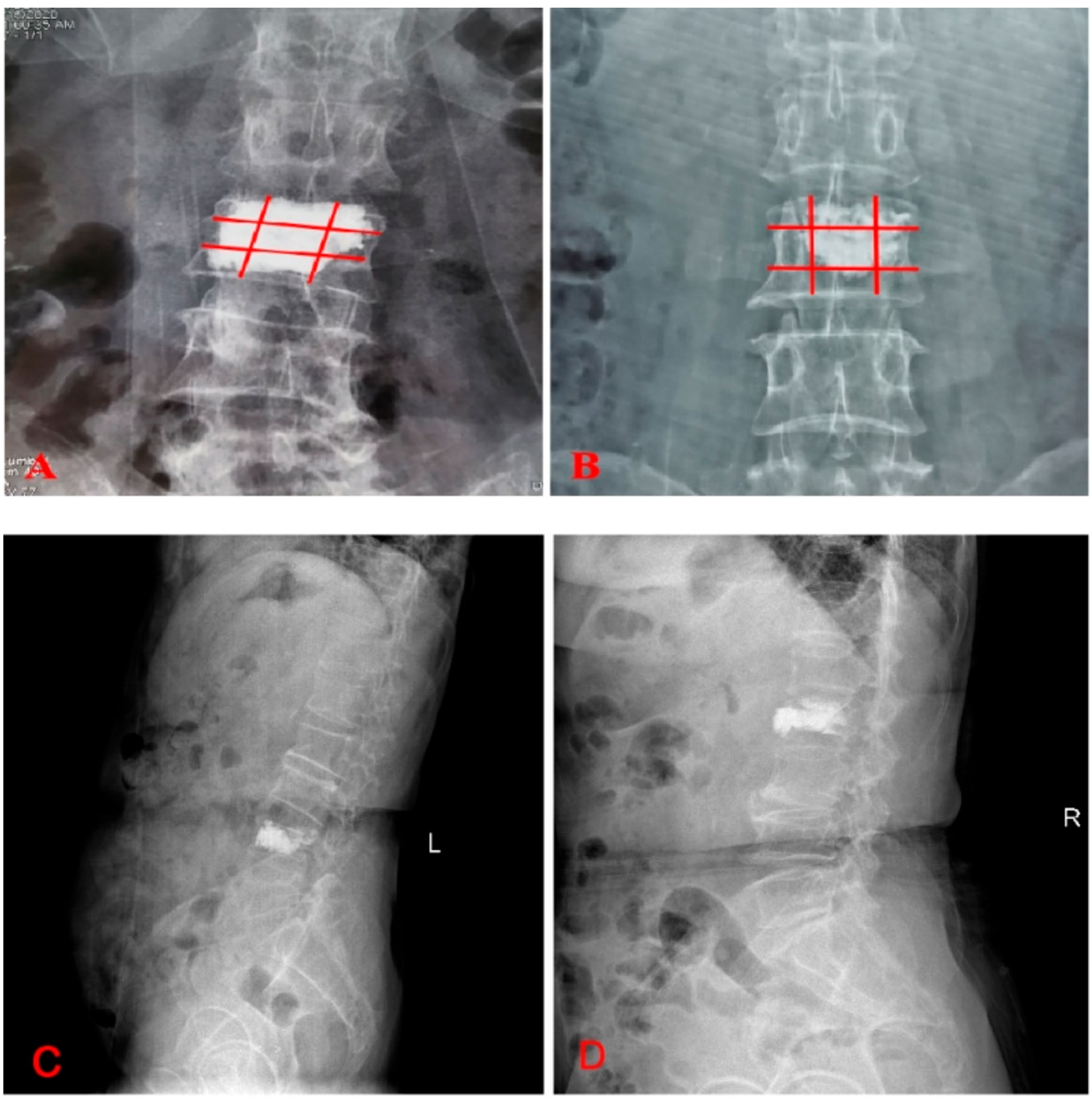

Fig. 5 The bone cement distribution according to postoperative X-ray films of the thoracic and lumbar spines

Discussion

Summary of evidence

Osteoporotic thoracolumbar compression fractures are a common type of fracture in the elderly, mainly related to osteoporosis [16, 17]. As age advances, bone density decreases gradually, making osteoporosis and fractures more likely [18]. Various factors contribute to the occurrence of such fractures, including osteoporosis, trauma, lack of exercise, vitamin D and calcium deficiency, long-term smoking and excessive alcohol consumption,

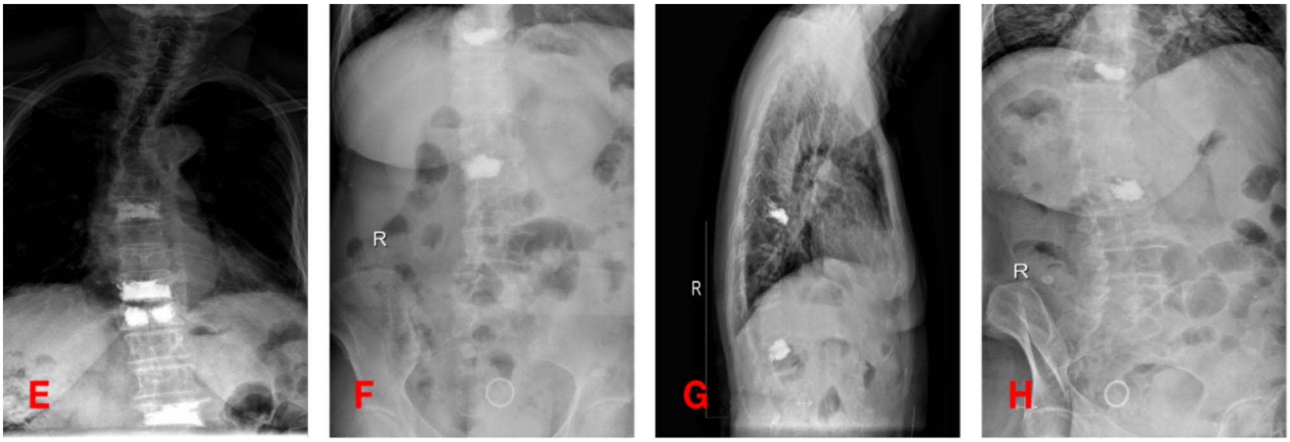

Fig. 6 Refractures of injured vertebrae and other vertebrae due to uneven diffusion

prolonged use of steroids, thyroid disease, osteomyelitis, bone cancer, etc [19]. The main symptoms include persistent pain in the thoracolumbar region and lower limb dysfunction, leading to restricted mobility and significantly affecting the quality of life of patients and their families ((20–21). In traditional clinical treatment, conservative treatment or anterior and posterior open reduction and internal fixation surgery are commonly used [22]. However, conservative treatment requires patients to rest in bed for a long time, which may lead to complications such as lung infection, pulmonary embolism, and lower limb venous thrombosis, even life-threatening conditions [23]. Surgical treatment, on the other hand, is not ideal due to osteoporosis of the vertebral body, making internal fixation devices prone to loosening. Therefore, unilateral percutaneous vertebroplasty provides a new approach for the treatment of osteoporotic thoracolumbar vertebral fractures [24]. This treatment method has the advantages of minimal trauma, rapid pain relief, improved function, effective restoration of vertebral height, and reduced incidence of complications, making it a safe, effective, and convenient treatment method [25]. Although unilateral percutaneous vertebroplasty is simple, safe, and effective, the distribution of bone cement within the vertebral body further affects the surgical outcome, clinical efficacy, and patient prognosis. Particularly, poor distribution of bone cement may lead to vertebral re-fractures, adjacent vertebral fractures, bone cement leakage, etc [26]. Since there is no consensus on bone cement dispersion related studies, clinical bone cement distribution needs to meet both the biomechanical properties of the fractured vertebra and avoid leakage [27]. Therefore, how to effectively control the distribution of bone cement in unilateral percutaneous vertebroplasty for the treatment of osteoporotic thoracolumbar vertebral compression fractures has become a challenge and focus of clinical research.

The results of this study indicate that currently, clinical practice often employs bone cement infusion in unilateral percutaneous vertebroplasty for treatment. By injecting bone cement, it disperses to the fracture ends and fractured trabeculae, thereby improving vertebral stability, restoring vertebral strength, and providing stable support for fracture healing [28]. Comparison of preoperative data between the good dispersion and poor dispersion groups, as well as preoperative and postoperative indicators, and comparison of VAS and ODI scores between the two groups at one month and one year postoperatively, showed that VAS scores at one month and one year postoperatively were $P < 0.05$, indicating statistical differences between the two groups, suggesting that the good dispersion group has a good pain relief effect and short-term clinical efficacy. This study is consistent with the findings of Huang Hui [29], who reported in "Chinese Community Physicians" that the VAS score in the observation group (good dispersion group) (2.55 ± 0.85) was significantly lower than that in the control group (5.16 ± 0.56) ($P < 0.05$), suggesting that the results of this study are highly reliable. Chen Changli [30] and others believe that an "H"-shaped distribution of bone cement between the endplates is a satisfactory distribution effect, while an "O"-shaped distribution, indicating poor dispersion, results in point-like support and stress on the trabeculae within the vertebral body, exacerbating micro-movement of the trabeculae, inadequate fixation of vertebral micro-fractures, affecting vertebral stability, and causing residual pain at the fracture site. Research by Mo [31] and others confirmed that inadequate dispersion of bone cement can affect the pain relief effect after unilateral percutaneous vertebroplasty. In addition, there is a correlation with delayed postoperative vertebral height loss. Li [32] and other authors also believe that a dispersed distribution of bone cement can better maintain postoperative vertebral height and local kyphosis angle, reduce the risk of vertebral collapse and long-term pain, and achieve better short-term clinical efficacy.

The results of this study demonstrate that the incidence of fractures after unilateral percutaneous vertebroplasty in the good dispersion group is significantly lower than that in the poor dispersion group (overall fracture incidence and re-fracture rate of injured vertebrae) ($P < 0.05$), with statistical significance, which can better maintain vertebral height and reduce the risk of vertebral re-compression. Shen [33] and other researchers believe that the distribution of bone cement in unilateral percutaneous vertebroplasty is an important factor affecting surgical efficacy and the occurrence of various postoperative complications. Some studies have shown that good dispersion of bone cement effectively reduces the postoperative incidence of thoracolumbar vertebral fractures and the re-fracture rate of injured vertebrae, effectively restores vertebral mechanical strength and stiffness, and provides good support. This study mainly analyzes the dispersion distribution of bone cement to explore how to rationally select surgical methods and achieve better clinical efficacy and prognosis, providing reference for surgery.

Limitations of the study

(1) Only patients undergoing unilateral puncture surgery were included, which may affect the distribution of bone cement. Cases of bilateral puncture should be considered to make the study more convincing.(2) The study only classified the distribution of bone cement based on X-ray images. CT three-dimensional reconstruction can be used to classify the distribution of bone cement, making the study more rigorous.(3) This study is retrospective and may have result bias, but our research group strictly recorded preoperative and postoperative clinical indicators and conducted rigorous follow-up to ensure the integrity of clinical data.(4) Due to the diversity of patients, medical conditions, surgical methods, research methods, follow-up time, and other variable factors, the reliability of the above conclusions still needs further confirmation through prospective studies.(5) The grouping method of this study is different from previous studies, which may lead to subjective bias in the results. Therefore, to better understand the effect of bone cement distribution in unilateral percutaneous vertebroplasty on the repair efficacy of thoracolumbar vertebral compression fractures, large sample size, multicenter studies are needed.

Conclusion

Compared with the poor dispersion group, patients in the good dispersion group achieved better short-term clinical efficacy, and the long-term prognosis still needs to be observed. Moreover, the good dispersion group can significantly reduce the overall fracture incidence and re-fracture rate of injured vertebrae, thereby achieving better surgical outcomes, clinical efficacy, and prognosis.

Abbreviations

BMD	Bone mineral density
EOH	Estimated original vertebral body height
HRR	Height restoration rate
LKA	Local kyphosis angle
ODI	Oswestry disability index
OVCF	Osteoporotic vertebral compression fractures
PFH	Preoperative fractured vertebral body height
PKP	Percutaneous kyphoplasty
VAS	Visual analogue scale
PMMA	Polymethyl methacrylate
PRH	Postoperative restored vertebral body height

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Author contributions
Study design, conception, and critical revision: LYT and T.A. Analysis and interpretation of data: A.Y and L.H. Literature search and drafting of manuscript: A.H, A.K，M A，Y.A and A.A. A.H and MXY. contributed to critical revision of the manuscript for important intellectual content and approved the fnal version of the manuscript. All authors read and approved the fnal version of the manuscript.

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Data availability
Osteoporotic vertebral fractures and their complications pose increasing risks to the elderly. The purpose of this study was to evaluate the clinical efficacy of unilateral percutaneous vertebroplasty in patients with osteoporotic vertebral compression fractures (OVCF) by assessing postoperative cement distribution., so the dataset analyzed in this study is not publicly available but is available to the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
We confrm that all experiments were performed in accordance with the Declaration of Helsinki. The study was approved by the Ethical Committee of the Sixth Afliated Hospital of Xinjiang Medical University, NO. LFYLLSC20230510-01. Each patient provided written informed consent before participating in the study.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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