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RESEARCH

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Clinical efficacy analysis of extrapedicular unilateral percutaneous vertebroplasty via the upper edge of the transverse process for lumbar osteoporotic vertebral compression fractures

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Abstract

Objective To investigate the clinical effect of vertebroplasty through unilateral upper edge of transverse process in the treatment of lumbar osteoporotic vertebral compression fracture (OVCF), and to explore the surgical indications and operation points of this technique.

Methods Ninety patients with osteoporotic vertebral compression fractures of the lumbar spine treated in our hospital from June 2020 to June 2021 were retrospectively analyzed and divided into the experimental group and the control group for vertebroplasty according to the principle of randomization; the experimental group was treated with a lateral pedicle approach through the upper edge of the unilateral transverse process, and the control group was treated with a unilateral pedicle approach. After more than 1 year of follow-up, the operation time, intraoperative fluoroscopy times, bone cement injection volume, Oswestry disability index (ODI), Visual analogue scale (VAS) were compared between the two groups to assess the functional recovery of the patients.

Results There was no significant difference in the general data (age, gender, location and number of fractured vertebral bodies, and follow-up time) between the two groups before surgery. In the experimental group, there were 42 OVCF patients (15 males and 27 females), and the operated segments were L1 vertebral body in 17 cases, L2 vertebral body in 13 cases, L3 vertebral body in 8 cases, L4 vertebral body in 3 cases, and L5 vertebral body in 1 case. The control group consisted of 48 OVCF patients (16 males and 32 females), and the operated segments were L1 vertebral body in 21 cases, L2 vertebral body in 15 cases, L3 vertebral body in 8 cases, L4 vertebral body in 2 cases, and L5 vertebral body in 2 cases. In terms of operation time and intraoperative fluoroscopy times, the experimental group was less than the control group, and the difference had statistical significance ($P<0.05$); in terms of bone cement injection volume, the difference between the two groups had no statistical significance ($P>0.05$); in terms of pain VAS score and dysfunction index ODI score, the scores of the two groups were improved with the extension of follow-up

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time compared with those before surgery, but the difference between the two groups had no statistical significance ($P > 0.05$).

Conclusion Compared with the traditional approach, PVP via the unilateral extrapedicular approach at the upper edge of the transverse process has the advantages of less operation time and fluoroscopy times, uniform diffusion of bone cement, and is comparable to the traditional surgical approach in relieving pain and improving patient function, but due to the limitation of the length of the puncture needle, careful operation is required during the operation.

Keywords Percutaneous vetebroplasty, Osteoporotic vertebral compression fracture, Unilateral transverse process extrapedicular approach

Introduction

Due to the serious problem of aging in today's society. The incidence of osteoporotic fractures is increasing year by year, and it is predicted that by 2050, the number of osteoporotic fractures in China will reach 5.99 million. Among them, osteoporotic vertebral compression fracture (OVCF) accounts for the largest proportion, which seriously affects the quality of life of patients and brings great economic burden to patients and society [1]. In recent years, percutaneous vertebroplasty (PVP) can significantly relieve the pain caused by OVCF and improve the quality of life of patients, and has become the main surgical method for the treatment of thoracic and lumbar OVCF [2]. At present, PVP puncture path in thoracic vertebral compression fractures in addition to transpedicular puncture, but also can take the extrapedicular puncture path through the costotransverse joint, unilateral puncture to achieve bilateral transpedicular puncture cement diffusion effect [3]. However, vertebral compression fractures of the lumbar spine often require puncture of bilateral pedicles due to the larger sagittal diameter of the spinal canal, increased pedicle length, smaller coronal angulation of the pedicle, and the need for a large abduction angle during puncture, which is difficult to achieve the effect of bilateral diffusion through unilateral pedicle puncture, but it will lead to long operation time and increase patient pain, and bilateral puncture is not convenient for the observation of cement diffusion and increases the risk of surgery [4–6]. In order to solve this problem, the author improved the puncture path and summarized a simple and feasible puncture method, which passed through the lateral wall of the pedicle through the upper edge of the transverse process to the fractured vertebral body. To investigate the therapeutic effect of unilateral puncture PVP through the lateral pedicle approach at the upper edge of the transverse process.

Methods

The clinical data of 90 patients with lumbar osteoporotic vertebral compression fractures treated from June 2020 to June 2021 were retrospectively analyzed. According to the principle of randomization, the experimental group was treated with a lateral pedicle approach through the superior border of the unilateral transverse process, and the control group was treated with a unilateral pedicle approach. The study was approved by the Ethics Committee of our hospital, and written informed consent from participants was received. The inclusion criteria were as follows: (1) Dual-energy X-ray absorptiometry showed bone mineral density T value ≤ -2.5 SD; (2) there were significant symptoms of low back pain and limitation of motion; (3) fresh fractures, T2 fat compression image of MRI showed abnormal high signal intensity in the vertebral body; (4) the posterior edge of the vertebral body was intact without spinal cord and nerve root compression; (5) there were no other fractures or dysfunction of important organs and could tolerate surgery. intraoperative needle biopsy confirmed the diagnosis of OVCF. The exclusion criteria included: (1) Patients with primary or metastatic vertebral lesions, multiple myeloma, metabolic bone disease; (2) Patients with severe cardiopulmonary dysfunction and severe coagulation disorders; Patients with a history of drug abuse or oral anticoagulants; (3) Patients with coma or incapacity; (4) MRI contraindications (cardiovascular and cerebrovascular stents, cardiac pacemakers, biostimulation, and other implantation history); (5) Patients with severe infection uncontrolled or high fever; (6) Patients allergic to bone cement; (7) Patients who have previously undergone vertebral augmentation surgery and other spinal surgeries.

Surgical procedure

Patients were placed in the prone position, vital signs were monitored, and intravenous analgesia anesthesia was administered if necessary. The target vertebral body was located under fluoroscopy with a G-arm X-ray machine and checked with imaging data to determine. Adjust the position of G-arm X-ray machine, so that the anteroposterior view of pedicle is best, the spinous process is located in the middle of vertebral body, and the position of pedicle and transverse process is marked on the skin. Routine surgical area was disinfected and draped, and local infiltration anesthesia was performed by opening 1 cm beside the upper edge of the midpoint of the transverse process indicated on the body surface: the skin, lumbodorsal fascia, and the upper edge of the middle transverse process were anesthetized layer by layer, the metal puncture needle head of the indwelling needle was replaced, crossing the upper edge of the transverse process, adjusting the abduction and tailing angles to puncture to the lateral wall of the pedicle, sliding anteriorly to the vertebral body, and infiltration anesthesia was performed. The skin was incised at the point of anesthesia, and according to the steps of local anesthesia puncture, the puncture needle was placed at the junction of the pedicle and vertebral body with an integrated puncture needle, and attention was paid to slow needle insertion to observe the patient's response and prevent damage to the nerve roots and dural sac. The puncture needle was gradually entered along the direction of the posterior edge of the vertebral body, and G-arm fluoroscopy was performed after reaching the bony structure, and when the needle tip reached the junction between the posterior edge of the vertebral body and the pedicle in lateral fluoroscopy, the anteroposterior fluoroscopy needle tip was located at the lateral edge of the pedicle projection on the puncture side. Continue inserting the needle until the needle tip reaches the center of the vertebral body in the lateral position and reach the spinous process in the anteroposterior view, or reach or approach the inner edge of the contralateral pedicle when the needle tip reaches the anterior vertebral body in the lateral position. Pull out the stylet and slowly expand the bony channel with the appropriate drill bit or K-wire to the anterior cortex of the vertebral body (Figs. 1 and 2). After successful puncture, Under intermittent fluoroscopic monitoring of the G-arm, local tissues were obtained with a biopsy needle for pathological examination, the bone cement was prepared and timed, and 5 min later, the bone cement was slowly injected into the vertebral body under anteroposterior and lateral fluoroscopic monitoring through a cement plunger. After the bone cement is evenly distributed in the vertebral body, pull out the working cannula and bone cement injection device, and compress and bandage the puncture point.

In the transpedicular group, the patient was placed in the prone position, the G-arm body surface was located, and the anteroposterior position of the injured vertebra confirmed that the spinous process was located at the midpoint of the pedicles on both sides. Body surface marker pedicle projection on the puncture side of the injured vertebra. Local infiltration anesthesia was performed on the puncture site, and the needle insertion point was at the junction of the root of the transverse process and the superior facet. The puncture trocar punctured through the pedicle into the vertebral body, and the needle tip was located on the posterior wall of the vertebral body in the lateral position and at the medial edge of the pedicle projection in the anteroposterior position. The stylet was removed, a guide wire was placed, and the working cannula was replaced. Solid vertebral body drilling and reaming caused the anterior third of the vertebral body, the bone cement inserter was placed into the vertebral body along the pedicle, and the G-arm machine continuously confirmed whether the needle insertion route was safe, the degree of cement diffusion and whether the bone cement leaked during the whole operation. All working channels were removed, the skin was sutured, and the surgical incision was dressed. All patients were operated on by the same team.

Postoperative management and Outcome Evaluation

After operation, the patients were given bed rest, fluid infusion, and other symptomatic and supportive

Fig. 1 Diagram of puncture point (taking L3 vertebral body as an example): **A** lateral view shows that the puncture point is located at the upper edge of pedicle and the junction with vertebral body; **B** oblique view shows that the puncture point is located at the upper edge of transverse process and the junction with vertebral body; **C** anteroposterior view shows the puncture direction

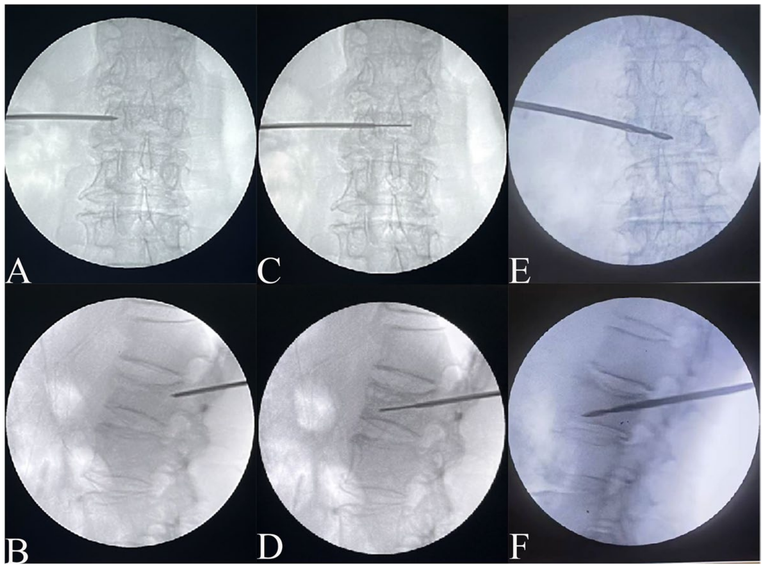

Fig. 2 Intraoperative fluoroscopy determined position, **A**-**B** Lateral view showed reaching the junction of the posterior vertebral body and the pedicle when the needle tip was located at the outer edge of the pedicle projection. **C**-**D** When the needle tip crosses the spinous process in the anteroposterior view, the lateral view shows that the needle tip reaches the middle and anterior third of the vertebral body. **E**–**F** The access instruments were replaced and bone drills were passed into the bone following the access trajectory

treatment to observe whether there were subcutaneous hemorrhage, infection, spinal cord nerve injury pulmonary embolism, and other symptoms, and rehabilitation exercise was performed under the guidance of a physician. After discharge, the patients were given anti-osteoporosis treatment.

The operation time, intraoperative fluoroscopy times, bone cement injection volume, bone cement distribution (Bone cement distribution score (refer to the bone cement space distribution score proposed by Liu et al. [7]: the distribution scores of bone cement were calculated based on its characteristics observed on postoperative anteroposterior and lateral X-rays, as well as CT images. Coronal and sagittal plane distribution scores were determined using postoperative X-rays, while horizontal plane distribution scores were calculated using postoperative CT images at the level of the surgical vertebra. For the horizontal plane, a horizontal and a vertical line passing through the center of the vertebral body were drawn on CT images, dividing the vertebra into four regions (quadrants). Bone cement distribution across these quadrants was assessed, with 1 point assigned for each region occupied by bone cement. For the sagittal plane, postoperative lateral X-rays were analyzed, and two vertical lines perpendicular to the anterior edge of the vertebral body were drawn to divide the vertebra into upper, middle, and lower thirds, with 1 point assigned for each section occupied by bone cement. For the coronal plane, postoperative anteroposterior X-rays were used, and two lines perpendicular to the upper endplate of the vertebra were drawn to divide the vertebra into left, middle, and right sections, with 1 point assigned for each section occupied by bone cement. In all three planes, bone cement was considered to occupy a region if it covered more than 50% of the region's total area. If the coverage was less than 50%, it was considered negligible and excluded from the score, with a maximum score of 10 points)), visual analogue scale (VAS), Oswestry disability index (ODI), incidence of complications such as refracture of the injured vertebra, bone cement leakage, and nerve injury were compared between the two groups.

Statistical analysis

The SPSS 21.0 software (Chicago, IL, USA) was applied for statistical analysis. Continuous variables were expressed as mean ± standard deviation and analyzed by the Kirmogrov-Smirnov test for normality assessment. Differences were analyzed by unpaired t-test or Mann–Whitney U test. Categorical variables were analyzed by chi-square test. $P < 0.05$ was considered a statistical significance.

Results

A total of 90 patients were enrolled in this study according to the above inclusion criteria, including 42 patients in lateral approach to pedicle of superior border of unilateral transverse process (experimental group) and 48 patients in unilateral pedicle approach (control group).

In the experimental group, there were 15 males and 27 females; the mean age was 73.55 ± 8.76 years; there were 17 L1 fractures, 13 L2 fractures, 8 L3 fractures, 3 L4 fractures, 1 L5 fractures. In control group, there were 16 males and 32 females with an average age of 75.33 ± 9.15 years; there were 21 L1 fractures, 15 L2 fractures, 8 L3 fractures, 2 L4 fractures, 2 L5 fractures. After statistical analysis, there was no significant difference in gender, age, fractured vertebral body, and other baseline data between the two groups ($P > 0.05$) (Table 1).

The operation time was (25.31 ± 3.33) min in the experimental group and (30.13 ± 3.43) min in the control group, and the difference had statistical significance ($P < 0.001$). Compared with the control group, the number of intraoperative fluoroscopy were significantly reduced, the bone cement distribution was better in the experimental group, and the differences were statistically significant ($P < 0.05$) (Table 1). Typical cases are shown in Figs. 3– 4.

The VAS score of low back pain in the follow-up at 1 days and 1 years after operation in both groups was significantly lower than that before operation, and there was significant difference between the follow-up at each time point after operation and that before operation ($P < 0.05$); the comparison between the two groups showed no difference in the VAS score of low back pain after operation between the two groups ($P > 0.05$). The ODI in the follow-up at 1 days and 1 years after operation in both groups was significantly lower than that before operation. There was significant difference in the follow-up at each time point after operation compared with that before operation ($P < 0.05$). There was no significant difference in the ODI between the two groups ($P > 0.05$) (Table 2).

None had postoperative subcutaneous hemorrhage, infection, spinal cord nerve injury, or pulmonary embolism. In the experimental group, cement leakage occurred in 2 case and lateral pedicle wall in 1 case, no intraspinal or intervertebral foraminal leakage occurred, and the patient had no postoperative discomfort symptoms. In the control group, cement leakage occurred in 3 cases, including 3 cases at the anterior vertebral body, and no radicular neurotic symptoms occurred. The incidence of intraoperative cement leakage was 4.7% (2/42) in the experimental group and 6.2% (3/48) in the control group.

Discussion

In today's society, with the increasing aging of the population, the number of patients with osteoporosis is increasing, and OVCF secondary to it has become one of the most common diseases in spinal surgery [8]. OVCF not only brings physical and psychological pain to patients but also reduces their daily life and work ability [9]. PVP has the characteristics of small trauma, short operation time, and quick effect, which can not only significantly relieve the symptoms of patients after PVP, but also significantly reduce the related complications caused by long-term bed rest [10]. However, as PVP is widely used in clinical practice, its existing problems have gradually aroused people's attention. Traditional PVP surgery

Table 1 Analysis of general data of patients

	Experimental group	Control group	t/^{2}	*P* value
Number of patients	42	48		
Age (year)	73.55 ± 8.76	75.33 ± 9.15	t = −0.945	$P = 0.347$
Sex (%)				
Male	15(35.7)	16(33.3)	2 = 0.056	$P = 0.813$
Female	27(64.3)	32(66.7)		
Vertebral fracture level (%)				
L1	17	21	2 = 0.700	$P = 0.951$
L2	13	15		
L3	8	8		
L4	3	2		
L5	1	2		
Duration of operation (min)	25.31 ± 3.33	30.13 ± 3.43	t = −6.739	$P < 0.001$
Intraoperative fluoroscopy times	10.31 ± 1.25	12.73 ± 1.25	t = −9.130	$P < 0.001$
Injection volume of bone cement (ml)	4.31 ± 0.51	4.23 ± 0.42	t = 0.798	$P = 0.427$
Cement Distribution Score	7.91 ± 1.14	5.71 ± 1.95	t = 5.297	$P < 0.001$
Complication Rate (%)				
No	42(95.3)	48(93.8)	2 = 0.095	$P = 0.758$
Yes	2(4.7)	3(6.2)		

RA Robot assisted group, *TF* Traditional fluoroscopy Group

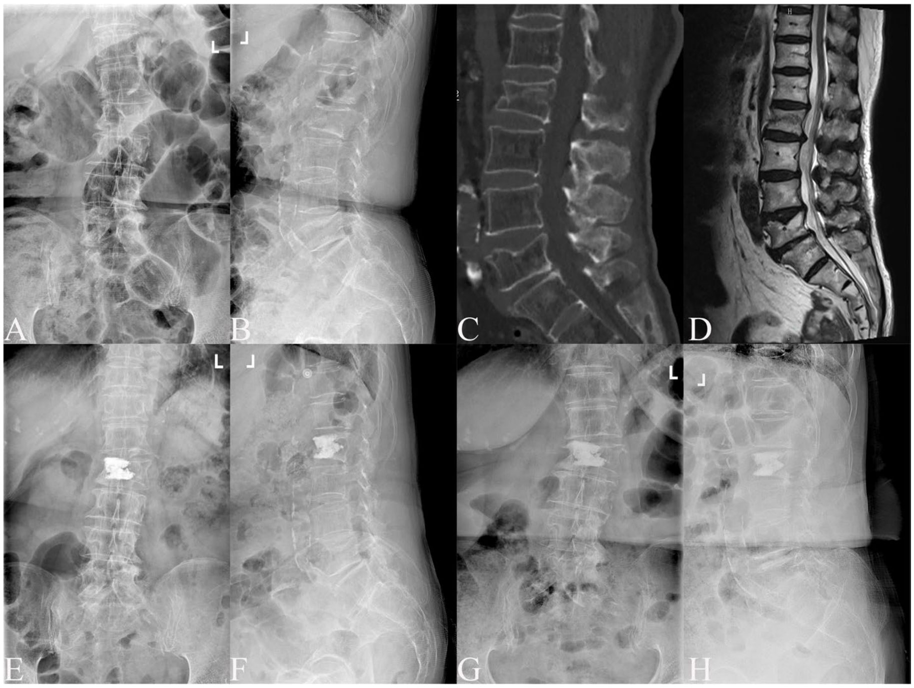

Fig. 3 Traditional group: A 79-year-old female presented with L2 vertebral compression fracture (OVCF) caused by a fall and underwent PVP surgery. **A**-**B** Preoperative lumbar anteroposterior and lateral X-ray showed L2 vertebral wedge change, intestinal pneumatosis was obvious; **C**-**D** preoperative lumbar CT and MRI showed L2 vertebral fresh compression fracture, upper and lower vertebral endplates were in good shape; **E**–**F** postoperative lumbar anteroposterior and lateral X-ray showed L2 vertebral bone cement filling well, but the position was poor; **G**-**H** postoperative 1-year follow-up lumbar anteroposterior and lateral X-ray showed bone cement filling and vertebral body shape was good, vertebral body height was satisfactory, no local kyphosis occurred

usually depends on the experience of the surgeon combined with intraoperative C-arm multiple fluoroscopy to determine the puncture direction and needle insertion point, which greatly increases the operation time and the amount of radiation received by patients and medical workers, and still cannot completely avoid the occurrence of complications such as cement leakage.

The puncture route of classic PVP is transpedicular approach, and bilateral puncture is required to achieve the effect of total vertebral diffusion of bone cement in the lumbar spine due to the limitation of pedicle angle. In the thoracic spine, it can be punctured from the extrapedicular approach through the costotransverse joint, so that the cement cannula crosses the midline or even punctures to the contralateral side of the vertebral body to achieve unilateral puncture and diffusion of the whole vertebral body [11]. Bilateral puncture fluoroscopy has more times and longer operation time, which increases the patient's pain and the intensity of doctor-patient exposure to radiation, and the two sides overlap with each other when bone cement is injected, which is not conducive to fluoroscopy [12, 13]. Compared with bilateral puncture, unilateral puncture has obvious advantages in operation time, blood loss and safety. Unilateral puncture also has advantages over bilateral puncture in terms of the number of intraoperative fluoroscopy and the amount of bone cement injected [14]. For patients with severe osteoporotic vertebral compression fractures, some scholars have performed unilateral pedicle puncture and achieved satisfactory clinical results [15]. Some scholars perform lumbar puncture from above the posterolateral lower endplate of the vertebral body at a 45° angle of posterolateral abduction of the lumbar spine and penetrate the puncture needle to the midline of the anterior vertebral body to achieve the effect of unilateral puncture bilateral diffusion of the lumbar spine, however, this operation technique is complex and requires repeated fluoroscopy, which also increases the patient's pain [16]. After clinical exploration and practice, the author's team proposed a lateral pedicle approach through the upper edge of the transverse process. The results of this study showed that unilateral puncture PVP through the lateral pedicle approach at the upper edge of the transverse process for the treatment of lumbar osteoporotic vertebral compression fractures resulted in significant relief of lower back pain and rapid functional recovery after surgery, which is a simple, safe and effective

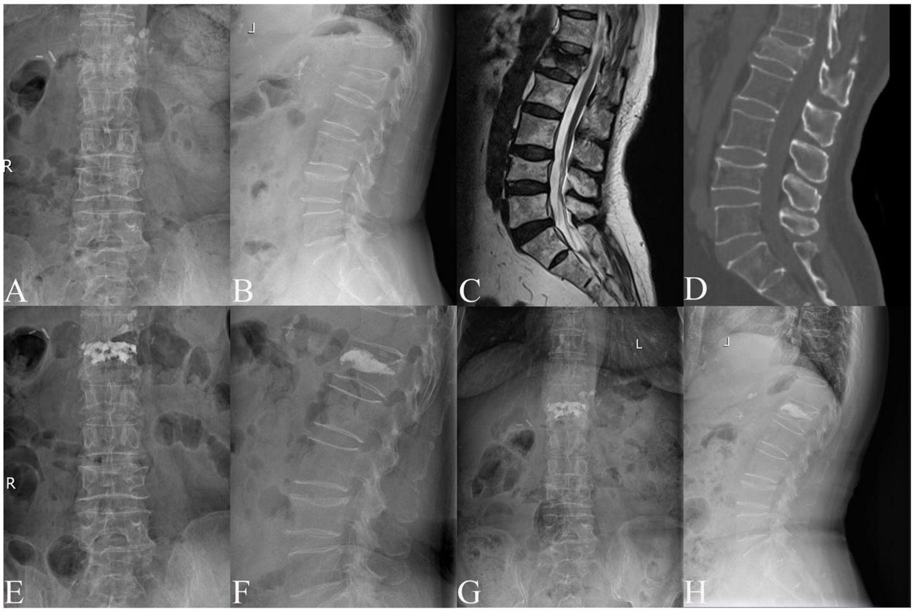

Fig. 4 Modified puncture surgery group: female, 78 years old, L1 vertebral compression fracture (OVCF) caused by fall, PVP surgery was performed. **A**-**B** Preoperative anteroposterior and lateral X-ray of lumbar vertebra showed wedge change of L1 vertebral body and collapse of upper endplate of vertebral body; **C**-**D** preoperative lumbar CT and MRI showed fresh compression fracture of L1 vertebral body and obvious compression of upper 1/2 of vertebral body; **E**–**F** postoperative anteroposterior and lateral X-ray of lumbar vertebra showed satisfactory filling of L1 vertebral bone cement and uniform filling in the fracture area; **G**-**H** postoperative 1-year follow-up anteroposterior and lateral X-ray of lumbar vertebra showed good filling of L1 bone cement and vertebral body shape, and satisfactory vertebral body height

Table 2 Comparison of ODI index and VAS score of low back pain before operation and at each follow-up time point after operation between the two groups

	VAS scores			**ODI**		
	Preoperative	**1 days post-op**	**1 years post-op**	**Preoperative**	**1 days post-op**	**1 years post-op**
Experimental group	7.67 ± 0.81	2.55 ± 0.67*	1.74 ± 0.66*	76.07 ± 9.02	8.51 ± 3.86*	7.20 ± 2.65*
Control group	7.81 ± 0.76	2.54 ± 0.68*	1.81 ± 0.73*	75.05 ± 8.16	8.28 ± 3.61*	7.65 ± 2.93*
P value	$P = 0.386$	$P = 0.967$	$P = 0.615$	$P = 0.578$	$P = 0.772$	$P = 0.444$

RA Robot assisted group, *TF* Traditional fluoroscopy Group

* $P < 0.05$ compared to preoperative

surgical method with uniform cement perfusion in the fractured vertebral body.

When performing the lateral wall approach of the upper edge of the transverse process, the needle was inserted from the opening beside the upper edge of the midpoint of the transverse process, crossing the upper edge of the transverse process, increasing the abduction angle, avoiding the lateral venous plexus of the pedicle, reaching the outer wall of the pedicle, sliding to the vertebral body, appropriate tailing, inserting the needle from the junction of the pedicle and the vertebral body, followed by replacement of the cement cannula, and injection of the cement into the vertebral body through the cement cannula [17]. The lateral approach to the upper edge of the transverse process passes through the upper edge of the transverse process, the outer wall of the pedicle, and the posterolateral cortex of the vertebral body, and the localization of the three bony landmarks is clear, which is operated from the bottom edge of the safe trigone and is not constrained by the pedicle during the operation, which can flexibly adjust the direction and depth of the cement cannula, improve the accuracy of puncture, stay away from the medial wall of the vertebral body, reduce the risk of injuring the dural sac, easily reach the anterior third of the vertebral body, and make the injection of cement more flexible. It simplifies the operating procedure and reduces the number of intraoperative fluoroscopy. Increased safe distance to the thecal sac and nerve roots reduces the risk of intraoperative nerve injury. Local infiltration anesthesia in this approach can directly anesthetize to the vertebral body and reduce the patient's pain during puncture.

In terms of operation time and fluoroscopy frequency, the control group underwent surgery using a unilateral puncture approach. Although the surgeon had extensive experience, fluoroscopy in both the anteroposterior and lateral views was required for path confirmation, as the puncture path was within the pedicle. In contrast, the experimental group used the transpedicular approach through the transverse process, allowing for more flexibility in puncture. As a result, the tolerance for fluoroscopic error was higher during surgery, requiring only a small amount of fluoroscopy for path confirmation. Consequently, the operation time was shorter in the experimental group compared to the control group. The results of this study showed that compared with the control group, the patients in the experimental group had shorter operation time, fewer intraoperative fluoroscopy times, uniform bone cement distribution, and fewer complications. The VAS and ODI scores of the two groups at 1 day after operation were improved compared with those before operation, and there was significant difference between the two groups at different time points after operation ($P < 0.05$), indicating that the two groups had certain advantages in improving the pain symptoms and quality of life of the patients. Symmetrical distribution of bone cement in the vertebral body greatly affects the strength and stability of the postoperative vertebral body. Bilateral cement diffusion can easily be achieved by a lateral pedicle approach through the superior border of the transverse process. The average cement distribution score in the experimental group was 7.91 ± 1.14, which was significantly higher than that in the control group (5.71 ± 1.95).

Cement leakage in the spinal canal often leads to varying degrees of spinal cord or nerve root injury. In order to avoid the internal injury of puncture needle and spinal cord or nerve root, the inclination angle of puncture needle should not be too large, so it is difficult to insert the needle to the center of vertebral body in unilateral pedicle approach, which makes the bone cement unevenly dispersed and the hardness of both sides of vertebral body uneven [18, 19]. In order to allow the cement to diffuse as far as possible towards the contralateral side, the internal inclination angle is often increased or the amount of cement injected is increased. Studies have reported that the recurrence rate of vertebral fractures within 1 year after PVP/PKP is as high as 19.59%. Among them, secondary adjacent vertebral compression fracture (AVCF) accounted for 55.17% of the total number of refractures [20]. Several studies have also shown that patients with PVP or PKP have a higher incidence of secondary fractures of the adjacent vertebral body, and usually occur within 1 month after PVP/PKP surgical treatment [21]. Excessive cement bolus increases the risk of cement leakage and refracture of adjacent vertebral bodies [22]. The main causes of intraspinal leakage of bone cement include incomplete posterior wall of vertebral body, excessive injection of bone cement and rupture of medial wall of pedicle. The extrapedicular approach through the upper edge of the unilateral transverse process is used, because the puncture needle directly enters the vertebral body and will not injure the spinal cord or nerve roots during puncture, so the puncture angle is not constrained by the risk of spinal cord injury or nerve root injury, the puncture needle head can reach the contralateral side of the vertebral body, and when bone cement is injected, both the puncture side and the contralateral side can be taken into account [23]. It reduces the risk of cement leakage, biomechanical stability, and low rates of refracture of adjacent vertebral bodies. No nerve root or dura mater injury occurred in the two groups. Two and three patients developed cement leakage in the experimental group and the control group, respectively. All patients had asymptomatic paravertebral or intervertebral space leakage without intraspinal leakage. We believe that the key to achieving bilateral diffusion using a unilateral approach is the choice of puncture insertion point and puncture angle. Our puncture target is the posterosuperior margin of the vertebral body, and the risk of injuring the spinal cord and nerve roots is relatively small. Experience in clinical application of vertebroplasty via unilateral extrapedicular approach at the upper edge of transverse process: (1) Simplify the surgical procedure. Unilateral puncture makes the operation less invasive, avoids the mutual interference between bilateral puncture and injection of bone cement in bilateral puncture fluoroscopy, and has a shorter operation time. (2) Reduce intraoperative radiation exposure. Traditional transpedicular puncture requires high puncture entry point and puncture angle, and repeated fluoroscopy such as adjusting the puncture point, adjusting the direction during transpedicular process, and confirming the anteroposterior and lateral position when reaching the vertebral body is required. In this puncture technique, there are three clear bony localization markers during puncture: the upper edge of the transverse process, the outer wall of the pedicle, and the posterolateral cortex of the vertebral body, and the puncture process is very safe due to the operation from the bottom edge of the safe trigone. (3) Reduce the patient's pain. After transpedicular puncture, most patients complained of varying degrees of pain when the puncture needle entered the bone. This puncture technique allows good local infiltration anesthesia because the puncture route is performed in the soft tissue. (4) Cement diffusion is controlled. This puncture technique gets rid of the binding of the pedicle, can adjust the direction and depth of the cement cannula during surgery, and can adjust the head inclination angle and abduction angle of the cannula according to the effect of cement diffusion to ensure that the cement achieves the ideal diffusion effect. (5) Improving the safety of surgery. During the puncture, the needle is located outside the pedicle, avoiding the risk of injuring the dural sac and nerve roots. The controllability of cement bolus injection ensures cement diffusion while reducing the risk of cement leakage into the spinal canal. (6) All patients underwent lumbar MRI examination prior to surgery. In addition to evaluating vertebral fractures, a risk assessment for vertebral arterial-venous vascular variations was also conducted to reduce the risk of local hemorrhagic complications caused by puncture. (7) L4 vertebral body, especially L5 vertebral body, is basically half oval, and the third bony landmark point is not easy to explore due to flattening of the vertebral body, which limits the application of this puncture technique to some extent. For L4 and L5 vertebral fractures, the shape of the vertebral body needs to be judged according to the preoperative CT examination to decide whether to apply this puncture technique.

In some patients, congenital developmental issues result in small pedicles or even the absence of a medullary cavity, raising concerns about the safety of traditional transpedicular approaches for this specific population [24]. In many elderly individuals, degenerative changes in the lumbar spine lead to weakened extensor muscles, which disrupt the sagittal spine-pelvis balance. This imbalance often reduces lumbar lordosis while increasing thoracic kyphosis, causing the body's center of gravity to shift forward to compensate for the altered alignment. To adapt to these structural changes, pedicles undergo remodeling due to decreased mechanical load, gradually leading to reduced pedicle width-a condition particularly common in postmenopausal women with osteoporosis [25–28]. The transpedicular approach is a key technique in spinal surgery, where pedicle width plays a critical role in pedicle puncture and screw placement. Improper implant positioning, however, can result in severe complications for patients [24].

The superior transverse process extrapedicular approach offers an effective solution to these challenges. This technique is easy to perform due to the clear identification of three anatomical landmarks: the superior edge of the transverse process, the outer wall of the pedicle, and the posterolateral cortical surface of the vertebral body. The procedure can even be performed with the patient in the lateral position. By avoiding the constraints of pedicle anatomy, this approach allows for greater flexibility in adjusting the puncture angle, enabling bone cement to be delivered to the anterior midline of the vertebral body through a single puncture. This achieves optimal mechanical stability, reducing the risk of adjacent vertebral fractures and postoperative lumbar discomfort caused by uneven stress distribution. Furthermore, the superior transverse process extrapedicular approach is more cost-effective, minimally invasive, and time-efficient. It effectively protects the facet joints, reduces postoperative pain, and minimizes the risk of complications involving the central nervous system.

This study still has shortcomings: (1) the follow-up time was short, and the difference in long-term postoperative complications between the two groups could not be observed, such as secondary fracture, adjacent vertebral fracture, etc.; (2) the sample size was small, and the results may have some bias; (3) retrospective designs and single-center studies can potentially impact research outcomes. Retrospective studies are susceptible to selection and information biases. To address these issues, strict inclusion and exclusion criteria can be applied to ensure the homogeneity of the study population. Additionally, incorporating prospective study designs or utilizing instrumental variable methods can enhance causal inference. Single-center studies, on the other hand, may face limitations in external validity due to the regional specificity of the sample. This can be mitigated by expanding sample sources through multi-center studies, which can improve the diversity and representativeness of the study population.

Conclusion

The results of this study showed that the clinical efficacy of vertebroplasty via unilateral upper edge of transverse process extrapedicular approach in the treatment of lumbar osteoporotic vertebral compression fractures was satisfactory, with the advantages of less operation time and fluoroscopy times, uniform diffusion of bone cement, etc. and it was equivalent to the traditional surgical approach in relieving pain and improving the patient's function, the low diffusion effect of bone cement leakage rate was satisfactory, the long-term risk of adjacent vertebral refracture was small, the risk of spinal cord injury was lower, the operation after proficiency was simpler, and it was safe and reliable, and it should be popularized and applied in clinical work.

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Authors' contributions
JRZ, HPL, YH, LH, PYH, XNW and QSS developed the research questions and scope of the study. JRZ, HPL, XW, QJW and QSS conducted preoperative and postoperative data screening and data charting. JRZ drafted the manuscript, and prepared tables, and figures with HPL's contribution. JRZ and QSS developed the literature search strategies in collaboration with the other authors. JRZ, HPL, YH, PYH, and QSS contributed to the organization, analysis, and interpretation of the results. All authors read and approved the final manuscript.

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Data availability
The data sets generated and analyzed during the current study are not publicly available due to restrictions on ethical approvals involving patient data and anonymity but can be obtained from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
This retrospective study was approved by the Ethics Committee of the Third Affiliated Hospital of Shihezi University and carried out by the ethical standards set out in the Helsinki Declaration. Informed consent was received from all participants.

Consent for publication
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Competing interests
The authors declare no competing interests.

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