Unilateral percutaneous vertebroplasty in osteoporotic vertebral compression fractures: A clinical efficacy evaluation

DONGDONG SHI, XIAOLING LI, FANG HUANG, GEJIN WEI and ZHOUDAN LIN

Department of Spine Surgery, People's Liberation Army Hospital No. 923, Nanning, Guangxi 530021, P.R. China

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Abstract. Osteoporotic vertebral compression fractures, often resulting from low-energy trauma, markedly impair the quality of life of elderly individuals. The present retrospective study focused on the clinical efficacy of unilateral percutaneous vertebroplasty (PVP) in the treatment of osteoporotic compression fractures. A total of 68 patients, representing 92 vertebral bodies, who underwent the unilateral PVP technique from March 2020 to January 2023 were evaluated. Key parameters such as visual analogue scale (VAS) values, Oswestry disability index (ODI) scores, Cobb angle measurements, and anterior vertebral height (AVH) were documented pre- and post-surgery. The mean follow-up period was 15.41±3.74 months. The mean pre-operative VAS score was 8.08±0.79, which was significantly reduced to 2.25±0.71 by 24 h post-surgery and stabilized at 1.58±0.51 by the final follow-up. The ODI showed a significant improvement from a pre-operative average of 67.75±7.91 to 19.74±2.90 post-surgery, and was maintained at a low level of 28.00±4.89 at the last assessment. Radiological evaluations revealed significant alterations in Cobb angle and AVH post-operation. Notably, during the follow-up, eight patients developed new compression fractures in different vertebral segments. In conclusion, the unilateral PVP method is safe and efficient for the management of osteoporotic vertebral compression fractures.

Introduction

Osteoporotic vertebral compression fractures can lead to lower back pain and long-term complications in elderly individuals, including spinal deformity, thrombosis and other issues associated with prolonged bed rest (1). In 2013, the International Osteoporosis Foundation reported that an osteoporotic fracture occurs every 3 sec worldwide (2). Additionally, ~50% of women and 20% of men will have suffered an osteoporotic fracture after the age of 50 years. Furthermore, 50% of patients with osteoporotic fractures are likely to suffer a re-fracture (3). In women, the risk of re-fracture of an osteoporotic vertebral fracture is four times higher than that of a non-vertebral fracture. Osteoporotic fractures of the thoracolumbar spine account for >90% of all spinal fractures, making it the most common site for such fractures (4). Surgical interventions typically involve unilateral or bilateral percutaneous vertebroplasty (PVP), in which polymethylmethacrylate is injected into the fractured vertebra to alleviate pain and correct kyphosis (5-7). While unilateral vertebroplasty has benefits such as a shorter duration of surgery and reduced radiation exposure when compared with bilateral PVP, it often results in uneven bone cement distribution (8). To achieve a more even cement spread, the abduction angle of the metal puncture rod is typically increased during unilateral puncture, which could theoretically elevate the risk of spinal cord injuries. In this context, the present study introduces a refined unilateral PVP method that is aimed enhance the safety and efficacy of the procedure. It may serve as a comprehensive guide for those new to the technique.

Correspondence to: Professor Zhoudan Lin, Department of Spine Surgery, People's Liberation Army Hospital No. 923, 52 Zhiwu Road, Nanning, Guangxi 530021, P.R. China
E-mail: lzd923gk@163.com

Key words: vertebral compression fractures, unilateral percutaneous vertebroplasty, osteoporotic fractures, elderly, quality of life

Materials and methods

Ethics approval and patient consent. Prior to the procedure, each patient provided written informed consent, granting permission for the use of relevant clinical images for scientific research and online publication. The research received approval from the Ethics Committee of the People's Liberation Army Hospital No. 923 Support Force (Nanning, China) and adhered to the ethical principles of the Declaration of Helsinki 2013 revision (9). All patients underwent PVP using the unilateral pedicle cement anchoring technique. The procedures were consistently conducted by an experienced surgeon from the Department of Spine Surgery at People's Liberation Army Hospital No. 923 (Nanning, China) from March 2020 to January 2023.

Study patients. Prior to surgery, all patients received symptomatic treatments, including bed rest and pain management. They underwent routine physical evaluations, with laboratory tests, computed tomography (CT) scans, X-rays, magnetic resonance imaging (MRI) and other diagnostic imaging.

Surgical tolerance was assessed for each patient, and those with underlying conditions were given appropriate symptomatic support treatments.

The inclusion criteria were as follows: i) X-ray, CT and MRI showed a single- or double-level fresh lumbar vertebral compression fracture; ii) with or without a history of low-energy trauma; iii) the detection result of lumbar bone mineral density indicated osteoporosis; iv) age >60 years; v) percussion pain of the injured vertebra; and vi) lower back pain activity was limited, and mainly manifested as obvious pain upon getting up and turning over. The exclusion criteria comprised: i) Severe cardiovascular and cerebrovascular diseases such that the patient could not tolerate surgery; ii) mental disorders that prevented the patient from cooperating with the surgery; iii) clearly abnormal coagulation function; iv) evident scoliosis or kyphosis of the spine; and v) spinal bones destroyed by infection or tumor. A total of 68 cases were included, including 22 males and 46 females. The age of the patients ranged from 60 to 86 years, with an average of 70.06±5.58 years. There were 92 vertebral bodies with fractures: T12 in 28 vertebrae, L1 in 36 vertebrae, L2 in 16 vertebrae, L3 in 5 vertebrae, L4 in 5 vertebrae and L5 in 2 vertebrae. The detailed characteristics of the patients are summarized in Table I.

Surgical management

Preoperative CT imaging preparation. The extent of vertebral compression could be determined from preoperative radiographs taken in the orthostatic (Fig. 1A) and lateral (Fig. 1B) positions. The injured vertebrae exhibited a low signal in the T1 sequence (Fig. 1C) and a high signal in the T2 sequence (Fig. 1D) of the MR. It is important to note that this evaluation was objective and based solely on radiographic findings. It was critical for the puncture to be performed according to the angle and approximate distance measured on the preoperative CT film. On the CT section, the cross-section of the fractured vertebral body was roughly divided into nine equal parts, and various points were marked on the section (Fig. 1E). Point c marked the target puncture point, and point b marked the outer edge of the pedicle. Point b was projected onto the surface skin as point a, which was connected to line bc, which extended to the surface of the body as point d. Point d was the point of puncture on the surface skin, and the angle between cd and ab was the angle of puncture. Similarly, the direction and angle of puncture in the sagittal plane were also measured (Fig. 1F). In this case, point c on the sagittal plane was the target of the puncture, and line dc was the direction of the puncture. Point e was the projection of the midpoint of the spinous process.

Anesthesia and body position. Surgery was performed under local anesthesia combined with basic anesthesia, which provide a very good analgesic effect and facilitated blood pressure control. Local anesthesia was applied using 2% lidocaine injection 5 ml + 1% ropivacaine injection 5 ml + 0.9% sodium chloride injection 10 ml. In addition, a 0.02 mg/kg dose of midazolam was administered intravenously before the procedure, followed by a maintenance dose of dexmedetomidine hydrochloride at 0.6 μg/kg/h to enhance sedation and analgesia based on the patient's weight. All patients were in the prone position during surgery, and the abdomen was suspended by cushions beneath the anterior superior iliac spine and the upper chest, to allow the fracture position to be reset. The operating table was adjusted appropriately to ensure that the muscles on both sides of the waist were as level as possible to make it easier to determine the correct inclination angle of the puncture.

Surgical procedures. C-arm fluoroscopy was used to identify the fractured vertebral body. Following routine disinfection and towel laying, a syringe needle with a length of ~10 cm was inserted at the approximate needle entry point beside the spinous process according to the preoperative measurements. The needle tip was inserted until it reached the outer upper edge of the unilateral pedicle, and the position of the injection needle was adjusted under the perspective of a C-arm X-ray machine until it was higher than the lateral level of the injured vertebral pedicle. Then, a bone cement puncture cannula was used to puncture the transverse process along the trajectory of the positioned connection line. The puncture continued along the outer wall of the pedicle, and extended to the opposite side of the midline of the vertebral body using the bisection method. In order to ensure safety during puncture, it was necessary to perform fluoroscopy 3-5 times. When observing the spine using fluoroscopy, it was possible to see when the needle crossed the midline level of the vertebral body, enabling movement of the needle to be stopped at the appropriate position. Then, the puncture needle was taken out of the cannula, and a Kirschner needle with a diameter of ~1 mm was inserted into the cannula. Exploration revealed the presence of a bony structure at the distal end of the channel. The bone cement was then slowly injected. After each injection of 0.5-1 ml of bone cement, it was necessary to check whether there was any bone cement leakage. After each injection, the patient was asked whether any numbness was evident in the lower limbs. Positive and lateral perspectives were checked to confirm that the distribution of bone cement was satisfactory. When the bone cement was solidified, the working sleeve was rotated and pulled out. Before pulling out the sleeve, it was necessary to check that there was no bone cement in the sleeve in order to prevent any bone cement from being left behind in the soft tissue (Fig. 2). The patients were required to stay in bed for 24 h after the operation, and to carry out muscle contraction training and joint activity training in bed to prevent deep vein thrombosis. At 6 months after the surgery, the patients were prescribed oral risedronate sodium for anti-osteoporosis treatment.

Clinical and radiographic assessments. The number of X-ray fluoroscopy examinations during operation (the total times of fluoroscopy during surgery plus those when puncturing with the positioning tube), the duration of surgery (from positioning the syringe needle to pulling out the working channel following solidification of the cement), complications (vascular nerve injury, pulmonary embolism, cement insertion syndrome and cement leakage) and the distribution of cement were recorded. In addition, 24 h after the surgery, the curative effect was evaluated using the lumbar MacNab standard (10). The visual analog scale (VAS) score (11) and Oswestry disability index (ODI) (12) of lumbar pain were compared before the procedure, 24 h after surgery and at the last follow-up after the surgery. The height and cobb angle of the anterior edge of the injured vertebra were measured by the hospital imaging system before and after surgery using X-ray lateral films and compared.

Table I. Characteristics of the study patients.

Characteristics	Patients
Sex (males/females), n	22/46
Age, years	70.06±5.58
Follow-up duration, months	15.41±3.74
Vertebral segment, n	
Total	92
T12	28
L1	36
L2	16
L3	5
L4	5
L5	2

Vertebral segments from 68 patients, where 44 patients had single segments and 24 patients had double segments.

Statistical analyses. Statistical analysis was performed using SPSS 22.0 software (IBM Corp.). Data that adhered to a normal distribution are presented as the mean ± standard deviation. Data were analyzed using repeated measures of analysis of variance (ANOVA) followed by Bonferroni's correction. P<0.05 was considered to indicate a statistically significant difference.

Results

Surgical findings and follow-up. A total of 92 vertebral body operations in 68 patients were successfully completed. The average duration of surgery was 37.69±6.91 min (range, 26-55 min). The total number of X-ray fluoroscopy examinations performed during the surgery was 18.37±4.35 (range, 12-28). Bone cement leakage occurred in 23 vertebral bodies, including 15 cases where leakage was to the side or front of the vertebral body, seven cases where leakage to the upper intervertebral disc occurred, and 1 case of leakage to the posterior wall of the vertebral body. The 68 patients were followed up for a mean duration of 15.41±3.74 months (range, 8-23 months). No complications, such as vascular nerve injury, pulmonary embolism or bone cement implantation syndrome, occurred in any of the patients. The anteroposterior X-ray images showed that the bone cement was distributed in the form of a central aggregate mass in 60 vertebral bodies, a unilateral aggregate mass in 21 vertebral bodies, and a diffuse honeycomb in 11 vertebral bodies. The mean injected cement volume was 5.5±1.0 ml. Compared with preoperative values, the average Cobb angle and anterior vertebral height were significantly improved (P<0.05). The mean Cobb angle decreased from 17.69±4.13˚ before surgery to 10.68±2.35˚ 24 h post-operatively. At the final follow-up, the mean Cobb angle was 12.61±4.52˚. The anterior height of the vertebral body increased from 19.05±4.62 mm before surgery to 22.34±2.57 mm 24 h after the surgery. At the final follow-up, the height of the anterior vertebral body was 20.91±2.07 mm. Statistically significant differences in kyphosis correction and vertebral height recovery were detected between preoperative and postoperative time points (P<0.05; Table II).

Therapeutic effect. The therapeutic effect was evaluated by the lumbar MacNab standard 24 h after the operation, and was found to be excellent in 54 cases, good in 10 cases and fair in 4 cases. The 4 cases whose curative effect was evaluated as fair all had a clear history of trauma, and all had obvious lumbar fascia edema on preoperative magnetic resonance T2-weighted images. After these 4 cases were given oral non-steroidal analgesic drugs to assist with acupuncture and physiotherapy, their lower back pain was improved and they were able to get out of bed freely.

Effect on VAS scores and ODI values. The back pain of the patients was significantly ameliorated after the surgery, and the self-care ability and quality of life of the patients was also improved (Table II). The mean VAS score was 8.08±0.79 prior to surgery, and decreased to 2.25±0.71 24 h post-operatively. At the final follow-up, the VAS score remained low at 1.58±0.51. The differences in the VAS scores of lumbar pain before and after surgery were statistically significant (F=1,875.36, P<0.05), and the VAS score of lumbar pain 24 h post-operatively was significantly lower than the average pre-operative VAS score (t=45.15, P<0.05). In addition, the VAS score of pain at the last follow-up after surgery was significantly lower compared with that at 24 h after surgery (t=6.33, P<0.05). The average pre-operative ODI was 67.75±7.91; at 24 h post-surgery, it dropped to 19.74±2.90, and at the last follow-up it was 28.00±4.89. The ODI values before and after surgery were statistically significantly different (F=1,417.33, P<0.05). The ODI value 24 h post-surgery was significantly lower than that before surgery (t=46.98, P<0.05), and the ODI index at the last follow-up after surgery was higher than that 24 h after the procedure (t=-11.92, P<0.05). The patients included 8 cases who developed fresh compression fractures in other vertebral bodies during the follow-up.

Discussion

The present study indicates that the unilateral PVP technique is safe and effective in the treatment of osteoporotic compression fractures. Traditional internal fixation surgery for spinal fractures presents drawbacks such as extensive trauma and prolonged recovery time (13). However, the emergence of minimally invasive spinal surgery technology has led to the widespread clinical use of PVP (14,15). This technique has been shown to be effective in achieving improved analgesia and increased vertebral body strength, as is widely acknowledged in the field (16,17). PVP stabilizes the fractured vertebral body and reduces the pain caused by vertebral fracture edema. This promotes patient recovery and reduces the incidence of chronic non-healing pain. Unilateral or bilateral pedicle puncture PVP is a key procedure performed by spinal surgeons (18). A previous study demonstrated the safety and minimal invasiveness of unilateral puncture PVP, which results in reduced soft-tissue damage and good cement distribution compared with bilateral PVP (19). It has been observed that there is no significant difference in pain relief between unilateral and bilateral puncture PVP (20).

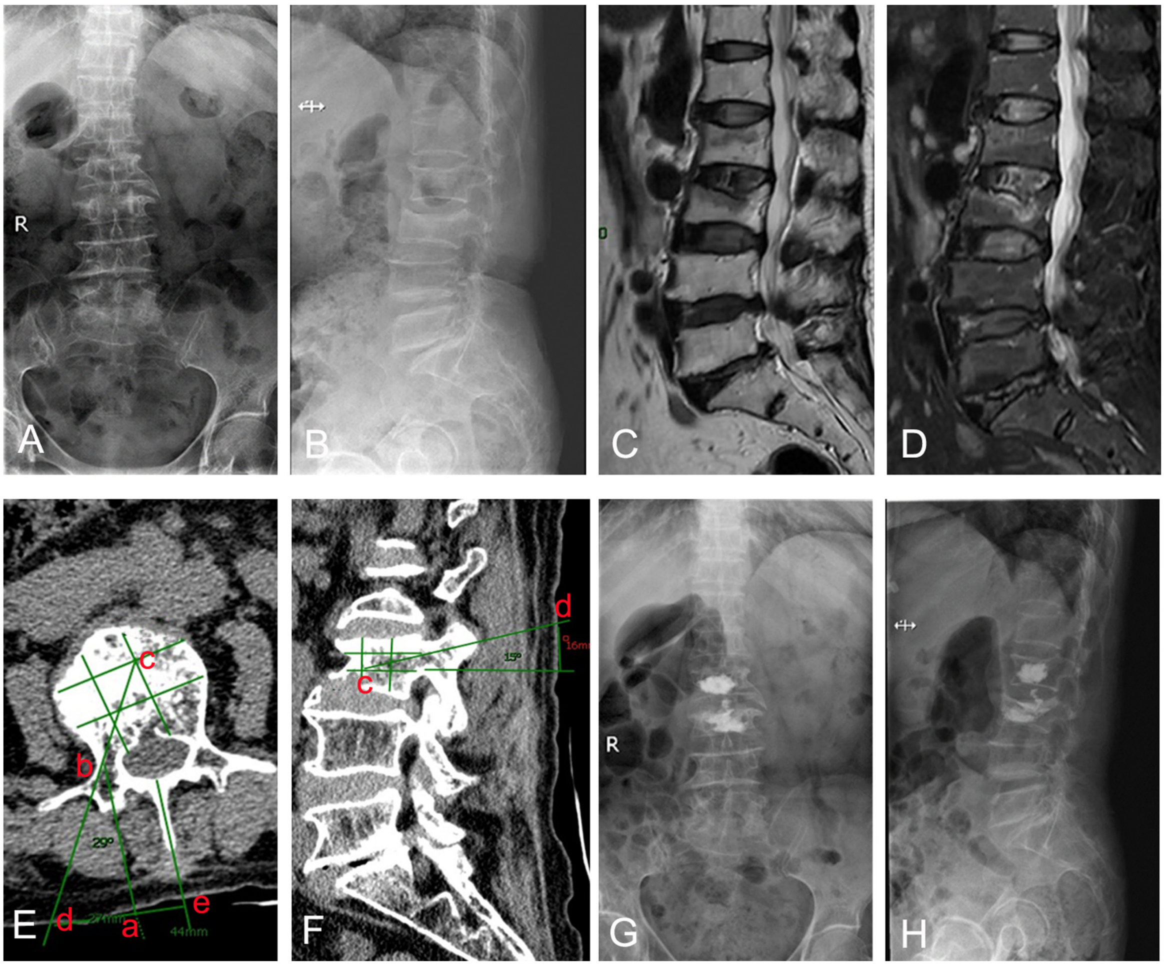

Figure 1. Pre- and post-operative imaging from the same patient. (A) Orthopantomogram of the preoperative X-ray image, (B) X-ray image in lateral position. (C) T1 sequence and (D) T2 sequence of the magnetic resonance imaging. The L2 and L3 vertebrae have abnormal signals on magnetic resonance as manifestations of new fractures. Skin entry points were determined from preoperative (E) axial and (F) sagittal images at the target level. Point c is the target puncture point; point b is the lateral margin of the superior articular eminence; point d is the skin entry point for unilateral abduction of the PVP; point a is the lateral margin of the pedicle root to the body projection point; and point e is the center of the spinous process to the body projection point. (G) Orthopantomogram of the post-surgical X-ray images. (H) Lateral X-ray image after surgery.

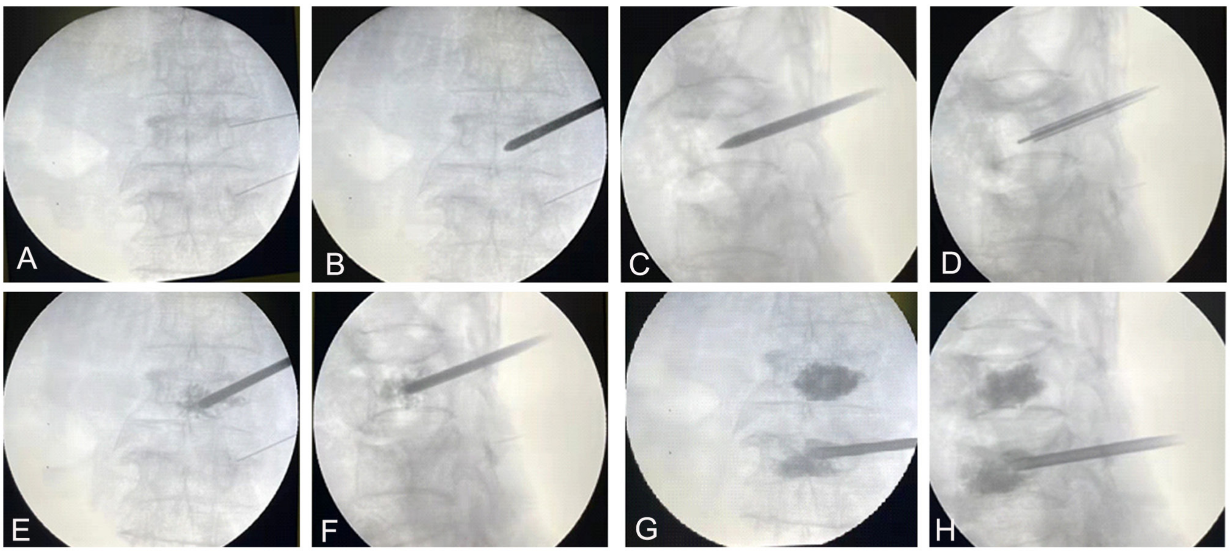

Figure 2. Anteroposterior and lateral views of the trajectory of the needle as it is inserted into the vertebral body via a unilateral extrapedicular puncture. (A) The vertebral body. (B) A long syringe needle is used to locate the puncture point. (C) The distal end of the fluoroscopic orthotopic puncture reaches the level of the vertebral midline, which is close to the preoperatively planned point. (D) The Kirschner needle is advanced to probe around the channel for bony structures. (E and F) Bone cement (0.5-1 ml) is injected and observed for leakage. (G and H) The position of the cement cannula is adjusted according to the dispersion of cement during the surgery.

Table II. Comparisons of preoperative, postoperative and final follow-up clinical parameters.

Parameters	Preoperative	24 h after surgery	Final follow-up	F-value	P-value
VAS (n1)	8.08±0.79	2.25±0.71[a]	1.58±0.51[b]	1,875.36	<0.001
ODI, % (n1)	67.75±7.91	19.74±2.90[a]	28.00±4.89[b]	1,417.33	<0.001
AVH, mm (n2)	19.05±4.62	22.34±2.57[a]	20.91±2.07[b]	23.51	<0.001
Cobb angle, ˚ (n1)	17.69±4.13	10.68±2.35[a]	12.61±4.52[b]	62.20	<0.001

Data were analyzed using repeated measures ANOVA followed by Bonferroni's correction. [a]P<0.05 vs. preoperative; [b]P<0.05 vs. 24 h after surgery. VAS, visual analog scale; ODI, Oswestry disability index; AVH, anterior vertical height; n1, 68 total patients; n2, 92 total vertebrae.

However, it has been suggested that to diffuse the cement bilaterally during unilateral vertebroplasty, the angle of puncture adduction must be increased so that the tip of the puncture needle is positioned near to the contralateral side of the vertebral body. This approach, however, also heightens the risk of cement leakage and peripheral vascular and neurological injuries (21). Li *et al* (22) discovered that the implementation of 3D-printed navigation templates during PVP resulted in significantly lower intraoperative puncture positioning times and reduced the requirement for X-ray fluoroscopies compared with that in cases where freehand positioning was used. Although the navigation templates were found to be effective, they were prone to inaccuracies caused by skin deformation and changes in body position. The use of modified surgical instruments with directional pins for unilateral PVP has been shown to provide very good results without increased clinical risk (23). However, the drawbacks include a steeper learning curve and the intraoperative procedure being more complex. Complications associated with PVP are mainly associated with the surgical puncture technique and the injected bone cement. Reported perioperative complications predominantly comprise injuries to the spinal cord and nerve roots, pulmonary embolism, cement leakage and cement implantation syndrome (24-28). Spinal cord and nerve root injuries can be classified into two categories. The first category is caused by puncture and may be associated with the level of experience of the surgeon and inadequate monitoring during surgery. The second category is cement-related injury, which can result from the site of puncture access being too close to the spinal cord, resulting in local compression injuries and thermal damage. It is important to note that these two categories of injury can have severe consequences and should be prevented whenever possible. This may be achieved by carefully studying the imaging data to gain a full understanding of the clinical signs of the patient. Segments with lesions such as partial destruction of the posterior edge of the vertebral body, vertebral body collapse, endplate rupture, and pedicle erosion and destruction should be carefully selected. Any abnormal sensations in the lower extremities and changes in the patient's complaints about pain and numbness that occur during the puncture should be fully considered and carefully managed. It is also important for the surgeon to master the surgical techniques correctly. In particular, the puncture technique and the quality of imaging surveillance should be optimized. In severely compressed and deformed vertebrae, the puncture point and route are particularly individualized, and the experience of the operator is very important.

In the present study, it was found that thorough and diffuse distribution of the cement was obtained by the use of CT and the division of the vertebral body into nine equal parts, with puncture along the superior articular process-vertebral pedicle or the lateral aspect of the superior articular process-vertebral pedicle only to the anterolateral zone close to point c or directly to point c. This has the following advantages: i) Improved safety of the procedure. The abduction angle of the puncture device in the transverse plane and the cephalic tilt angle in the sagittal plane can be determined prior to surgery. With regard to the method of lumbar pedicle nailing during open surgery, if the lateral aspect of the base of the upper articular process is chosen as the insertion point during surgery, accurate puncture is generally possible. Intraoperatively, it is usually possible for the lateral aspect of the base of the superior articular process to be accurately identified as the final entry point as long as it is possible to detect a sense of 'slippage' from the lateral aspect of the synchondrosis and to explore the transverse process. The 68 patients in the present study had no evidence of spinal cord or nerve root injury and were safely treated. ii) High satisfaction rate of bone cement morphology. When the puncture breaks through the midline of the spinous process on the fluoroscopic orthopantomogram and reaches the anterior contralateral third of the vertebral body on the lateral X-ray, the cement is slowly pushed into the vertebral body. When injecting bone cement, the distribution of cement can be adjusted by varying the depth of the channel cannula of the bone cement injection device. Postoperative orthopantomograms of the 92 vertebrae showed the cement was present as centrally aggregated masses in 60 vertebrae, unilaterally aggregated masses in 21 vertebrae, and dispersed honeycombs in 11 vertebrae. iii) It can effectively reduce the pain felt by the patient. The procedure creates only one 0.5-mm diameter puncture wound, and uses a number of preoperatively planned puncture points and puncture paths with the aim of achieving the correct needle placement in order to avoid repeated multi-point puncturing, which would destroy the integrity of the vertebral body. The mean VAS score decreased from 8.08±0.79 preoperatively to 2.25±0.71 postoperatively and was reduced further to 1.58±0.51 at the final follow-up appointment. The mean ODI improved from 67.75±7.91 preoperatively to 19.74±2.90 postoperatively, and remained low at 28.00±4.89 until the final follow-up. iv) It is easy to use. The procedure can be performed by a single person, and involves the one-sided injection of bone cement, which shortens the injection time and reduces the waste of bone cement that hardens too quickly to be used.

The goal of PVP is to increase vertebral stability by restoring or increasing the strength of the vertebral body, and overfilling results in suboptimal biomechanics (29,30). In addition, the greater the injection volume, the greater the risk of leakage (31). In the present study, the mean volume of cement injected was 5.5±1.0 ml, which is very small, but good efficacy was achieved in all cases. To prevent leakage to the anterior side, the tissue anterior to the trocar can be gently touched with a probe to determine whether it is a bony structure or not; if it is a hollow or ductile structure, a small gelatin sponge can be applied before the cement is injected. If a leak is observed that is not posterior to the vertebral body, it can be observed for 30 sec, and then re-injection of the cement can be attempted while the first injected bone cement continues to polymerize and solidify, sealing the leak, or the procedure can be terminated. It is essential that the viscosity of the bone cement is appropriate, the injection pressure is not too high, and the whole process is monitored by X-ray. If it is found that the bone cement is spreading rapidly with venous return or leaking into the epidural or intervertebral foramen, injection of the cement must be stopped immediately and the viscosity increased slightly prior to continuing the injection. Intravertebral leakage often has terrible consequences; therefore, if it occurs, the injection of cement should be stopped completely, and a CT scan should be performed if possible, to clarify the degree of loading. In addition, the neurological function of the patient should be closely monitored. For patients with severe destruction of vertebral cortical bone confirmed by preoperative examination, it is preferable to use a higher viscosity injection agent. The viscosity of the bone cement is important, as if it is too thin it will easily leak, while if it is too thick it will be difficult to inject.

In addressing the occurrence of new fractures post-vertebroplasty, it is critical to explore preventative measures and management strategies. The aim of preventative approaches is to mitigate the risk factors associated with new fractures. This includes optimizing bone density through the management of osteoporosis, which is of utmost importance (32). Moreover, lifestyle modifications such as weight-bearing exercises and fall prevention strategies are essential components of a comprehensive prevention plan (33). In terms of management, the early identification and treatment of new fractures are crucial. The literature suggests a multidisciplinary approach that encompasses pain management, physical therapy and, where appropriate, surgical intervention (34). It is also important to consider the role of the distribution of cement in the vertebral body and the precision of fracture repositioning during the initial treatment, as these factors can influence the likelihood of subsequent fractures. Furthermore, for patients presenting with mild symptoms post-re-fracture, non-surgical management involving rest, medication and careful monitoring may be sufficient, as suggested by Clark *et al* (35). By contrast, for cases with severe complications, such as progressive kyphosis or neurological deficit, revision surgery should be considered, as indicated in the American Academy of Orthopedic Surgeons Clinical Practice Guidelines reported by McGuire (36). Ultimately, a tailored approach based on individual patient factors, including the severity of osteoporosis, the extent of the initial fracture and the overall health status of the patient is important to inform the prevention and management strategies for post-treatment fractures.

However, the present study has certain limitations. Firstly, it was a retrospective study and did not use bilateral vertebroplasty as a control. Although good clinical results were achieved, the sample size was small, and a prospective randomized controlled trial with a large sample size is required to further validate the clinical efficacy of the method. Secondly, there were 21 vertebral bodies with unilateral bone cement distribution in the present study with a short follow-up period, and it is not clear whether the uncemented side would become recompressed, leading to worsening recurrent pain. While the current study effectively demonstrates the short-term efficacy of unilateral PVP in alleviating pain and disability, it is important to note as a limitation the absence of long-term outcome data, specifically regarding the risk of secondary fractures post-procedure. Future research with extended follow-up is essential to elucidate the potential long-term implications and to develop comprehensive strategies for the prevention and management of new fractures in this patient population.

In conclusion, the findings of the present study support the use of unilateral PVP in the treatment of acute osteoporotic vertebral compression fractures. By optimizing the puncture angle in the unilateral puncture PVP procedure, the potential harm to essential structures as well as cement leakage and associated risks are reduced. The outcomes were positive, irrespective of the cement distribution pattern, with no notable variance in patient prognosis.

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Availability of data and materials

The data generated in the present study may be requested from the corresponding author.

Authors' contributions

DS wrote the manuscript. XL, FH and GW analyzed and interpreted the patient data. DS and ZL made substantial contributions to the conception, design and intellectual content of the study. DS and ZL confirm the authenticity of all the raw data. All authors read and approved the final version of the manuscript.

Ethics approval and consent to participate

The study was conducted in accordance with the Declaration of Helsinki. All participants signed an informed consent form. This study was approved by the Ethics Committee of People's Liberation Army Hospital No. 923 Support Force (approval no. 923LL-KY-2023LW-012-01; Nanning, China).

Patient consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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