# Unilateral Percutaneous Vertebroplasty For Osteoporotic Lumbar Compression Fractures: A Comparative Study Between Transverse Process Root-Pedicle Approach And Conventional Transpedicular Approach

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# Abstract

**Purpose:** Percutaneous Vertebroplasty (PVP) is a routine operation for the treatment of osteoporotic lumbar compression fracture (OLCF). Because of bilateral puncture takes a long operation time and patients receive more X-ray irradiation, more and more scholars deem that the unilateral approach should be adopted. But, with conventional transpedicular approach (CTPA), the cement may asymmetrically dispersed, so some surgeons use the transverse process root-pedicle approach (TPRPA). The objective of this study is to compare the clinical results and bone cement distribution of PVP for OLCF with unilateral TPRPA and CTPA, determine the advantages and disadvantages of the two surgical options.

**Patients and methods:** From January 2016 to June 2019, seventy-two elderly patients who underwent unilateral PVP for single-level OLCF were retrospectively reviewed. Operation time, injection amount and distribution type of bone cement, and bone cement leakage and surgical complication were recorded. The visual analogue scale (VAS) scores and Oswestry disability index (ODI) scores were used to evaluate the clinical results. All patients were followed up for at more than 12 months and the assessment was based primarily on clinical and radiological outcomes.

**Results:** There were significant difference in the surgical time, the volume and distribution type of bone cement between the two groups. But, there was no statistical difference in bone cement leakage. Moreover, there were no significant differences in VAS and ODI between the two groups at 2 days and 12 months after operation.

**Conclusion:** Unilateral TPRPA and CTPA are practical and feasible methods in PVP for treatment of OLCF, with similar clinical effects. However, TPRPA has the advantages of fair distribution of bone cement and short operation time, without increasing the rate of bone cement leakage.


# Introduction

Osteoporotic lumbar compression fracture (OLCF) is the most common form of clinical osteoporosis complications. The pain caused by the fracture significantly affects the patient's quality of life [1]. Percutaneous Vertebroplasty (PVP) is widely used to treat such fracture, which can rapidly maintain the strength of the injured vertebral body, effectively relieve pain, and improve the quality of life of patients [2, 3].

The bone cement injection through bilateral pedicle approach is a common method, which has a definite therapeutic effect and can also create symmetrical distribution of bone cement [4]. However, bilateral puncture requires more operative time and more X-ray exposure. In recent years, most studies indicate that unilateral puncture is equivalent to bilateral puncture PVP [5, 6].Conventional transpedicular approach (CTPA) is the most commonly used puncture route. However, there was concern about the asymmetric diffusion of bone cement in the vertebral body by CTPA.

Some studies [7, 8] on anatomy and imaging have shown that extrapedicular and transverse process root-pedicle approach (TPRPA) can be used for PVP, but the individual and level selection is required. TPRPA is penetrated into the pedicle through the root of transverse process and lateral part of the pedicle, which allows for greater abduction angle and safer relatively [8]. To the best of our knowledge, although TPRPA has been used by some surgeons, but no published literature on clinical results has included comparative study between TPRPA and CTPA. The objective of this study was to compare and analyse the clinical effect of PVP for OLCF with unilateral TPRPA and CTPA, determine the advantages and disadvantages of the two surgical options.

# Material And Methods

### General Information

We performed a retrospective analysis of patients suffering single-level OLCF treated with unilateral PVP from January 2016 to June 2019. According to the follow criteria, seventy-two patients were included in this study. Inclusion criteria included:  age of 65 years or older;  T score $< -2.5$ in bone mineral density (BMD) examination of lumbar vertebral;  a single-level fracture in the lumbar vertebra (L1-L5);  preoperative collapse exceeded 15% of the height of the injured vertebra, but not more than two-thirds;  preoperative pain was over 5, measured by visual analogue score (VAS);  bisphosphonates were used for anti-osteoporosis therapy after surgery. Exclusion criteria:  the fracture due to osteoporosis;  failure to obtained informed consent;  the patient got coagulopathy;  pathological fracture caused by tumour or spine infection;  there was a symptomatic nerve damage;  patients with incomplete data. Patients were assigned to the TPRPA group (38 cases) and the CTPA group (34 cases).

### Surgical Procedure

### TPRPA group

All the PVP procedures were performed by two senior orthopedic surgeons (Wenwu Zhang and Shenpeng Liu ) skilled in such surgery. Patients were placed in the prone position, and two soft pillows under the chest and pelvis made the abdomen vacant to reduced the abdominal compression; Then, manipulative reduction was performed to restore the height of the injured vertebra as much as possible. The target vertebral body was observed by C-arm X-ray machine and marked the body surface and skin puncture point after fluoroscopy. Local infiltration of 1% lidocaine for anesthesia, from skin puncture point gradually deep into the periosteum around the junction of the pedicle and transverse process root. When anaesthesia was sufficient, a 0.5 cm incision was made at the skin puncture point and unilateral transverse process root–pedicle approach was adopted. Fluoroscopy determined that the junction between the lateral edge of the pedicles and transverse process root was the entry point of the vertebra body [Figure 1](Note: All the figures titles and legends are at the end of the file). The core puncture needle was inserted into the pedicle through the root of the transverse process under C-arm X-ray machine surveillance. The tilt angle of puncture needle or tail was adjusted according to intraoperative fluoroscopy and angle measured by CT preoperative. when the tip reached the posterior margin of the vertebral body, the point did not break through the medial wall of the pedicle under anteroposterior position and lateral fluoroscopy, and then continued to punctured to the first third of the vertebral body. Patients were closely observed during the operation. Frequent fluoroscopy was required during the injection of bone cement, and the injection of bone cement was stopped when posterior third of the vertebral body was filled with bone cement or when bone cement leakage occurred [Figure 2]. All injection components were removed after the injection of bone cement, and the incision was sutured. All patients stayed in bed for 6 hours and resumed their activities the next day. Bisphosphonates were routinely used for anti-osteoporosis therapy on the second day after surgery.

### CTPA group

The difference in insertion point was the main difference between the two groups; details can refer to Fig. 1. Postoperative anti-osteoporosis treatment were the same as TPRPA group.

### Outcome Measures

The operation time, bone cement leakage, injection amount and distribution types of bone cement were recorded for each patient. The clinical assessments were evaluated by using the VAS and ODI preoperatively and at 2 days and 12 months postoperatively. Postoperative X-ray films were completed in all patients, and CT was further improved for suspected bone cement leakage. The distribution of bone cement was divided into two types, according to radiographs. Type 1(T1): bone cement contacted both upper and lower endplates. Type 2(T2): bone cement missed at least one endplate. Detailed typing items could refer to previous literature [9].

### Statistical Assessments

All statistical analyses were performed with the SPSS software, version 22 (IBM, Armonk, USA). The paired t-tests were used to compare pre- and postoperative variables outcome scores. Difference in cement leakage rate and fracture site composition ratio of 2 groups were assessed using $\chi 2$ test, but the latter used a union treatment because of some values were less than 5. $P < 0.05$ was considered to have statistical significance.

## Results

### Preoperative Demographic Characteristics and Outcomes

The operations of both groups were completed successfully. All patients were followed at least 12 months. No complications such as nerve damage or pedicle fracture occurred in all patients except bone cement leakage. No recurrent fractures occurred during 12 months of follow-up. In baseline data of patients, no significant difference was found between the two groups (Table 1). Typical case was shown in Fig. 3.

### Intraoperative Measurement

The average operation time and the volume of the injected cement in TPRPA group and CTPA group, a statistically significant difference were found between the two groups ($P < 0.05$). The operation time in the TPRPA group were significantly shorter than those in the CTPA group, and the bone cement injection amount were more. (Table 2).

### Clinical Results

There was no statistically significant differences in VAS and ODI between the two groups. Scores of both groups were reduced after PVP, and there was no statistically significant difference between the two groups at 2 days and 12 months after PVP. (Table 3).

Table 1
Comparison of baseline data between group TPRPA and group CTPA

| | **Group TPRPA** | **Group CTPA** | **Statistics** | ***p*** |
|---|---|---|---|---|
| Year | 73.13 ± 7.15 | 72.35 ± 6.99 | $t = 0.466$ | 0.643 |
| Gender(M/F) | 15/23 | 14/20 | $\chi2 = 0.220$ | 0.883 |
| Body mass(kg) | 73.53 ± 5.94 | 74.56 ± 5.00 | $t$=-0.793 | 0.431 |
| Height(cm) | 167.37 ± 8.32 | 167.97 ± 5.76 | $t$=-0.353 | 0.725 |
| OLCF level | | | | |
| L1 | 20 | 18 | $\chi2 = 0.001$ | 0.979 |
| L2 | 9 | 7 | | |
| L3 | 5 | 6 | | |
| L4 | 3 | 2 | | |
| L5 | 1 | 1 | | |

Table 2
Comparison of two groups of the surgical time and bone cement injection volume

| | **Operation time (mins)** | **Bone cement volume (ml)** |
|---|---|---|
| Group TPRPA | 50.53 ± 8.45 | 5.54 ± 0.72 |
| Group CTPA | 60.88 ± 11.96 | 4.62 ± 0.86 |
| Statistics | $t$=-4.277 | $t = 4.941$ |
| $P$ | 0.000 | 0.000 |

### Radiological Results

In term of bone cement leakage rate, there was no significant difference between the two groups($P$ > 0.05). but, there was a statistical difference in the distribution of bone cement between the two groups. In group TPRPA, 8 cases(21.05%) had cement leakage, 26 cases (68.42%) belonged to Type 1. While in the CTPA group, 11 cases (32.35%) had cement leakage, and 15 cases (44.12%) belonged to Type 2 (Table 3).

Table 3
Comparison of postoperative VAS, ODI, bone cement leakage and distribution types between two groups

| | Group TPRPA | Group CTPA | Statistics | $P$ |
|---|---|---|---|---|
| VAS | | | | |
| Preoperative | 5.79 ± 0.70 | 5.82 ± 0.67 | $t$=-0.209 | 0.835 |
| Postoperative 2 days | 2.79 ± 0.96 | 2.59 ± 0.99 | $t$ = 0.874 | 0.385 |
| Postoperative 12 months | 0.92 ± 0.85 | 0.94 ± 0.85 | $t$=-0.100 | 0.920 |
| ODI | | | | |
| Preoperative | 79.30 ± 10.40 | 78.04 ± 9.80 | $t$ = 0.527 | 0.600 |
| Postoperative 2 days | 35.26 ± 3.53 | 35.21 ± 3.28 | $t$ = 0.064 | 0.949 |
| Postoperative 12 months | 16.45 ± 5.89 | 16.47 ± 5.84 | $t$=-0.017 | 0.987 |
| Bone cement leakage | 8(21.05%) | 11(32.35%) | $\chi2$ = 1.180 | 0.277 |
| Distribution types | | | | |
| T1 | 26 (68.42%) | 15(44.12%) | $\chi2$ = 4.323 | 0.038 |
| T2 | 12 | 19 | | |

# Discussion

The puncture route of PVP mainly includes conventional transpedicular approach, extrapedicular approach and transtransverse process root-pedicle approach. Whether to perform unilateral or bilateral puncture for PVP remains controversial, but unilateral approaches is gradually accepted due to less surgery time, radiation dosage compared to bilateral approaches [10, 11]. The Conventional unilateral transpedicular approach is a common and safe puncture route for PVP and PKP, and it has been used in clinical practice for decades. However, numerous associated complications and problems will still been reported, such as puncture difficulty, pedicle fracture, cement leakage, and cement distribution [12, 13].

Therefore, some scholars have used the extrapedicular approach and TPRPA in clinical practice, but extrapedicular approach is mainly used in cases with mid-thoracic vertebra or thin pedicle due to the risk of vascular injury [14–18]. Yan L, et, al. reported TPRPA is a relatively safe and effective approach with less radiation dosage and shorter surgical time [19, 20]. In this study, although no specific comparative analysis was conducted on the number and time of X-ray fluoroscopy between the two groups, the total surgical time of the TPRPA group was shorter than that of the CTPA group. As we know, PVP surgery requires frequent X-ray fluoroscopy throughout the whole process, so we can conclude that the number of X-ray fluoroscopy in the TPRPA group is lower than that in the CTPA group. Of course, this result requires the establishment of the above indicators for rigorous comparative analysis. All patients in the TPRPA group had no intraoperative pedicle fracture or difficulty in puncture, so we also believed that this technique was safe and reliable when applied to the lumbar spine, which was basically consistent with previous studies.

VAS and ODI score are important indicators to evaluate pain degree and quality of life of patient. Therefore, it is commonly used for evaluating the clinical efficacy before and after treatment. In this study, we compared the clinical effectiveness between CTPA and TPRPA group, through VAS and ODI. Our study showed that postoperative pain symptoms were significantly relieved and quality of life was significantly improved. This results were embodied in the significant changes in VAS and ODI scores. The results support that both CTPA and TPRPA PVP were effective methods for OLCF. In addition, the injection amount of bone cement was different between the two groups, but there was no difference in a therapeutic effect, this result suggested that the clinical effect of PVP was independent of the cement volume.

To our knowledge, many scholars have studied the relationship between bone cement distribution patterns and bone cement leakage and therapeutic effect. Bin et al [21]. found that all cement distribution patterns can relieve pain and reduce spinal biological curvature, but extensive distribution of treated vertebrae has certain advantages in long-term pain relief. Lei et al [9]. proved that sufficient contact of bone cement with upper and lower endplates is an ideal distribution type, which can better maintain the height of the fracture vertebral and reduce the risk of long-term vertebral re-fracture of the vertebral body [22]. Therefore, lateral radiographs were used in this study to evaluate the distribution type of bone cement and compare the ratio of type 1 distribution between the two groups. However, several factors were found to influence the bone cement distribution during PVP procedures. Such as uneven bone density, fracture classification, injection techniques. In our opinion, injection technology is a factor that the surgeon can control. The puncture point of CTPA goes through the articular process and more close to the inner wall of the pedicle, extraversion angle is not enough. By contrast, the TPRPA puncture point is more lateral to the facet joint, with a larger extraversion angle, and is more likely to reach the optimal target position of the anterior and middle 1/3 of the vertebral body. In this study, compared with the CTPA group, TPRPA group had more bone cement injection amount and more type 1 distribution. This result indicated that the injection amount of bone cement was correlated with its distribution. We hold the point that in the absence of bone cement leakage, increasing the amount of bone cement injection can improve the injection pressure and promote the distribution of bone cement. However, the relevant conclusion needs to be further verified. We summary that TPRPA has following advantage: 1) Ideal target puncture, bone cement can diffuse to the anterior and contralateral vertebra; 2) Apply stratified injection technology, can inject more bone cement and obtain extensive distribution; 3) Use the root of the transverse process for positioning, with a clear structure, and bitter hand feel, easier to succeed and shorten operation time.

In this study, bone cement leakage in the two groups was 21.05%(8/38) and 32.35%(11/34) respectively, but the difference was not statistically significant. The results showed that increasing injection of bone cement could promote the distribution of bone cement, but did not increase the leakage rate of bone cement. However, It is not an ideal method to increase the excess volume of bone cement to obtain extensive distribution of bone cement. Because research based on laboratory biomechanics has found that when the amount of bone cement reaches about 15% of the vertebral body, the stiffness of the damaged vertebral body can be restored. If the amount of bone cement injected exceed this value, there is no obvious benefit, which may result in the asymmetric distribution of bone cement and excessive vertebral stiffness [23]. In addition, increasing the amount of bone cement may increase the risk of cement leakage [24, 25]. Although the exact relationship between the cement amount and cement leakage rate cannot be obtained in this study, we agree with the above viewpoints.

# Limitations

The study has some limitations: 1): Due to the strict inclusion criteria in our study, the number of patients was relatively small; 2): The classification of the distribution type of bone cement using lateral radiographs only, the fine structure was not clearly observed; 3): No indexes such as height recovery and late loss of operative vertebrate were added in this study, so the evaluation was not comprehensive.

# Conclusion

This study confirmed that both TPRPA and CTPA are effective and feasible used for PVP in the treatment of OLCF. Both methods achieved good clinical outcomes during 12 months of follow-up. However, bone cement was more widely distributed in the vertebral body through TPRPA, which took less operation time, without increasing the incidence of bone cement leakage.

# Abbreviations

PVP: Percutaneous Vertebroplasty; OLCF: Osteoporotic lumbar compression fracture; CTPA: Conventional transpedicular approach; TPRPA: Transverse process root-pedicle approach; VAS: Visual analogue scale; ODI: Oswestry disability index; BMD: Bone mineral density; CT: Computed tomography; MRI: Magnetic resonance imaging.

# Declarations

## Acknowledgements

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### Authors' contributions

WWZ, LW and YW conceived of the design of the study. WWZ and SPL performed the operations and the data collection. WWZ and XHL carried out statistical analysis. WWZ, LW and XL finished the manuscript. All authors read and approved the final manuscript.

### Availability of data and materials

All data are fully available without restriction.

### Ethics Approval and Informed Consent

This study was approved by the Ethics Committee of the Xinxiang Medical University Affiliated The First Hospital. Before operation, All patients were explained the treatment process in detail and signed the informed consent.

### Consent for publication

Not applicable.

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### Competing interests

The authors report no conflicts of interest in this work.

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# Figures

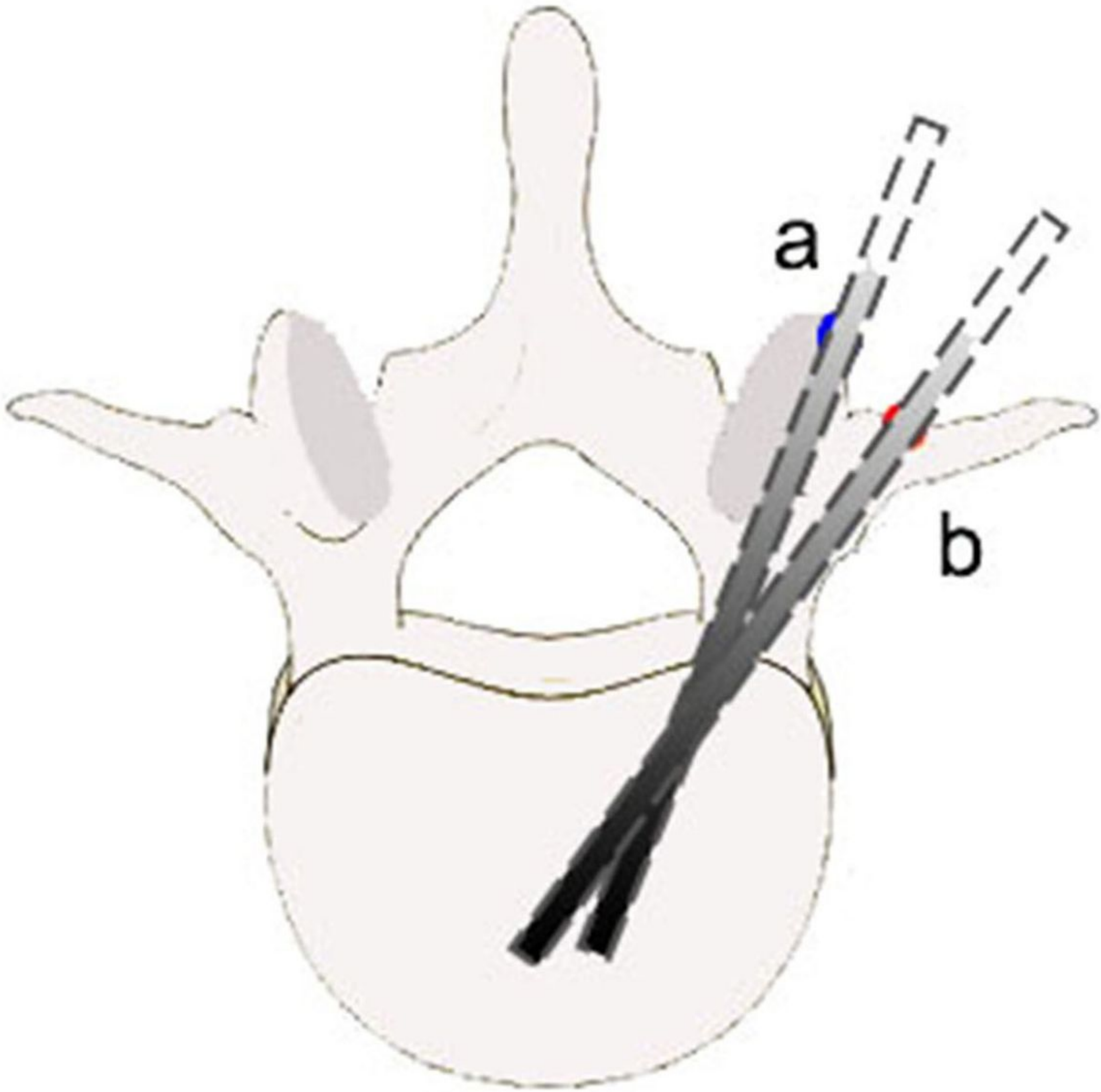
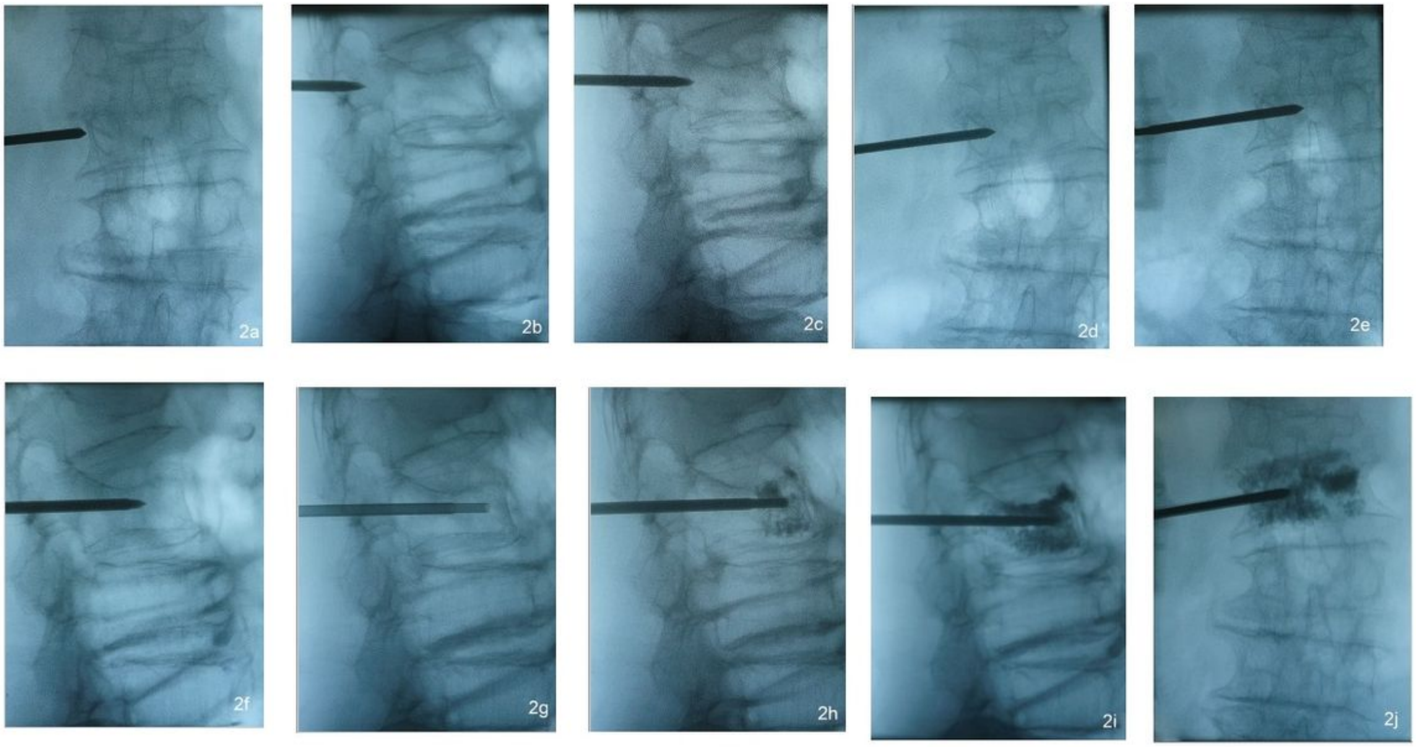


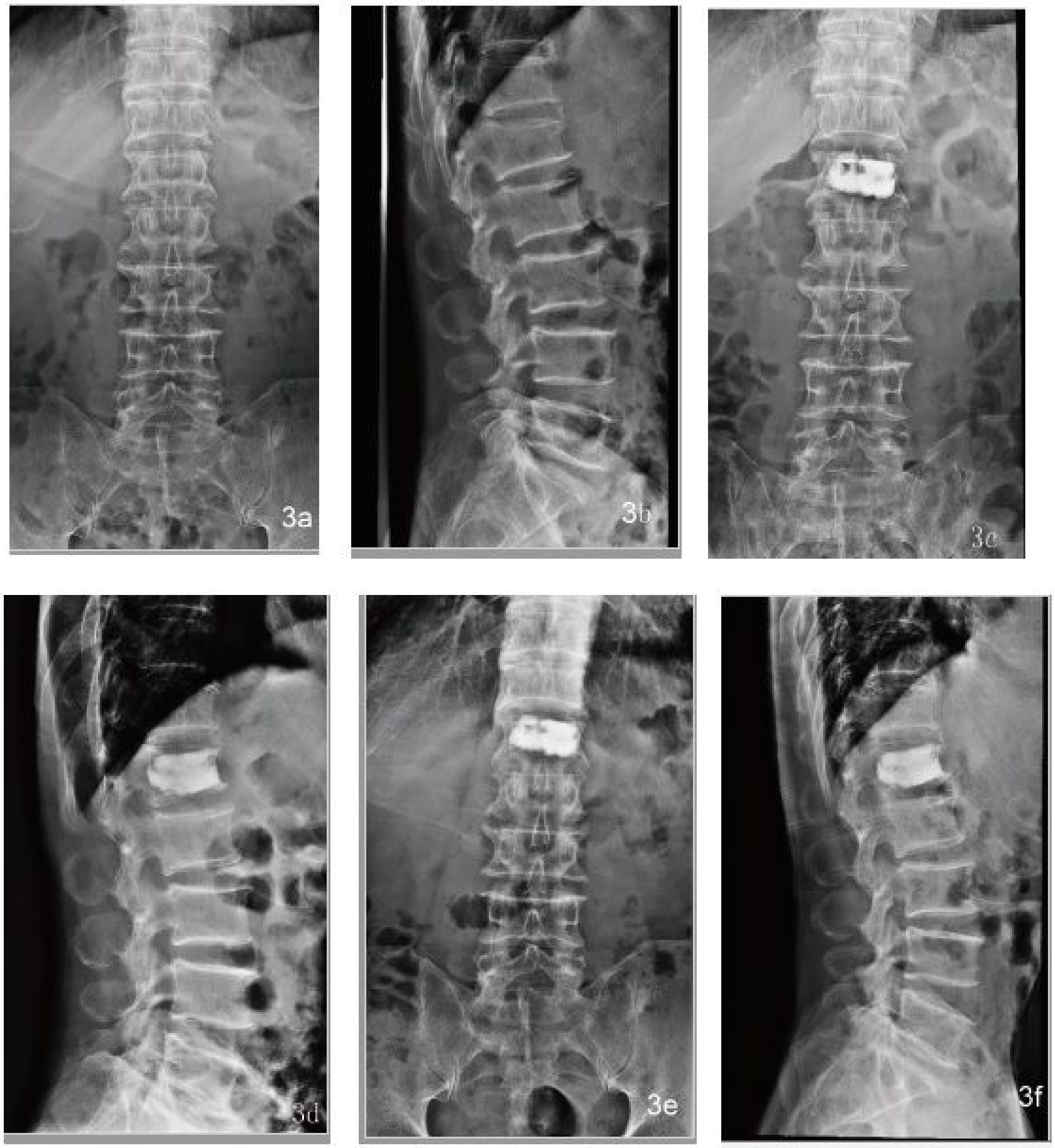

**Figure 1**

Schematic diagram of needle entry points of two methods. a CTPA group: the insertion point was located at the lateral facet of the articular process. b TPRPA group: the insertion point was located at the junction of the root of the transverse process and the pedicle.




## Figure 2

Intraoperative fluoroscopic images of the surgical procedure of the TPRPA PVP. a Posteroanterior fluoroscopy: the needle tip was located at the junction between the root of the transverse process and the pedicle. b Lateral fluoroscopy: the needle tip was approximately located one third posterior the pedicle. c, d Lateral and posteroanterior fluoroscopies: the cannula tip reached the posterior margin of the vertebral body and the inner wall of the pedicle. e, f Posteroanterior and lateral fluoroscopies; the needle tip reached the middle of the vertebral body. g, h Lateral fuoroscopies: the cannula reached the anterior part of the vertebral body and begun to inject bone cement. i, j Lateral and posteroanterior fluoroscopies: bone cement injection was complete.




## Figure 3

67-year-old man with L1 vertebra fracture treated with TPRPA PVP. a, b preoperative spinal column: L1 vertebral fracture. c, d 2 days postoperative, spinal column: the bone cement is symmetrically distributed and touches the upper and lower endplates. e, f 1 years after operation spinal column: the bone cement remains symmetrically distributed.