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Effect of percutaneous vertebroplasty through UTPP approach on prognosis and quality of life in elderly patients with osteoporotic vertebral compression fractures: a retrospective study

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Abstract

Background To explore the clinical characteristics of percutaneous vertebroplasty (PVP) via unilateral transverse process-pedicular (UTPP) approach in the treatment of osteoporotic vertebral compression fracture (OVCF) in the elderly.

Methods A total of 120 elderly patients with lumbar OVCF who underwent PVP via unilateral pedicular (UTP) and UTPP approaches in our hospital from January 2022 to January 2024 were retrospectively analyzed. The postoperative VAS score (visual analog scale), ODI score (Oswestry disability index), surgical indicators, and imaging indicators were recorded in the two groups.

Results The VAS scores and ODI scores of the two groups of patients were lower than those before surgery 1 day, 6 months, and 12 months after surgery ($P < 0.05$). The amount of bone cement (BC) injected in the UTPP group was greater than that in the UTP group, the excellent BC distribution rate was higher than that in the UTP group, and the BC leakage rate was lower than that in the UTP group (all $P < 0.05$). The vertebral anterior edge height and Cobb angle of the UTPP group were significantly different from those of the UTP group 1 day after surgery ($P < 0.05$).

Conclusions After UTPP-PVP, BC is fully diffused, the BC leakage rate is low, and the analgesic effect is good, which can enable patients to get out of bed early and improve their quality of life.

Keywords Unilateral transverse process-pedicular, Osteoporotic vertebral compression fracture, Percutaneous vertebroplasty

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Background

With the aging of the population and increasing health requirements, osteoporosis (OP) has attracted more and more attention from society. OP is a systemic bone disease feature by reduced bone density, and destruction of trabecular bone microstructure, which can easily lead to fragility fractures [1]. Research shows that the prevalence of OP in my country is increasing significantly, and elderly women are the main affected population [2, 3]. The incidence of OP-related fractures in the elderly is as high as 30%, among which osteoporotic thoracolumbar fractures in the elderly are regarded as a symbol of the decline of physical functions in the elderly [4]. Osteoporotic fracture is a serious complication of osteoporosis, and some studies predict that the number of cases will increase to nearly 6 million per year in my country by 2040 [5]. Osteoporotic vertebral compression fractures (OVCF) can not only cause patients with low back pain and affect their daily lives, but some patients with long-term chronic pain may also experience mental abnormalities, such as depression and anxiety [6]. Osteoporotic thoracolumbar fractures in the elderly account for more than 90% of spinal fractures and their clinical treatments are divided into three categories: conservative treatment, traditional surgical treatment, and minimally invasive surgical treatment.

The main principle of percutaneous vertebroplasty (PVP) is to use imaging technology to guide the puncture needle into the injured vertebral body (VB) through the pedicle. Polymethylmethacrylate (PMMA) is then injected to strengthen the VB, thereby relieving pain and promoting early ambulation for the patient. PVP technology was first used to treat compression fractures [7, 8] and has now become one of the main methods for treating compression fractures. Currently, there are three main methods of PVP puncture technology, including unilateral puncture, bilateral puncture, and transverse process root puncture. Each method has its advantages and disadvantages, and there are currently no uniform selection criteria. Unilateral puncture is quick, simple, and reduces radiation but may cause uneven VB stress. However, it has shortcomings such as long operation time, high radiation exposure, and BC blocking each other during injection. Transverse process root puncture offers a larger needle angle, even BC distribution, and reduced facet joint damage but may harm the psoas major muscle and great abdominal vessels, with difficult needlepoint selection.

PVP is mainly suitable for patients with obvious painful compression vertebral fractures, caused by hemangioma and myeloma or cancer, as well as patients with intact posterior vertebral walls after vertebral fracture [9]. This surgery can quickly relieve pain relief rate can reach more than 90%. It may be related to the fact that the collapsed trabeculae in the VB tend to stabilize after being formed, the BC disperses the heat generated by the BC destroys the nerve endings inside, the BC itself is toxic, and can kill nerve endings, and the BC has a decompression effect on the nerve roots after injection [10, 11]. PVP surgery has many advantages such as relieving pain, partially restoring VB height, preventing kyphosis, and promoting patients to get out of bed as soon as possible. However, there are also risks such as BC extravasation leading to various complications, recurrence of fractures after the injured vertebrae, and damage to the spinal nerve roots.

The classic VB augmentation surgery is a bilateral transpedicular approach, some scholars proposed a unilateral transpedicular approach and achieved similar clinical effects to bilateral surgery [12, 13]. It has been published that to achieve the postoperative biomechanical balance of the VB through a unilateral approach, the BC injected after puncture must be distributed across the midline of the VB [14], the first 1/3 point of the VB midline is the ideal target point for the unilateral approach [15]. To reach the target point with the puncture needle through the traditional pedicle approach, the puncture external deflection angle is usually increased. A large external deflection angle is often caused by damage to the nerve root. To solve this problem, many scholars have tried to improve the unilateral pedicle puncture technique and achieved success [16, 17], but it has not been widely used in clinical applications. To optimize the puncture trajectory of unilateral PKP surgery, researchers designed and systematically described the unilateral transverse process-pedicle approach to perform lumbar VB augmentation surgery, with good clinical results [18]. Therefore, the reliability, feasibility, and clinical application prospects of this approach were confirmed, and the first anatomical data were subsequently measured and obtained [19, 20]. However, there is a relative lack of research on the unilateral transverse process-pedicular (UTPP) approach technology in the treatment of OVCF. This study retrospectively analyzed the application of the UTPP approach and the traditional unilateral transpedicular (UTP) approach in the treatment of lumbar OVCF in elderly patients, and compared the clinical effects of the UTPP and UTP.

Methods and materials

Basic information

A retrospective analysis was implemented on 120 elderly patients with lumbar OVCF who underwent PVP treatment in the Department of Orthopedics of the Second Affiliated Hospital of Guangdong Medical University from January 2022 to January 2024. They were divided into the UTP group (60 cases) and the UTPP group (60 cases) according to different surgical puncture approaches. Before surgery, the patient's

cardiopulmonary function and other important organ functions are corrected until the patient can tolerate the surgery. The study was approved by the ethic committee of Second Affiliated Hospital of Guangdong Medical University. Written informed consent was obtained from all individuals included in this study.

Inclusion and exclusion criteria

Inclusion criteria The patient had a bone mineral density (BMD) T value <-2.5 and combined with vertebral fragility fracture, specifically a single VB fracture that exhibited a high signal on T2-weighted MRI and a low signal on T1-weighted image. The fractured VB did not spinal cord and nerve root compression symptoms, and the prone position could tolerate local anesthesia surgery. Additionally, the follow-up data were complete.

Exclusion criteria Patients with fracture fragments intruding into the spinal canal and compressing the nerve roots or with diseases such as VB tumours and spinal infections or with other contraindications to surgery such as uncontrollable diabetes mellitus, cardio-cerebral and cerebral vascular diseases, and coagulation abnormalities.

Methods

UTP group The patient was put in a prone position, with pillows on the chest and both sides of the iliac crest, and the abdomen suspended in the air to facilitate VB reduction. Determine the target VB under C-arm fluoroscopy, make sure that there is no "bilateral sign" on the upper and lower endplates, the spinous process is in the midline, and the body surface is marked with lines marking the lateral edge, the upper edge of the vertebral pedicle. An appropriate amount of 5% lidocaine was used to anesthetize the skin to the periosteum, and the skin was incised about 0.5 cm. Insert the C-shaped arm of the puncture trocar at 9 o'clock (left) and 3 o'clock (right) on the outer edge of the vertebral pedicle under fluoroscopy, and continue to insert the needle. When the needle tip is situated on the inner wall of the vertebral pedicle in the lateral position and has just passed through the front edge of the vertebral pedicle, the needle is inserted until the front 3/4 of the VB is situated in the center of the VB, and the puncture needle is removed. When the BC reaches the viscous stage, slowly push the push rod into the VB. Under fluoroscopy, the BC in the VB is filled and no longer spreads and has not invaded the spinal canal. Stop the injection. When the BC becomes hot and hard, rotate and remove the puncture cannula, disinfect it, and suture the skin.

UTPP group Position, anesthesia, and intraoperative procedures were the same as those of the UTP group. The puncture needlepoint is slightly outside the junction between the lateral edge of the pedicle projection and the transverse process.

The patients in both groups were allowed to wear lumbar braces and do moderate activities 24 h after surgery. Anti-osteoporosis treatment (bisphosphonates, calcitriol, vitamin D) was given for at least 6 months after surgery.

Observation indicators

The low back pain visual analog scale score (VAS) and Oswestry Disability Index (ODI) were recorded 1 day after surgery, 6 months after surgery, and 12 months after surgery. The VAS score is drawn into 10 equal parts with a 10 cm long straight horizontal line, and the two ends are marked "0" and "10" respectively. "0" means no pain, and "10" means intolerable pain, the larger the value, the more severe the pain; the ODI score has 10 items, and each item is scored from 0 to 5, with 0 indicating normal function and 5 indicating the most severe functional limitation.

Record the operation time, BC injection volume, and other surgical indicators. Record the distribution characteristics of BC: The VB was divided into 9 parts (a-i) in the axial position, and the distribution characteristics of BC in the two groups were analyzed. The excellent BC distribution rate was recorded according to the degree of diffusion of BC between the two vertebral pedicles on the postoperative anteroposterior X-ray film, the BC distribution quality is divided into four levels, the midline of the VB is the 50% defining point, and the midpoint of the line connecting the midline of the VB and the pedicle is the 25% defining point(ipsilateral puncture) and 75% defining point(contralateral puncture), 75% and above is considered excellent, 50% ≤ BC filling < 75% is good, 25% ≤ BC filling < 50% is poor, and < 25% is failure. The Pflugmacher method was used to measure the distance between the upper endplate and lower endplate of the anterior edge of the fractured VB and measure the Cobb angle before surgery and 1 day after surgery. Record BC leakage and adjacent VB fractures.

Statistical method

Statistical analysis was performed using SPSS 26.0. The measurement data conformed to the normal distribution had homogeneous variance, and were expressed as $\bar{x}\pm s$. The independent sample t-test was used for comparison between groups, and the analysis of variance was used for comparison within the group. The count data was analyzed using the non-parametric test χ^2. $P<0.05$ means the difference is statistically significant.

Table 1 Comparison of general information of patients

item	UTP group ($n=60$)	UTPP group ($n=60$)	t/χ^2	*P*
gender [n (%)]			0.139	0.709
male	23 (38.33)	25 (41.67)		
female	37 (61.67)	35 (58.33)		
age (years, $\bar{x}\pm s$)	70.48 ± 7.28	70.53 ± 5.76	-0.042	0.967
bone density T-score ($\bar{x}\pm s$)	3.20 ± 0.25	3.23 ± 0.24	-0.671	0.504
time from fracture to operation (d, $\bar{x}\pm s$)	3.66 ± 1.43	3.87 ± 1.48	-0.790	0.431
fracture type [n (%)]			0.671	0.715
wedge	38 (63.33)	42 (70.00)		
biconcave	19 (31.67)	15 (25.00)		
comminuted	3 (5.00)	3 (5.00)		
fracture segment [n (%)]			1.355	0.852
L_1	20 (33.33)	23 (38.33)		
L_2	20 (33.33)	17 (28.34)		
L_3	8 (13.33)	11 (18.33)		
L_4	8 (13.33)	6 (10.00)		
L_5	4 (6.67)	3 (5.00)		

Table 2 Comparison of patient VAS scores and ODI scores

	group	before surgery	1 day after surgery	6 months after surgery	12 months after surgery
VAS scores	UTP group ($n=60$)	7.18 ± 1.13	2.15 ± 0.73*	1.80 ± 0.44*	1.48 ± 0.50*
	UTPP group ($n=60$)	7.16 ± 1.09	1.92 ± 0.50*	1.75 ± 0.44*	1.35 ± 0.48*
	t	0.099	2.013	0.622	1.453
	P	0.922	0.046	0.535	0.149
ODI scores	UTP group ($n=60$)	33.55 ± 4.88	16.68 ± 2.81*	8.88 ± 1.96*	8.18 ± 1.84*
	UTPP group ($n=60$)	33.30 ± 5.10	16.32 ± 3.16*	9.02 ± 2.20*	8.25 ± 2.03*
	t	0.274	0.659	-0.368	-0.198
	P	0.784	0.511	0.713	0.843

Note: * indicates $P<0.05$ compared with preoperative

Results

Comparison of general information between groups of patients

There were 48 male patients and 72 female patients; the average age was 70.50 (62–80) years old; the average bone density T value was 3.22 ± 0.25; there were 120 cases of single-vertebral fractures, including 43 cases of L_1, 37 cases of L_2, 19 cases of L_3, 14 cases of L_4, and 7 cases of L_5; 80 cases of wedge fractures, 34 cases of biconcave fractures, and 6 cases of comminuted fractures; the average time from fracture to operation was (3.95 ± 1.35) days.

Univariate analyses comparing the clinical general data of UTP and UTPP patients in terms of gender, age, bone density T value, time from fracture to surgery, fracture type, and fracture segment, the results showed no significant difference (all $P>0.05$) (Table 1).

Comparison of patients' VAS scores and ODI scores

There was no difference in the preoperative VAS and ODI scores between the two groups ($P>0.05$). The VAS and ODI scores in the two groups gradually decreased over time, and the differences at each time point were statistically significant compared with those before surgery ($P<0.05$). The VAS scores between the two groups on the first day after surgery were statistically significant ($P<0.05$).The specific data are shown in Table 2.

Comparison of patient surgical indicators

There was no significant difference in the operation time between the two groups ($P>0.05$). The amount of BC injected in the UTPP group was greater than that in the UTP group ($P<0.05$). In the UTPP group, the BC was mostly distributed in the anterior and middle parts (a-f), while in the UTP group, the BC was mostly distributed in the lateral parts (a, d, g or c, f, i). The excellent BC distribution rate in the UTPP group was higher than that in the UTP group ($P<0.05$). In the UTPP group, 5 patients had BC leakage, including 3 cases in the paravertebral area, 1 case in the vertebral endplate, and 1 case in the anterior margin of the VB; in the UTP group, 14 patients had BC leakage, including 8 cases in the paravertebral area, 2 cases in the anterior margin of the VB, 1 case in the vertebral endplate, 1 case in the posterior margin of the VB, 1 case with pulmonary vein leakage, and 1 case in the spinal canal. All patients had no clinical symptoms. The BC leakage rate in the UTPP group was lower than

Table 3 Comparison of patient surgical indicators

group	surgery time (min, $\bar{x}\pm s$))	BC injection volume (ml, $\bar{x}\pm s$))	excellent BC distribution rate [*n* (%)]	BC leakage [*n* (%)]	fracture of adjacent VB [*n* (%)]
UTP group (*n* = 60)	50.47 ± 3.99	4.05 ± 0.51	37 (61.67)	14 (23.33)	9 (15.00)
UTPP group (*n* = 60)	49.92 ± 3.70	5.10 ± 0.34	56 (93.33)	5 (8.33)	8 (13.33)
t/χ^2	0.783	-13.269	17.252	5.065	0.069
P	0.435	0.000	0.000	0.024	0.793

Table 4 Comparison of patient imaging parameters ($\bar{x}\pm s$)

group	vertebral body front edge height (mm)		Cobb angle (°)	
	before surgery	1 day after surgery	before surgery	1 day after surgery
UTP group (*n* = 60)	15.13 ± 3.05	18.62 ± 2.30*	17.43 ± 2.03	11.02 ± 1.20*
UTPP group (*n* = 60)	15.06 ± 3.08	17.39 ± 2.20*	17.90 ± 2.05	11.62 ± 1.22*
t	0.125	2.993	-1.262	-2.716
P	0.901	0.003	0.209	0.008

Note: * indicates $P < 0.05$ compared with preoperative

that in the UTP group ($P < 0.05$). At the last follow-up, 8 patients in the UTPP group had adjacent vertebral fractures; 8 patients in the UTP group had adjacent vertebral fractures and 1 patient had a distant vertebral fracture. Specific data are shown in Table 3.

Comparison of patient imaging parameters

One day after surgery, the vertebral anterior edge height and Cobb angle of the two groups of patients were restored compared with those before surgery ($P < 0.05$) (Table 4).

Discussion

Percutaneous vertebral augmentation is a mature minimally invasive technique for the spine. It can quickly relieve pain, improve kyphosis, and reconstruct spinal biomechanics. It can help patients get out of bed early, thereby avoiding complications such as hypostatic pneumonia. The puncture point of lumbar spine UTPP approach PVP surgery is more outward than that of UTP approach PVP surgery, and the outward angle is larger. Studies have shown that intraoperative surface positioning in the UTPP group is 1.5 to 3.8 mm outward compared with the UTP group, and the outward angle increases by 5° to 15° [21]. The puncture needle makes the BC more fully diffused. The surgery is performed under C-arm fluoroscopy. The puncture point needs to be accurately positioned during the surgery, and the abduction angle should be noted. The operation is performed under local anesthesia. In addition, biomechanical studies have shown that the ideal distribution area of BC is the anterior 2/3 of the VB [22]. UTPP-PVP can make the puncture endpoint closer to the midline, achieve BC diffusion from the midline on the coronal plane, and diffuse BC more evenly to both sides of the VB. In this study, the excellent rate of BC diffusion in the UTPP group was 93.33%. It has been reported that BC diffusion along the UTP puncture path tends to be biased to one side, making the strength of the target vertebra uneven, resulting in an increased risk of wedge-shaped contralateral VB and adjacent vertebral fracture [23]. However, BC diffuses from the midline through the UTPP approach, which is more evenly diffused and reduces the risk of vertebral fracture.

Our results showed that the height of the vertebral anterior edge was higher and the Cobb angle was improved in both groups 1 day after surgery compared with that before surgery, indicating that both approaches of PVP can restore the height of the fractured vertebra. The better of the middle part of the vertebra is better than that of the vertebral anterior edge. This is related to the distribution of BC and the concave shape of the vertebral endplate [24]. Adjacent vertebral fractures may be related to the progression of osteoporosis in patients. Therefore, it is recommended that OVCF patients, especially those after PVP, pay attention to anti-fracture osteoporosis treatment. Studies have shown that BC leakage is related to the severity of fracture, BC injection speed, and BC injection volume [25]. However, in this study, the amount of BC injected in the UTPP group was greater than that in the UTP group, and the BC leakage rate was lower than that in the UTP group ($P < 0.05$). We believe that this conclusion is related to the puncture endpoint of the UTPP group being closer to the midline. Biomechanical studies have pointed out that when the amount of BC injected is 15% of the vertebral volume, the strength of the fractured vertebra can be restored [26]. When this value is exceeded, it may cause excessive vertebral strength. Some scholars also believe that the UTPP approach PVP surgery has advantages over the UTP approach PVP surgery, such as shorter radiation exposure time, but the difference in clinical effect is not

statistically significant [27]. Other studies recommend that the ideal distribution of BC is from top to bottom to the end plate and from left to right to the pedicle, with a good clinical prognosis [28], which is consistent with the conclusion of this study.

Our results showed that the VAS scores of both groups of patients decreased compared with those before surgery one day after surgery ($P<0.05$), but the VAS score of the UTPP group was lower than that of the UTP group, which was considered to be related to the more uniform diffusion and more adequate filling of the BC in the UTPP group. Studies have shown that residual pain after PVP is related to the degree of BC filling along the fracture line [29]. The thermal effect of BC disables the nerve endings around the fracture, and the adhesion of BC reduces the micro-motion of the fracture. The better the filling degree, the smaller the residual pain. Follow-up to 12 months after surgery, accompanied by the disappearance of bone edema around the BC and fracture healing, the VAS scores of the two groups were further reduced compared with those before surgery. The puncture path of UTPP does not interfere with the small joints and can also reduce the pain score [30]. The ODI scores of both groups of patients one day after surgery were improved compared with those before surgery, and they can wear braces to get out of bed and gradually return to their families and society, relieving the burden of family members' care. Early walking can also reduce the incidence of bone loss and depression caused by bed rest, and even reduce the mortality rate.

Conclusion

In conclusion, both UTPP-PVP and UTP-PVP can alleviate the low back pain symptoms of patients, enable patients to walk early, improve their quality of life, and reduce social and economic costs. The UTPP approach has the advantages of large BC injection volume, sufficient BC diffusion, and low leakage rate, and is worthy of clinical promotion and application.However, this study also has limitations such as a small sample size, so there is a need to expand the sample size and more relevant studies to support the validation.

Supplementary Information

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Supplementary Material 1

Supplementary Material 2

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Author contributions
XJB is responsible for the guarantor of integrity of the entire study, study concepts, definitionof intellectual content, literature research, clinical studies, data acquisition & analysis, statistical analysis, manuscript preparation & editing & review; LDZ is responsible for the guarantor of integrity of the entire study, study design, definition of intellectual content, clinical studies, experimental studies, data acquisition, data analysis, statistical analysis, manuscript preparation & review; TC is responsible for the guarantor of integrity of the entire study, study concepts & design, literature research, clinical studies, data acquisition & analysis, manuscript editing & review; ZMC is responsible for the study concepts & design, definition of intellectual content, literature research, experimental studies, data analysis, statistical analysis, manuscript editing & review; ZP is responsible for the study design, literature research, clinical studies, experimental studies, data acquisition, statistical analysis, manuscript preparation & editing. All authors read and approved the final manuscript.

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Data availability
All data generated or analysed in this study are included in this published article and its supplementary information file.

Declarations

Ethics approval and consent to participate
The study was approved by the ethic committee of Second Affiliated Hospital of Guangdong Medical University. Written informed consent was obtained from all individuals included in this study. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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