Percutaneous vertebral-disc plasty for thoracolumbar very severe osteoporotic vertebral compression fractures

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Research Article

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Abstract

Background: To compare the clinical outcomes and radiological parameters of patients undergoing percutaneous vertebroplasty (PVP) versus those undergoing percutaneous vertebral-disc plasty (PVDP) for back pain, segmental instability, and kyphosis due to thoracolumbar very severe osteoporotic vertebral compression fractures (vsOVCFs).

Methods: 31 patients with thoracolumbar vsOVCFs were retrospectively reviewed. All the patients were divided into the PVP group and the PVDP group. The visual analogue scale (VAS), Oswestry Disability Index (ODI), local kyphosis angle, and disc height were recorded preoperatively and postoperatively.

Results: Significant postoperative improvements on the VAS, ODI, and the local kyphosis angle (LKA) were shown, compared with the preoperative values in both groups ($p < 0.05$). The average VAS, ODI, and LKA for patients in the PVP group were increased compared to those in the PVDP group were observed at the last follow-up ($p < 0.05$). The DHA, DHP, and LKA were seen to be maintained in the PVDP group at the last follow-up ($p > 0.05$). In those parameters, the change was significantly lower in the PVDP group at the last follow-up. ($p < 0.05$).

Conclusions: PVDP may be a feasible and effective technique for the treatment of very severe OVCFs, that can restore intervertebral height, provide segmental stabilizing and improve kyphosis in the short term.

Background

Osteoporosis is a major global public health problem, causing more than 8.9 million fractures each year[1]. Osteoporotic vertebral compression fracture (OVCF) is the most frequent type of fracture in the elderly[2]. OVCF usually causes significant back pain and mobility limitations[3]. The conservative treatments need prolonged bed rest and drug therapy[4]. If patients are associated with a delay in accepting formal conservative treatment, multiple complications secondary to OVCF will occur, such as back pain, kyphotic deformity, a reduction of life quality, increased magnitude of vertebral compression, deep vein thrombosis, and pulmonary infection[5, 6].

Very severe osteoporotic vertebral compression fractures (vsOVCFs) have been defined as compression of the vertebral anterior column greater than two-thirds of their original height[7], which is accompanied by kyphosis deformity and endplate-disc complex injury(EDCI) [8, 9]. Folman Y [10]proposed that the local kyphosis angle(LKA) exceeds 20° , and the compression of the anterior column of the diseased vertebral column exceeds 50%, which can be considered as local instability of the fracture. In patients with vsOVCFs, vertebral compression and EDCI are often aggravated due to the failure of formal conservative treatment in the early stage of the disease, which accelerates the degeneration of the damaged intervertebral disc and even the appearance of disc vacuum phenomenon, which further leads to instability of the thoracolumbar spine and further kyphotic deformity.

Traditional osteotomy and pedicle screw fixation and fusion operation are used to correct kyphotic deformity and treat segmental instability, which is too risky for elderly patients with severe underlying disease[11]. As imaging and surgical techniques have improved, percutaneous vertebroplasty (PVP) has gradually been applied to the treatment of vsOVCFs that was once considered a relative contraindication to surgery[12], but the results are quite different. Varga et al. [13]introduced an emerging minimally invasive surgery called the percutaneous cement discoplasty (PCD), which was modified and supplemented by Sola et al.[14]. PCD is used effectively to treat axial pain and disability associated with severe lumbar disc degeneration and provides a prompt segmental stabilizing effect. Nevertheless, this technology is not yet used in vsOVCFs. Because patients with vsOVCFs often suffer from residual back pain due to spinal instability after PVP, and the incidence of intervertebral disc cement leakage is particularly high, it is natural to link the two techniques together. Much like the terms vertebroplasty and kyphoplasty, we call the procedure percutaneous vertebral-disc plasty (PVDP).

In this study, we performed this retrospective analysis of clinical and radiological results in two patient groups with vsOVCFs, one treated with PVP and the other with PVDP. Our objective was to describe this minimally invasive technique and evaluate the feasibility, safety, and clinical efficacy of the treatment.

Methods

Patients

This was a retrospective clinical study approved by the Ethics Committee of the Affiliated 2 Hospital of Nantong University (NO.2018KY032). The electronic follow-up system was examined to identify 33 patients diagnosed with thoracolumbar vsOVCFs in our hospital and undergoing PVP treatment from November 2018 to March 2020. Based on the surgery technique, all the patients were divided into PVP group (n = 18) and PVDP group (n = 13).

Inclusion criteria were: (1) bone mineral density T scores < -2.5 ; (2) compression of the vertebral anterior column greater than two-thirds of their original height; (3) Kyphosis with LKA greater than 20° ; (4) the accordion phenomenon[14]: the different angles of a supine CT scan and a lateral standing X-ray measurement(Fig. 1b-c); (5) upper or lower vertebral endplate fracture; (6) the involved vertebral body was intact; (7) Elderly patients with a history of major illness (such as cardiovascular disease, cancer or active malignancy) and were intolerant of the traditional open surgery.

Exclusion criteria were: (1) Pathological vertebral fractures caused by spinal tumors, spinal tuberculosis, and spinal infection and so on; (2) Patients with symptoms of nerve roots or spinal cord compression; (3) Patients with a previous history of spinal fusion; (4) A history of abnormal bleeding or coagulation disorder dysfunction.

Radiological measurements

All the preoperative and postoperative radiological evaluation parameters were measured by two independent spinal surgeons who had more than 10 years of experience. We retrospectively measured radiological parameters including the local kyphotic angle (LKA), disc height anterior (DHA), and disc height posterior (DHP) from lateral plain radiographs preoperatively and at 1 day and final follow-up after surgery. The local kyphotic angle was calculated by a measurement called Cobb's method, which measured the angle between the superior endplate of the upper vertebrae and the inferior endplate of the lower vertebrae. A typical case is shown in Fig. 1.

Clinical outcomes

The visual analog score (VAS) was used to assess the preoperative and postoperative back pain relief. The Oswestry Disability Index (ODI) was used to assess the quality of life and was recorded preoperatively, postoperatively, and final follow-up.

Operative technique

In PVDP group, PVP and PCD both used a unilateral transpedicular approach into the vertebrae and disc[14]. Under general anesthesia, the patient was turned over to a prone position, and the deformity is reduced with a slight closed manipulative. Firstly, under fluoroscopic O-arm guidance, the puncture site was localized into the junction made by the transverse process and the superior articular process and entered the target area according to the puncture angle and depth measured before the operation (Fig. 2a). Secondly, the other puncture cannula was inserted into the intervertebral disc space adjacent to the ruptured endplate through the transpedicular access, and the target area was the middle of the intervertebral space (Fig. 2b). Thin-cut CT images were obtained intraoperatively by the O-arm fluoroscopy to confirm puncture needle placement location (Fig. 2d-e). Third, the bone cement was injected into the vertebrae and the intervertebral disc space, meanwhile, the cannula was also needed to move back to the vertebrae, and the bone cement in the vertebrae could connect the intervertebral disc space and the vertebrae to form a whole. Finally, the PVP group and the adjacent vertebrae performed by prophylactic vertebroplasty used bilateral pedicle puncture, under the guidance of the O-arm, two puncture needles were percutaneously inserted into the vertebrae, reaching about the middle of the vertebrae. Then, cement was slowly injected into the vertebral body, once cement leakage into the spinal canal or veins was detected, the injection was stopped.

Statistical analysis

SPSS 23.0 statistical software (SPSS, Inc, Chicago, IL, USA) was used for analysis. Quantitative data are expressed as mean $\pm$ standard deviation. The paired-samples t-test was used to assess a significant difference between preoperative and postoperative continuous variables for both groups. The independent two-sample t-test was used to identify a significant difference between the groups. A chi-squared test was used for categorical data. A value of $P < 0.05$ was considered to indicate statistical significance in all analyses.

Results

Patient Demographic characteristics

Concerning mean age, mean BMD, hospital days, and follow-up days, there was no significant difference between patients in the PVP group and the PVDP group (Table 1).

Table 1
Demographic and clinical characteristics of the patients

	PVP group	PVDP group	<i>P</i>
Age (years)	76.17 ± 5.25	72.00 ± 8.93	0.164
Sex(n)			0.634
Male	4	2	
Female	14	11	
BMD (T-score)	-3.21 ± 0.27	-3.17 ± 0.72	0.860
Vertebral compression (%)	70.72 ± 6.21	72.00 ± 9.42	0.657
Hospital time	3.22 ± 0.43	3.50 ± 0.52	0.141
Follow-up duration (months)	11.22 ± 0.94	12.17 ± 6.44	0.623

Spinal parameters

Radiological measurements are summarized in Table 2. In PVDP group sagittal plane, the mean thoracolumbar LKA was improved from 35.58°±11.57° preoperatively to 26.37°±11.19° postoperatively, which was seen to be maintained at the last follow-up (26.82°±10.73°). In the PVP group, the average LKA was 37.35°±6.76° on admission, decreased to 29.27°±6.80° one day after the operation and increased to 34.35°±6.16° at the last follow-up. At follow-up of 1 day and 12 months, the kyphotic Cobb angles of the PVDP group were significantly lower than that of the PVP group and the change was significantly lower in PVDP group at the last follow-up (LKA mean change: 5.08°±3.57° vs 0.44°±0.83°, $P < 0.05$). Compared with those on pre-operation, in PVDP group, the DHA changed from 5.62 ± 1.57mm to 6.91 ± 1.47mm, the DHP changed from 4.08 ± 1.55mm to 4.80 ± 1.24mm, which were seen to be maintained at the final follow-up (DHA: 6.85 ± 1.47mm; DHP: 4.78 ± 1.24mm). However, in the PVP group, the DHA increased from 6.53 ± 1.81mm one day after operation to 5.52 ± 1.23mm at the last follow-up and the DHP increased from 4.02 ± 0.59mm to 3.64 ± 0.56mm. The DHA and DHP for the patients in the PVP group were each significantly lower than in the PVDP group ($P < 0.05$). In both parameters, the change was significantly lower in PVDP group at the last follow-up (DHA mean change: -1.01 ± 0.82mm vs -0.06 ± 0.09mm, $P < 0.05$; DHP mean change: -0.38 ± 0.36 mm vs -0.025 ± 0.03 mm, $P < 0.05$).

Table 2
Results of the radiological measurements

	PVP group	PVDP group	<i>P</i>
DHA(mm)			
Pre-op	6.43 ± 1.84	5.62 ± 1.57	0.224
1day post-op	6.53 ± 1.81	6.91 ± 1.47	0.559
Final follow up	5.52 ± 1.23	6.85 ± 1.47	<i>0.018</i>
Post-op vs pre-op (mean change, %)	0.11(1.68%)	1.29(22.95%)	
p	0.174	<i>0.005</i>	
Final fu vs post-op (mean change, %)	-1.01(-15.48%)	-0.06(-0.81%)	
p	< <i>0.001</i>	0.052	
DHP(mm)			
Pre-op	4.34 ± 0.52	4.08 ± 1.55	0.582
1day post-op	4.02 ± 0.59	4.80 ± 1.24	<i>0.020</i>
Final follow up	3.64 ± 0.56	4.78 ± 1.24	<i>0.010</i>
Post-op vs pre-op (mean change, %)	-0.32(-7.37%)	0.75(18.38%)	
p	< <i>0.001</i>	<i>0.001</i>	
Final fu vs post-op (mean change, %)	-0.38(-9.45%)	-0.03(-0.52%)	
p	< <i>0.001</i>	<i>0.026</i>	
LKA (°)			
Pre-op	37.35 ± 6.76	35.58 ± 11.57	0.639
1day post-op	29.27 ± 6.80	26.37 ± 11.19	0.434
Final follow up	34.35 ± 6.16	26.82 ± 10.73	<i>0.043</i>

DHA (disc height anterior), DHP (disc height posterior), LKA (the local kyphosis angle)

Pre-op vs. post-op and post-op vs. Final fu change percentage represented in parentheses

	PVP group	PVDP group	<i>P</i>
Post-op vs pre-op (mean change, %)	-8.08(-21.63%)	-9.20(25.85%)	
p	<i>< 0.001</i>	<i>0.001</i>	
Final fu vs post-op (mean change, %)	5.08(17.36%)	0.44(1.67%)	
p	<i>< 0.001</i>	0.092	
DHA (disc height anterior), DHP (disc height posterior), LKA (the local kyphosis angle)			
Pre-op vs. post-op and post-op vs. Final fu change percentage represented in parentheses			

Clinical outcomes

The follow-up results are shown in Table 3. At postoperative follow-up, the VAS and ODI scores of the two groups of patients were significantly lower than those before the operation. However, in the PVDP group, the VAS and ODI scores further decreased to 2.75 ± 0.45 and $(19.42 \pm 6.10)\%$ at the final follow up, which were significantly lower than in the PVP group ($p \leq 0.05$).

Table 3
Summary of clinical outcomes results

	PVP group	PVDP group	<i>P</i>
VAS score			
Pre-op	7.17 ± 1.10	6.75 ± 0.87	0.257
1day post-op	3.11 ± 0.76	2.83 ± 0.72	0.320
Final follow up	3.72 ± 0.96	2.75 ± 0.45	<i>0.005</i>
Post-op vs pre-op (mean change, %)	-4.06(-56.62%)	-3.92(-58.07%)	
p	<i>< 0.001</i>	<i>< 0.001</i>	
Final fu vs post-op (mean change, %)	0.61(19.61%)	-0.08(-2.83%)	
p	<i>0.017</i>	0.754	
ODI score			
Pre-op	69.11 ± 5.56	70.00 ± 3.05	0.618
1day post-op	31.94 ± 8.71	28.67 ± 9.07	0.329
Final follow up	31.33 ± 6.60	19.42 ± 6.10	<i>< 0.001</i>
Post-op vs pre-op (mean change, %)	-37.17(-53.78%)	-41.33(-59.04%)	
p	<i>< 0.001</i>	<i>< 0.001</i>	
Final fu vs post-op (mean change, %)	-0.61(-1.91%)	-9.25(-32.26%)	
p	0.583	<i>0.003</i>	
VAS (visual analogue scale), ODI (Oswestry Disability Index), Pre-op vs. post-op and post-op vs. Final fu change percentage represented in parentheses			

Discussion

The treatment of vsOVCFs remains controversial. Conservative treatment is invalid for the pain relief of vsOVCF. For elderly patients, it often leads to various complications such as kyphosis, pulmonary infection, deep vein thrombosis, and bedsores. These patients are also not able to tolerate the osteotomy and internal fixation due to the large surgical trauma, difficulty in fixation, and high operative

complication. PVP has been widely considered as the most suitable approach for older patients unsuitable candidates for open surgery. However, vsOVCFs have always been recognized in the past as an absolute or relative contraindication due to the high risk of cement leakage and surgical technical difficulties.

With the development of imaging and minimally invasive surgical technology, PVP has gradually been applied to the treatment of vsOVCFs. The previous studies[15] have demonstrated that patients with vsOVCFs had immediate pain relief after PVP surgery. However, the injured vertebrae in patients with vsOVCFs have been a significant collapse and were usually accompanied by the upper or lower vertebral endplate fracture, therefore, patients were at a high risk of cement leakage. Nieuwenhuijse[16] et al reported that cement leakage occurred in 91.9% of patients with vsOVCFs receiving PVP treatment. Very severe vertebral compression fractures lead to severe reduction of intervertebral space height and kyphosis deformity. Meanwhile, Zhao et al[17]. have shown that the acute trauma on intervertebral discs and the cement leakage into the disc are both considered key factors in acceleration of disc degeneration, which will result in a decrease in the intervertebral space height and an increase in the local kyphotic angle. In vsOVCFs, PVP treatment can relieve pain and improve the quality of life, but the maintenance of intervertebral space height and the correction of kyphosis are limited. The reason for this result may be that the disc injury may result in acceleration of disc degeneration, and the intervertebral space leakage of bone cement will further accelerate the degeneration and decrease the height of the intervertebral disc, leading to the loss of kyphotic correction.

In this study, back pain symptoms of vsOVCFs patients after PVP often cannot be completely relieved. Endplate disc injury and kyphosis are some of the causes of pain, and segmental intervertebral instability is also an important reason. Some scholars[10] believe that the local kyphosis of the spine fracture exceeds 20° , and the compression degree of the anterior column of the diseased vertebral is more than 50%, it can be considered as an unstable fracture. Meanwhile, due to the injury of the intervertebral disc and the lack of formal conservative treatment, severe degeneration of the intervertebral disc or even the appearance of a vacuum phenomenon should also be regarded as a sign of instability[14], and the different angles of a supine CT scan and a lateral standing X-ray measurement are called the accordion phenomenon (Fig. 1.b-c). Percutaneous cement discoplasty (PCD) was an emerging technology proposed by P.P. Varga[13] first in 2014, and the principle is to use the cement injected into the disc as a simple interbody fusion to the therapeutic effect of achieving back pain relief caused by dynamic foraminal stenosis and vacuum phenomenon in the intervertebral disc. Carlos Sola studied that PCD can be considered as an alternative minimal invasive therapeutic modality for the treatment of advanced degenerative disc disease like a spinal deformity or degenerative spondylolisthesis, with satisfactory clinical effects. Recently, XUE YD et al.[18] have proposed that percutaneous kyphoplasty (PKP) combined with PCD to treat severe thoracolumbar vsOVCFs has also achieved good results. They shifted the working channel to insert the puncture needle into the upper intervertebral disc through the adjacent endplate, and then injected the cement. We believe that unnecessary vertebral body damage will occur during this transfer process, and the expansion of the balloon may cause secondary damage to the endplate.

In our study, we compare the clinical and radiological outcomes of patients with vsOVCFs in the PVP group and the PVDP group to prove whether the PVP combined with PCD surgery is more suitable for the treatment of vsOVCFs. To the best of our knowledge, this is the first study of its kind. The average VAS score and ODI score in both groups decreased after surgery and at the final follow-up, but more so for patients in PVDP group than those in the PVP group. These findings suggested that both PVDP and PVP could sustain pain relief, but PVDP outperformed PVP in patients with vsOVCFs. The better improvement of these symptoms might be attributed to the stabilization of the segmental intervertebral after PVDP. At follow-up of 1 day after surgery, the LKA was significantly decreased and DHA was significantly increased for patients in PVDP group, which was seen to be maintained at the last follow-up, however, the LKA was increased and DHA was decreased in the PVP group at the last follow-up. The significant improvements might be attributable to the effectively supporting effect of the anterior column maintained by the bone cement in disc space after PVDP.

Previous related studies have not reported whether PCD will increase the risk of adjacent vertebral fractures (AVF). However, most scholars[19, 20] currently believe that preoperative severe kyphosis deformity, the stiffness enhancement of the treated vertebra, and cement leakage in the intervertebral space increase the risk of AVF. Since all patients in the present study were diagnosed with primary osteoporosis, prophylactic vertebroplasty was performed on adjacent vertebrae undergoing PCD to reduce the risk of AVF.

The limitations of this study deserve mention. firstly, in the previous study, the disc vacuum phenomenon is an indication for PCD. This study defines the indication as severe degeneration of the intervertebral disc and the disc vacuum phenomenon because we believe that the dispersion of bone cement in the intervertebral disc may be also related to the density of the intervertebral disc. It may be necessary to further compare the two groups. Secondly, in this study, severe local kyphosis can be considered as spinal instability. It would be more meaningful if the flexion-extension radiograph of the spine can be performed under the premise of analgesia. Beyond that, it is a preliminary retrospective study with a relatively small number of patients eligible for inclusion criteria and a relatively short follow-up period. Future investigations with larger samples are required to verify the present results.

Conclusion

Due to the increased risk of perioperative complications, elderly patients with multiple comorbidities suffering from vsOVCFs are generally not suitable for long-term open surgery, we established that PVDP may be a feasible and effective technique for the treatment of very severe OVCFs, which could effectively relieve pain, improve life quality, restore intervertebral height and improve kyphosis.

Abbreviations

vsOVCFs, very severe osteoporotic vertebral compression fractures; PVP, percutaneous vertebroplasty; PCD, percutaneous cement discoplasty; PVDP, Percutaneous vertebral-disc plasty; VAS, visual analogue

scale; ODI, Oswestry Disability Index; LKA, local kyphotic angle; DHA, disc height anterior; DHP, disc height posterior.

Declarations

Ethics approval and consent to participate

This study was approved by the Ethics Committee of the Affiliated 2 Hospital of Nantong University and conducted in accordance with the standards of the National Research Council. Written informed consent was obtained from all participants.

Consent to publication

Not applicable.

Competing interests

The authors declare that they have no competing interest.

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Authors' contributions

ZMC, GHX and JWJ conceived and designed the study. JLZ and JWJ contributed in provision of study materials or patients. JWJ, JLZ, GFB and JJC collected and assembled of data. JWJ, JLZ, GFB, GHX, JJC, CSW and PFX contributed in data analysis and interpretation. All authors read and approved the final manuscript.

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Availability of data and materials

We do not wish to share our data due to individual privacy, and according to the policy of our hospital, the data should not be shared to others without permission.

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Figures

Figure 1

A 76-years old female with vsOVCFs and kyphosis at T12-L1 was treated with PVDP. a. Magnetic resonance imaging (MRI) at admission showed T12-L1 severe compression fracture with kyphosis in preoperative. b. Supine CT scan at admission showed the local kyphosis angle was 22° and T12-L1 with vacuum phenomenon. c. The lateral standing X-ray showed the local kyphosis angle was 37°, the different angulation due to the vertebral and intervertebral collapse (22° and 37°) called the accordion phenomenon. d. Postoperative 1day X-ray showed that cement was injected in the vertebra and the middle of the T12-L1 intervertebral space and kyphosis was corrected, the local kyphosis angle was 20°. e. The lateral standing X-ray showed that the local kyphotic angle (20°) was maintained at the last follow-up.

Figure 2

a and c. The puncture needle was inserted into the target area according to the puncture angle and depth measured before the operation. b. The other puncture cannula was inserted into the intervertebral disc space adjacent to the ruptured endplate through the transpedicular access. d-e. Thin-cut CT images were obtained intraoperatively by the O-arm fluoroscopy to confirm puncture needle placement location.