Original Article

Percutaneous vertebroplasty for single osteoporotic vertebral body compression fracture

Results of unilateral 3-D percutaneous puncture technique

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Abstract

Background: Percutaneous vertebroplasty (PVP) has been gradually used for osteoporotic vertebral compression fracture (OVCF) treatment, but severe osteoporotic vertebral body compression fractures (sOVCFs) due to the difficulty in performing a puncture and the characteristics of the fractured vertebrae, it has been considered as a contraindication to PVP. The aim of the following study was to evaluate the feasibility of a unilateral, three-dimensional (3D), accurate puncture in percutaneous vertebroplasty (PVP) for a single, severely osteoporotic vertebral body compression fracture (ssOVCFs).

Materials and Methods: 57 patients received PVP in the current study. Feasibility of a unilateral approach was judged before surgery using the 64-slice helical computed tomography (CT) multiplanar reconstruction technique, a 3D accurate puncture plan was then determined. The skin bone distance, puncture angle and needle insertion depth were recorded during surgery. 2D CT rechecking was performed for any complication at day 1 after operation. Preoperative and postoperative numerical data were compared.

Results: The procedure was completed smoothly in all patients. 2D CT scanning at day 1 after operation did not show any puncture related complications. Visual analog scoring (VAS) showed that the score at day 3 after surgery was reduced to 1.7 ± 0.4 (0-2.9 scale) from the preoperative 7.9 ± 2.1 (6.1-9.5 scale). No significant differences in measure numerical data were found before and after the surgery. At 12 months followup three patients presented with nonadjacent level fractures, VAS for other patients were 1.2 ± 0.3 (0-2.1 scale).

Conclusions: Application of CT scanning for a unilateral 3D puncture design helps realize an accurate puncture in PVP. It is a safe and effective method for ssOVCFs treatment.

Key words: Percutaneous vertebroplasty, severe vertebral body compression fractures, three-dimensional accurate puncture

MeSH terms: Spine, vertebroplasty, osteoporotic fractures

Introduction

Percutaneous vertebroplasty (PVP) refers to a technique in which a bone puncture needle is percutaneously inserted into an injured vertebral body for bone cement infusion to reinforce the injured vertebra and improve spinal stability[1]. It belongs to a class of image guided, non blood vessel interventional therapy, where procedures are often monitored using fluoroscopy or fluoroscopy and computed tomography (CT) scanning.[1] PVP was first applied in the treatment of aggressive vertebral hemangiomas in 1987.[2,3] From then on, it has been gradually used for osteoporotic vertebra compression fracture (OVCF) treatment[4-8] and good curative effects have been obtained. Since PVP the virtues of minimal invasiveness, is a low risk procedure with rapid and lasting analgetic effect, it has become one of the most effective and common methods for treatment of OVCF patients.[9-14]

Severe osteoporotic vertebral body compression fractures (sOVCFs) are defined as a disease in which the height of the fractured vertebrae drops to less than one-third of its original height. Due to the difficulty in performing a

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puncture and the characteristics of the fractured vertebrae, it has been considered as a contraindication to PVP.[15,16] With advancement in imaging equipments and the puncture technique, some reports on the application of PVP for sOVCFs have been published.[14,16,17] However, most of the studies involve the application of a fuzzy puncture method.[4-6] Therefore, it is imperative to find a safe and accurate puncture method for PVP in sOVCFs.

This study explored the effect of the unilateral three-dimensional (3D) puncture technique in PVP for single severe osteoporotic vertebral body compression fractures.

Materials and Methods

A total of 57 patients with sOVCFs received PVP treatment from May 2007 to October 2011. There were 46 females and 11 males. The age ranged from 65 to 87 years with a mean age of 74 years. Among them, mere thoracic or lumbar back pains were found in 39 patients. Thoracic or lumbar back pains accompanied with radiating pains toward bilateral periumbilicus, hypochondria or iliac crests in 18 patients.

Inclusion criteria: (1) The patient must be primarily diagnosed osteoporosis with a fresh vertebral body compression fractures (2) the height of the fractured vertebrae drops to less than one third of its original height (3) The patients who received PVP treatment with unilateral 3D puncture.The followup date include postoperative CT and clinical followup of patients. The study was approved by our hospital ethical committee.

Fractured vertebral body volume scanning and multiplanar reconstruction

After volume scanning, slices at a thickness of 1 mm with an interval of 0.8 mm were selected for thinning. The multiplanar reconstruction technique was adopted to evaluate the feasibility of a unilateral approach from multiple perspectives. The puncture path was determined. A triangular cross-section is reconstructed [Figure 1]. Point A is the target puncture point, point B is the intersection point of A and the spinous process in the midline and point C is the skin puncture point at the A level. Line AC is the oblique sagittal reconstruction line; angle BAC is the puncture angle in the cross-section and line BC is the distance of the paraspinous process opening in the cross-section. Data of the angle BAC and BC distance were recorded. An oblique sagittal plane was then reconstructed [Figure 2a and b]. The oblique sagittal plane was reconstructed on the basis of the line AC. Point D was the operative skin puncture point, Point E was the orthogonal intersection point of point D and line AC or its extension line. Point F is the bone needle-inserting point. AD represented the insertion depth as well as the puncture approach pathway. Line DE was the head or foot-sided schubweg of point C and line EC was the interior and exterior schubweg of point C. DF was the puncture distance from the skin to the bone. Angle CAD was the head or foot-sided tilt angle of the skin puncture point.

3D Exact puncture procedures

All operative procedures were performed under monitoring and fluoroscopy. The patient was placed in a prone position. C-arm parameters were set in normal and lateral positions. The spinous process of the fractured vertebral body was projected at the center of the vertebral body under normal side fluoroscopy and the upper and lower edges of the fractured vertebral body did not show a double-edge phase under lateral fluoroscopy.

Lines were drawn on the back skin [Figure 3]. Points A', C', D', and E ', on the skin surface were the projected points of A, C, D and E, D^1 was the skin puncture point. Line A^1D^1 was the projection of line AD and angle $D^1A^1E^1$ is equal to angle CAD.

After local anesthesia, the puncture distance from the bone to the skin was marked on the bone puncture needle. After the needle passed through the subcutaneous tissue, a semicircle meter was used for puncture angle calibration on the cross-section and the tilt angle was just the head or foot sided angle CAD. The needle tip should touch the bone puncture Point F when the needling depth reached the marked point on the needle.

The actual puncture distance from the bone to the skin was recorded after the bone puncture point was touched by needle tip under normal side observation. The needle tail was raised and the needle tip was then knocked into the cortex of bone. The semicircle meter was used for puncture angle corrections on the cross-section as well as on the sagittal plane. The needle was continued in. Lateral fluoroscopy was switched when the needle tip reached the vertebral arch. During the operative progress before the needle tip reached the vertebral posterior edge, observations and corrections of the puncture angle on the cross-section from the normal side and on the sagittal plane from the later side had to be carried out several times. When the angle on the cross-section was adjusted, the needle tip was stopped from proceeding to exceed the medial border of the vertebral pedicle. After the needle tip entered the vertebral body, the direction of the needle was adjusted and the needling angle was corrected under normal side fluoroscopy. Then, the needle tip was placed at the targeted site under lateral fluoroscopy.

A successful puncture should be as follows [Figure 4]: The needle tip is at the midline of the vertebral body under normal side fluoroscopy and at the anterocentral interface point (at the 1/3-1/4 point of the vertebral body) under lateral fluoroscopy. The actual needling length AD, angle BAC and angle CAD were recorded.

Poly methyl methacrylate (PMMA) was mixed and infused in a sticky thick phase. For patients complicated with morphological changes in the capsular space, pasty PMMA could be infused. For patients with lower lamina terminalis cracks, the cracks must be filled satisfactorily before treatment completion.

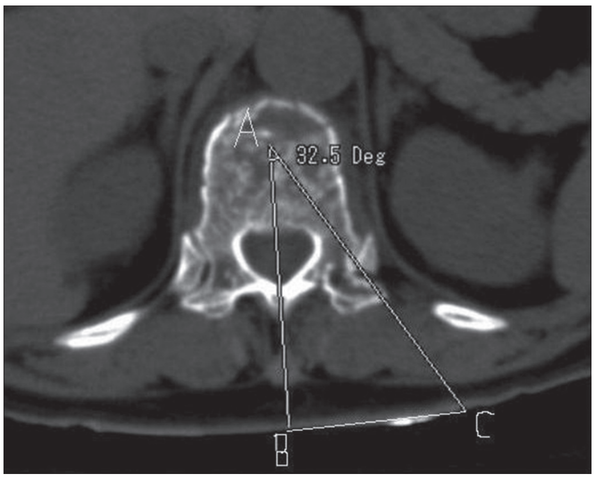

Figure 1: Axial computed tomography image showing the cross-section reconstructed triangle. Point A is the targeted puncture point, Point B is the intersection point of A and the spinous process midline, Point C is the skin puncture point at the A level. Line AC is the oblique sagittal reconstruction line, angle BAC is the puncture angle on the cross-section and BC is the distance of the paraspinous process opening on the cross section

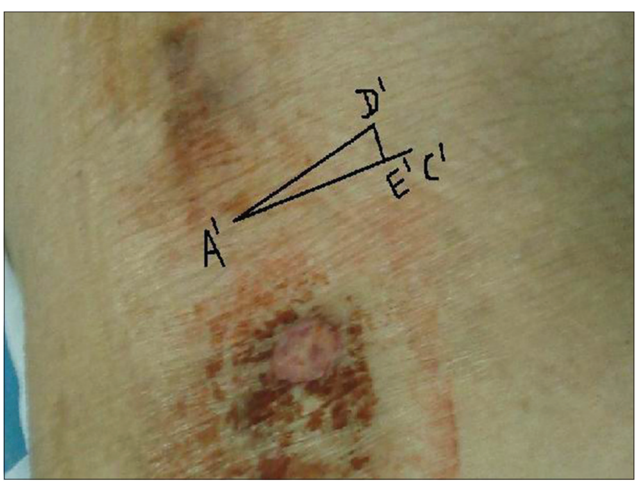

Figure 3: The clinical photograph showing that the skin surface puncture plan for a 78-year-old woman with T12 severe vertebral body compression fracture before three-dimentional precise puncture. A1, C1, D1 and E1 are the projected points of A, C, D and E on the skin surface, D1 is the skin puncture point. A1D1 is the projection of the AD line and angle D1 A1 E1 is equal to angle CAD

Successful operation criteria included (1) needle tip at the preoperative designated position (2) PMMA was filled well (3) no complications post surgery.

Postoperative CT rechecking

Bone cement distribution and leakage were observed at day 1 after surgery. The degree of the vertebral body collapse was measured based on the preoperative CT image of the maximal collapse on the sagittal plane. The vertebral body collapse degree = The vertebral height at the maximal collapse site/the average height of the normal vertebral body in vicinity.[16]

Statistical analysis

The data were analyzed using the Statistical Product and Service Solutions (SPSS) 16.0 software which development of American Stanford University by the two-sided significance *t*-test for comparison between groups. $P < 0.05$ was considered as significant.

Results

The mean collapses was 26.15% (range 13.69% - 32.85%) of 57 vertebral bodies. The involved vertebrae were located

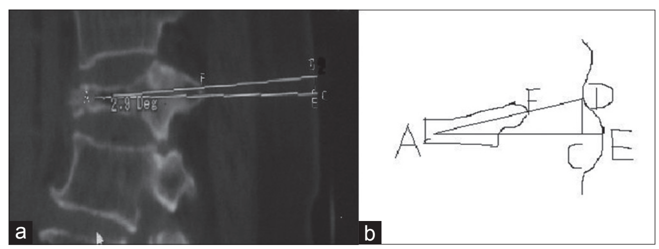

Figure 2: The oblique sagittal plane reconstruction (a) computed tomography images and line diagram (b) showing that the oblique sagittal reconstruction is based on the line AC; Point D is the operative skin puncture point, Point E is the orthogonal intersection point of D and AC or its extensive line; Point F is the bond needle insertion point; AD represents the insertion depth as well as the puncture approach pathway, DE is the cephalopodium-sided schubweg of Point C and EC is the interior and exterior schubweg of Point C; DF is the puncture distance from the skin to the bone; and angle CAD is the head or foot-sided tilt angle of the skin puncture point

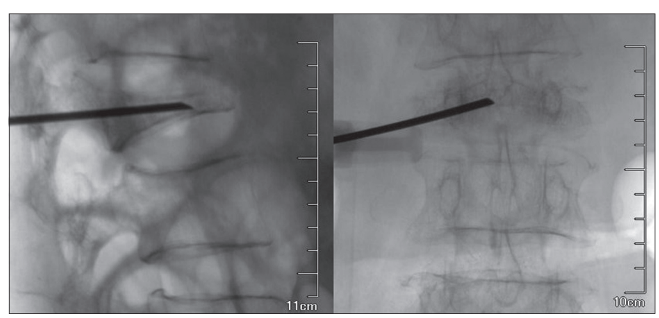

Figure 4: Normal side fluoroscopy shows the needle tip is on the central sagittal line of the vertebral body and lateral fluoroscopy shows that it is at the anterocentral intersection point of 1/3-1/4 of the vertebral body

from T5 to L5, including T5 (*n* = 1), T6 (*n* = 2), T7 (*n* = 3), T8 (*n* = 2), T9 (*n* = 1), T11 (*n* = 8), T12 (*n* = 15), L1 (*n* = 13), L2 (*n* = 4), L3 (*n* = 5), L4 (*n* = 2) and L5 (*n* = 1). 28 fractured vertebral bodies (49%) were located at the thoracolumbar junction.

2D CT scanning showed that upper vertebral end plate fractures occurred in 27 cases while lower vertebral end plate fractures occurred in 7 cases. Upper and lower vertebral end plate fractures occurred in 12 cases, cortex rupture at the anterior border of the vertebral body occurred in 37 cases, cortex rupture at the posterior border of the vertebral body occurred in 18 cases and sOVCFs complicated with capsular space changes occurred in 12 cases (7 cases were capsular space fluidify, 5 cases were capsular space pneumatosis). According to morphology, 25 fractured vertebral bodies were compressed to a gibbus shape, 26 were compressed to an H shape and 6 were compressed to a plana shape.

All the 57 patients received unilateral 3D precise puncture. Operation was completed with a successful operative rate of 100%. Comparisons between the pre and intraoperative numerical data did not show any significant difference [Table 1].

CT scanning and clinical examinations were performed after surgery. Leakage of small amounts of PMMA into the intervertebral space occurred in 45 cases (45/57) while leakage into the paravertebral soft-tissues occurred in 7 cases (7/57). No complications such as vertebral canal rupture, hematoma or pneumothorax were found. No new clinical symptoms were seen. Visual analogue score (VAS) showed that the scale was reduced to 1.7 ± 0.4) (0-2.9 scale) at 3 days after surgery from 7.4 ± 1.8 (5.7-8.6 scale) before the surgery. Followup ranged from 6 to 12 months (mean, 10 months and 9 days). No patient required second surgery.

Followup at 12 months showed that there were three patients in whom nonadjacent level fractures occurred.

Discussion

Many patients with sOVCFs suffer from kyphosis or scoliosis simultaneously. For these, a bilateral, rather than a unilateral posterior puncture approach is commonly adopted.[16,18,19] As a larger puncture angle will be involved in the unilateral approach, the vertebral pedicle as well as the spinal cord and nerves are easily exposed to high risks of injuries.[20] Meanwhile, inappropriate unilateral operation may wear through the lung tissues causing pneumothorax. Therefore, the current study took unilateral puncture approach involved in PVP as the study subject. Our aim was to find a more precise unilateral puncture method for sOVCFs patients to reduce and avoid complications during this procedure.

Previously, a point 1.5-2.0 cm lateral to the border of the vertebral pedicle was commonly choosen as the puncture point. The operation was mainly based on any individual's experience. Due to lack of precise data as reference, this procedure often resulted in various complications and caused high operative failures. With the development of multi slice spiral CT volume scanning technique, precise puncture has become possible. This technique can observe the injured vertebral body and the anatomic structure of its adjacent tissues from multiple perspectives, which has greatly contributed to the evaluation of the feasibility and the determination of the best path for unilateral puncture.

Based on large iconographic observations, combined with clinical experience, the current authors self design a unilateral 3D puncture method. According to this method, specially, the anterocentral interface point (at about 1/3-1/4) on the vertebral central sagittal line is taken as the puncture point, the simulation line of needle insertion is judged based on the oblique sagittal plane and the needle is to be inserted into the vertebral arch with 1 mm away from its inner margin in case that the needle may wear through the spinal canal wall, which may cause spinal cord and nerve injuries. The distance between the puncture point on the skin and that on the bone is measured in case of the occurrence of complications such as great hemorrhage and pneumothorax caused by inappropriate puncture. Further, the puncture angle is corrected constantly during operation and the puncture is tried to be performed according to the pre designed plan for the sake of accuracy.

A fractured vertebral body with a collapse height less than 1/3 of the original vertebral height is treatable, while those with a collapse height of more than 1/3rd pose technical difficulty in treatment.[21] Fractures with a collapse height of more than 1/3rd of the original height are termed as sOVCFs, which are a contraindication to PVP treatment.[6,22,23] In the current study, the comparisons of the numerical data before and after PVP did not show significant differences [Table 1]. These results indicate that if the puncture is performed according to standard procedures, the preoperative plan can be successfully

Table 1: Results (*n*=57)

Numerical data	Preoperative	Intraoperative	*t*	*P*
DF distance* (cm)	4.62±0.99	4.63±0.62	1.549	0.128
AD distance (cm)	9.19±0.98	9.18±1.01	1.527	0.134
Angle BAC	31.23±1.50	30.85±1.52	1.430	0.16
Angle CAD	10.95±7.11	10.85±6.99	−1.637	0.109

*DF distance=DF is the puncture distance from the skin to the bone, AD distance=AD represents the insertion depth as well as the puncture approach pathway, Angle BAC=Angle BAC is the puncture angle on the cross-section, Angle CAD=Angle CAD is the head or foot-sided tilt angle of the skin puncture point implemented, a 3D unilateral puncture can be realized and sOVCFs can be changed into an indication suitable for PVP. In the current study, operation on all the patients was successfully performed and with a successful operative rate of 100% and no complication associated with puncture was found in them, indicating that unilateral 3D precise puncture in PVP can be applied to sOVCFs patients.

sOVCFs are usually accompanied with vertebral end plate fractures, which are the main cause for pain.[24,25] Therefore, vertebral end plate cracks should be filled up during PMMA infusion. Otherwise, the operative effect will be greatly affected.

The CT sagittal plane can clearly deliviate the sOVCFs, especially the lamina terminalis fractures. This is very important for needle insertion and PMMA infusion. In our study, 57 sOVCFs cases were accompanied with 46 vertebral end plates fractures (80.70%). Postoperative CT scanning confirmed that these cracks were successfully filled up, indicating that the puncture positions were satisfactory. Although 45 cases of intervertebral leakage (45/57) caused by the PMMA crack filling were found among 57 cases, the VAS showed that the score was significantly reduced after operation and at 12 months followup. These results suggest that leakage of small amounts of PMMA into the intervertebral disc does not affect the surgical curative effect and does not increase the rate of adjacent level fractures.

Although CT scanning before unilateral 3D precise puncture can increase the risk of patients' preoperative exposure to radiation, but it can shorten the operative time, bring about more exact surgical puncture during PVP, greatly reduce the surgical risks and intraoperative X-ray radiation for patients as well as the medical staff and can thus be cost effective.[26,27] Thus, this method has more advantages than disadvantages. In the current study, each patient underwent CT scanning. During CT scanning, the scan required conditions were minimized as much as possible, the scan range was reduced and each patient was provided with the protective equipment. However, the unilateral 3D puncture approach adopted in the current study is aimed at sOVCFs and some upper thoracic spine fractures which are difficult for puncture operation. As for mild to moderate compression fractures, this method is not recommended.

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