Conversion to hypertrophic vertebral pseudarthrosis following percutaneous vertebroplasty

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Abstract To determine the role of percutaneous vertebroplasty (PVP) in bone formation and the union of vertebral pseudarthrosis, we analyzed 14 patients with an average follow-up duration of 21 months. Evaluation methods included back pain (visual analog scale: VAS), wedge angle, dynamic mobility, radiographic remodeling including callus and spur formation, and union status. The Student's *t* test was used for statistical analysis and a probability of less than 0.05 was determined as a significant difference. Back pain improved in all 14 patients with a VAS score of 57.8 ± 23.5 mm (average $\pm$ standard deviation) preoperatively and 14.7 ± 16.4 mm at the final follow-up ($P < 0.001$). The wedge angle decreased from $21.6^\circ \pm 8.3^\circ$ (average $\pm$ standard deviation) preoperatively to $13.2^\circ \pm 6.9^\circ$ at the final follow-up ($P < 0.001$). Callus formation was seen in four patients. Bony spurs were seen in the affected vertebra in preoperative radiographs in all patients, and were further developed to a solidified form during follow up after PVP. Dynamic mobility of the affected vertebrae was 6.9 ± 2.9 mm preoperatively, which decreased to $1.1^\circ \pm 0.7^\circ$ at the final follow-up ($P < 0.001$). Notably, all patients showed the dynamic vertebral mobility of 2 mm or less. Nevertheless, only two patients exhibited the dynamic vertebral mobility of 0 mm at the final follow-up, which is referred to as bone union. These findings indicate that PVP serves as a mechanical stabilizer for vertebral pseudarthrosis, which

leads to immediate pain relief and segmental bony responses.

Keywords Vertebral pseudarthrosis · Back pain · Percutaneous vertebroplasty · Remodeling · Bone union

Introduction

Vertebral pseudarthrosis is a relatively rare, painful condition associated with osteoporotic vertebral fractures [1–4]. To date, controversies still prevail regarding terminology, pathogenesis, and treatment of this condition. Accordingly, a variety of surgical procedures have been reported, including osteosynthesis [5], decompression and fusion surgeries by anterior [6, 7], posterior [7–9], and anteroposterior [10] approaches, percutaneous vertebroplasty (PVP) [11–13], and percutaneous kyphoplasty [14]. Whereas osteosynthesis and fusion surgeries aim at solid bone union for stabilization of the affected vertebra, union status following PVP or percutaneous kyphoplasty has not yet been addressed. In the present study, we evaluated clinical and radiographic outcomes of 14 patients with vertebral pseudarthrosis who had been treated with PVP, focusing on bone formation and union status.

Materials and methods

Between January 2006 and June 2008, 14 patients with vertebral pseudarthrosis were treated with PVP and evaluated for the union status by using sitting lateral and supine lateral radiographs (Table 1). Diagnosis of vertebral pseudarthrosis was determined by assessing clinical features, the presence of air- or fluid-containing intravertebral

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cleft and dynamic mobility of the cleft. Conventional anteroposterior and lateral radiographs, comparative sitting and supine lateral radiographs, CT scans with sagittal reconstruction, and magnetic resonance imaging (MRI) were taken in all patients preoperatively.

The indication of PVP is the treatment of symptomatic vertebral pseudarthrosis resistant to conservative treatments including medication and immobilization. The contraindications are ongoing local or systemic infections, poorly controlled coagulopathy, and retropulsion of the posterior wall resulting in myelopathy.

There were 11 female and 3 male patients with an average age of 78 (67–91 years). The affected vertebrae were distributed from T10 to L4. No patient exhibited neurological compromise. The average postoperative follow-up duration was 21 months (range 12–33).

PVP was carried out under local anesthesia. The patient was placed in the prone position on the operation table. Pillows were placed under the chest and the pelvis to reduce kyphotic deformity of the affected vertebra. Following small skin incisions, two needles were inserted through bilateral pedicles using an image intensifier. Contrast medium was then injected for vertebrography. In the majority of cases, the injected contrast medium came out from the other needle through an intravertebral cleft, without leakage outside the vertebra. In cases where the contrast medium leaked outside the vertebra, the contrast was injected from the other needle. Otherwise, the needles were reinserted. After washing out the contrast, PMMA cement (CEMEX[®], Exactech, USA) was injected using an injector (OsteojectTM, Sheen Mam

Co., Ltd., Japan). CEMEX[®] was chosen because it has a relatively low curing temperature [15]. Cement injection was discontinued when the cement reached the anterior two-thirds of the vertebral body. The amount of PMMA cement injected per vertebra was 3.4 ml on average (range 2.5–4.5). Postoperatively patients wore a hard body jacket for a period of 3 months.

Evaluation included back pain (visual analog scale: VAS), complications, the wedge angle of the affected vertebra, radiographic remodeling including callus and bony spur formation, and union status. The wedge angle of the vertebra was measured in lateral radiographs taken in the sitting position [16]. Radiographic remodeling was evaluated by serial anteroposterior and lateral (decubitus position) radiographs taken every 2–3 months during the postoperative follow-up. The radiographs were taken at a film-focus distance of 1.1 m. Callus was defined as the bone formation occurring within the affected vertebra, which bridges the pseudarthrosis area. Bony spur was determined as the bone formation emerging between the affected vertebra and the adjacent vertebrae. Union status was evaluated by measuring the dynamic mobility of the affected vertebra. Preoperatively vertebral dynamic mobility was calculated by measuring the difference of the vertebral height (anterior wall) between the sitting lateral radiograph and the supine lateral radiograph [17] (Fig. 1a, b). After PVP, the difference of the width of the radiolucent zones adjacent to the PMMA cement was alternatively used to represent dynamic mobility of the vertebra (Fig. 1c, d). Vertebrae were referred to as union

Table 1 Clinical and radiographic features of patients

Case	Age	Gender	Location	VAS (mm)		Wedge angle (degree)		Mobility (mm)		Radiographic remodeling	Follow-up (months)
				Preop.	Final	Preop.	Final	Preop.	Final		
1	87	F	T10	100	8	30	13	8	2	C, S, E	12
2	72	M	T11	31	0	34	23	3	2	C, S	33
3	78	F	T11	55	22	28	18	5	1	C, S	12
4	67	M	T12	30	7	26	20	5	2	S	27
5	78	F	T12	55	7	21	5	7	1	C, S, E	24
6	73	F	T12	65	0	23	13	4	1	S	20
7	75	F	T12	42	11	13	12	6	1	S	18
8	69	F	T12	38	5	18	14	8	1	S, E	13
9	81	F	L1	35	0	22	20	9	2	S, E	17
10	82	F	L1	38	5	28	15	5	1	S	13
11	74	F	L2	81	40	20	8	10	1	S	33
12	77	F	L3	65	55	27	20	5	0 ^a	S, E	12
13	83	F	L4	90	27	5	4	8	1	S	30
14	91	M	L4	84	10	8	0	14	0 ^a	S	24

C callus formation, S spur formation, E erosion of the adjacent endplate

^a Bone union

when they did not show any dynamic mobility. VAS score, wedge angle, and vertebral dynamic mobility were measured before surgery and at the final follow-up. In some patients, dynamic mobility of the vertebra was measured at different points during follow-up. The Student *t* test was used for statistical analysis and a probability of less than 0.05 was determined as a significant difference.

Results

To determine the role of PVP in bone formation and union of vertebral pseudarthrosis, we evaluated the clinical and radiographic outcomes of 14 patients. Back pain improved in all 14 patients with the VAS score of 57.8 ± 23.5 mm (average $\pm$ standard deviation) preoperatively and 14.7 ± 16.4 mm at the final follow-up (Table 1). The difference was statistically significant ($P < 0.001$). Complications

included cement leakage in three patients and a compression fracture of the adjacent vertebra in one patient. The cement leaked anterior to the vertebral body in two patients and the adjacent intervertebral disc in one patient. The wedge angle decreased from $21.6^\circ \pm 8.3^\circ$ (average $\pm$ standard deviation) preoperatively to $13.2^\circ \pm 6.9^\circ$ at the final follow-up ($P < 0.001$).

Callus formation was seen in four patients. As representatively shown in Fig. 2, there was a cortical defect of the anterior wall in the T12 vertebral body before and immediately after PVP. Three months following PVP, bone formation emerged over the anterior surface of the cement. The bone arose from both the superior and the inferior edges of the cortical defect in the anterior wall. Bony spurs of the affected vertebra were seen in preoperative radiographs of all patients. As representatively shown in Figs. 3 and 4, bony spurs further developed to a solidified form during follow-up after PVP. Beside these bone formation, five patients showed signs of erosion of the endplate of the adjacent vertebra corresponding to the PMMA cement (Figs. 1, 2, 5).

Dynamic mobility of the affected vertebrae was 6.9 ± 2.9 mm (average $\pm$ standard deviation) preoperatively, which fell to $1.1^\circ \pm 0.7^\circ$ at the final follow-up ($P < 0.001$). Notably, all patients showed a dynamic vertebral mobility of 2 mm or less (Table 1). Nevertheless, only two patients (cases 12 and 14) exhibited the dynamic vertebral mobility of 0 mm at the final follow-up, which is referred to as bone union (Figs. 4, 5).

Fig. 1 Case 1. Evaluation of dynamic mobility. Pseudarthrosis of the T10 vertebra. The height of the anterior wall of the T10 vertebra was 2 mm in the preoperative sitting lateral radiograph (a) and 10 mm in the preoperative supine lateral radiograph (b). The preoperative dynamic mobility of the T10 vertebra was thus calculated as 8 mm. At the final follow-up, there was no radiolucent zone around the PMMA cement in the sitting lateral radiograph (c), whereas radiolucent zones (arrowheads) emerged above and below the cement (d). The width of the radiolucent zones were measured as 1 mm, respectively, indicating a dynamic mobility of 2 mm at the final follow up. The emergence of radiolucent zones around the cement indicates that bone union has not been achieved. In addition, erosion of the lower endplate of the T9 vertebra was seen in c and d

Discussion

In the present study, we analyzed 14 patients with vertebral pseudarthrosis, focusing on radiographic changes and union status following PVP. We found that PVP induces segmental remodeling including bony spur and callus formation and erosion of the endplate of the adjacent vertebra. However, this procedure rarely achieved bone union as 12 of the 14 vertebrae showed residual dynamic mobility at the final follow-up in the sitting and supine lateral radiographs. These radiographic findings indicate that PVP possibly plays a role in converting an atrophic to a hypertrophic vertebral pseudarthrosis, by serving as a mechanical stabilizer.

A concern for treatment with PVP is the durability of its stabilizing effects. Recently, Lin et al. [18] reported on the presence of fluid between the cement interface and the residual bone following PVP. This fluid sign, as defined by magnetic resonance imaging, was observed in 8 of 22 vertebrae with intravertebral clefts at an average of 54.5 days after PVP. These observations indicate residual micromotion of the intravertebral clefts following PVP.

Fig. 2 Case 5. Pseudarthrosis of the T12 vertebra showing formation of callus. Preoperative T1-weighted (a) and T2-weighted (b) sagittal MR images exhibiting an accumulation of fluid in the intravertebral cleft in the T12 vertebral body. A lateral radiograph (c) taken immediately after PVP shows a defect of the anterior cortex of the T12 vertebral body. Three months after PVP, the lateral radiograph showed bone formation over the anterior surface of the PMMA

cement, representing callus (d). At the final follow-up (24 months postoperatively), the sitting lateral (e) and supine lateral (f) radiographs exhibited solid bone covering the anterior surface of the PMMA cement. However, there was a radiolucent area above the PMMA cement in the supine lateral radiograph (arrowheads in f), indicating that complete union has not been achieved. In addition, erosion of the lower endplate of the T11 vertebra was seen in d–f

Fig. 3 Case 7. Pseudarthrosis of the T12 vertebra showing bony spur. A preoperative reconstruction CT scan image (a) showed the presence of the intravertebral cleft and a defect of the anterior wall of the T12 vertebra. b An anteroposterior radiograph taken immediately after PVP revealed bony spurs between T12 and L1 vertebrae. c Eighteen months after PVP, bony spurs between T12 and L1 vertebrae became solid (arrows) and bridged across each other

Despite the presence of intravertebral micromotion, mechanical failures such as the dislodgement of PMMA cement have not been reported in the literature [11–13] or in the present study. This may be attributed to relatively short follow-up periods in these studies. Nevertheless, it is also possible that the segmental remodeling emerging after PVP complemented the limited stabilizing effects of PVP.

PVP has been performed in patients with vertebral pseudarthrosis [11–13, 19] and much more widely in patients with vertebral compression fractures [19–21]. The suitability of PVP for incident vertebral fractures remains controversial. One reason for such controversy is the lack of studies evaluating bone union status following PVP for incident fracture, as bone union is a standard endpoint of

Fig. 4 Case 14. Pseudarthrosis of the L4 vertebra showing bony spur formation and bone union. A T2-weighted sagittal MR image (a) represented an accumulation of fluid in the intravertebral cleft. Compared to the anteroposterior radiograph immediately after PVP (b), follow-up radiographs taken at 3 months (c), 6 months (d) and 1 year (e) after PVP exhibited the development of a bridging bony spur between L3 and L5 vertebrae, in association with a decrease in the height of the L4 vertebral body. At the final follow-up (2 years postoperatively), L3, L4 and L5 vertebrae were fused with solid bony spurs (f)

Fig. 5 Case 12. Pseudarthrosis of the L3 vertebra showing bone union. A preoperative reconstruction CT scan image (a) showed accumulation of air in the intravertebral cleft, which was communicated with the intradiscal air in the L2/L3 intervertebral disc. Three months after PVP, there was no radiolucent zone in the sitting lateral radiograph (b). In contrast, the radiolucent zones emerged above and below the PMMA cement (arrowheads) in the supine lateral radiograph (c). Eight months after PVP, the L3 vertebra united with the L2 vertebra with bony spurs, and no radiolucent zones were seen around PMMA cement in the sitting lateral (d) and the supine lateral (e) radiographs, an indication of union of the pseudarthrosis. In addition, erosion of the lower endplate of the L2 vertebra was seen in b–e

treatment for fractures. In this regard, comparative sitting and supine lateral radiographs constitute a simple and effective evaluation method for union of vertebral fracture.

A small number of patients, short follow-up periods, and the absence of a control group represent limitations of this

study. Because of the rarity of vertebral pseudarthrosis, other studies of PVP for vertebral pseudarthrosis comprised of 20 or fewer patients [11–13, 19]. Unless we conduct a comparative analysis with a control group, we are not able to answer the question whether or not PVP can change the

natural history of vertebral pseudarthrosis. Segmental remodeling observed in the present study may also naturally occur in vertebral pseudarthrosis. We consider it more important to determine if PVP prevents progression of the vertebral collapse and development of collapse-related myelopathy.

In conclusion, this is the first report evaluating radiographic remodeling and union status following PVP. Dynamic stabilization obtained by PVP leads to immediate pain relief and biological bony responses. It remains to be determined if this concept can apply to incident fracture cases treated with PVP.

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