


RESEARCH ARTICLE

Bone Cement and Pedicle Screw for the Treatment of Spinal Tumors with Spinal Cord Compression and Posterior Wall Defects

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Objective: To compare the safety and efficacy of posterior internal fixation with open vertebroplasty (VP) and posterior internal fixation with open kyphoplasty (KP) in the treatment of metastatic epidural spinal cord compression (MESCC) with posterior wall destruction.

Methods: This retrospective study, conducted between January 2016 and May 2019, equally divided 60 patients with MESCC and posterior wall destruction into two groups based on the surgical method: open vertebroplasty with pedicle screw fixation (VP group) and open kyphoplasty with pedicle screw fixation (KP group). Visual analogue scale (VAS), SF-36 scores, middle vertebral height (MVH), and posterior vertebral height (PVH) were evaluated for the two groups preoperatively, postoperatively, and 1 year after surgery. Spinal Instability Neoplastic Score, Frankel grades and complications were recorded and evaluated.

Results: Five patients were excluded from the analysis, and our study cohort consisted of 55 adult patients who met the inclusion criteria. The VAS and SF-36 scores of these two groups of patients significantly improved, when compared with those before the surgery ($P < 0.05$). There were significant differences in total cost (8835 ± 1468 vs 9540 ± 053 USD) and cement volume (4.51 ± 0.96 ml vs 6.35 ± 1.09 ml) between two groups ($P < 0.05$). The MVH and PVH of these two groups of patients significantly improved, when compared with those before the surgery ($P < 0.05$). The MVH was significantly larger in the KP group than in the VP group postoperatively (20.15 ± 4.86 vs 17.70 ± 3.78 , $P < 0.05$) and at the final follow-up (20.42 ± 5.59 vs 17.28 ± 3.23 , $P < 0.05$). However, the PVH of the two groups did not significantly differ at the two postoperative follow-ups ($P > 0.05$). No significant differences were found in surgery time, time from surgery to discharge, blood loss and complications between both groups postoperatively ($P > 0.05$).

Conclusion: In the short term, both approaches are effective and safe in patients with MESCC and posterior wall destruction. The posterior internal fixation with open VP may be a good choice of surgical method in patients with MESCC and posterior wall defects.

Key words: Kyphoplasty; Metastatic spinal tumors; Pedicle screw fixation; Spinal cord compression; Vertebroplasty

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Introduction

Skeletal metastases often involve the spinal column, 70% of patients with cancer will exhibit spinal disease, particularly in the thoracic spine, followed by lumbar spine and cervical spine.¹ Metastatic spinal tumors cause bone insufficiency resulting in spinal fractures and are a major contributor to morbidity in patients with cancer.² Metastatic epidural spinal cord compression (MESCC) occurs when an epidural metastatic lesion produces secondary compression of the spinal cord. This is reported in 5%–10% of patients with cancer, particularly with breast, lung, and prostate cancer.³ MESCC is a debilitating complication of metastatic spine disease that restricts movement and sensation, promotes sexual dysfunction, and leads to urinary and fecal incontinency.⁴ The estimated median survival rate of patients with MESCC is 3–7 months, with a 36% probability of survival rate spanning 12 months.⁵

The treatment of metastatic spinal tumors is complex and challenging, requiring a comprehensive treatment that includes surgery, radiotherapy, and chemotherapy.^{6–8} The surgical treatment of spinal metastases is aimed at pain relief, maintenance and/or restoration of nerve function, as well as for preserving spinal stability.⁹ Total en bloc spondylectomy (TES) was the ideal choice in the past. However, this radical procedure can induce secondary spinal instability and is associated with extensive dissection, massive blood loss, and long surgical duration with poor recovery.¹⁰ Bone cement augmentation procedures like kyphoplasty (KP) and vertebroplasty (VP) were first introduced for treating pathologic compression fractures in the 1990s and have been shown to be highly effective in the treatment of metastatic spinal disease.^{11,12} The major complication of VP and KP is bone cement leaking into the spinal canal or nerve root foramen, which can lead to spinal cord compression, radiculopathy, and related complications. Patients with MESCC usually present neurological deterioration due to the compression of neurologic areas and therefore require decompression and stabilization. Wenger *et al.* introduced the concept of open VP or open KP, which has shown satisfactory clinical outcomes in patients with MESCC.^{13,14}

In this study, we retrospectively analyzed patients who received open VP or open KP combined with pedicle screw fixation *via* a posterior midline approach in the treatment of MESCC and posterior wall defects. The present study aims: (i) to assess the safety and effectiveness of pedicle screw fixation combined with open VP or open KP; (ii) to assess the clinical outcomes of visual analogue scale (VAS), SF-36 score, Frankel grade, operation time, blood loss, time from surgery to discharge, total cost, cement volume, and complication between the KP and VP cohorts after surgery; and (iii) to evaluate the radiographic outcomes of the middle vertebral height (MVH) and posterior vertebral height (PVH) between the KP and VP cohorts.

Material and Methods

Patients

This study was approved by the Ethics Committee of the First Affiliated Hospital of Soochow University (No. 2020-312).

Between January 2016 and May 2019, 60 patients who underwent an open VP or open KP combined with pedicle screw fixation procedure for MESCC and posterior wall defects were enrolled.

Patients included: (i) patients having metastatic vertebral tumors with epidural spinal cord compression and posterior wall defects; (ii) posterior internal fixation with open VP and posterior internal fixation with open KP; (iii) comparison of clinical and radiological outcomes between the VP and KP groups.

The exclusion criteria were: (i) patients with intolerance to potential surgical complications, such as infections, psychiatric disorders and coagulation disorders; (ii) those diagnosed with primary malignant spinal tumors; (iii) no valid follow-up information; and (iv) those with expected survival less than 1 year were excluded.

Surgical Procedures

Anesthesia and Position

All surgeries were performed by the same surgeon. The patient was placed in the extended prone position after the induction of general anesthesia.

Approach and Decompression

A laminectomy was first performed to achieve decompression of the spinal cord and tumor debulking through a posterior approach to the vertebral column. The extent of decompression and tumor debulking was according to the range of compressive nerve instead of total removal of the pathological vertebral body and the tumor mass.

Bone Cement Injection and Placement

The pedicle screws were then put in place under C-arm guidance at the levels above and below the targeted vertebra. The vertebroplasty was then performed through a transpedicular approach. Finally, the sextant rods were placed, and the nut was locked (Figs. 1 and 2).

Preoperative and/or Postoperative Therapy

Chemotherapy and/or radiation therapy was offered to patients preoperatively and/or postoperatively to achieve local control of the lesion and avoid postoperative complications.

Clinical and Radiographic Evaluation

The Spinal Instability Neoplastic Score (SINS)

SINS is a reproducible and reliable evaluation of spinal stability. It considers the lesion location, mechanical pain, bone lesion, radiographic spinal alignment, vertebral body collapse, and posterolateral involvement. Based on SINS, patients were divided into three categories: those with stable (0–6), potentially unstable (7–12), and unstable (13–18) spines.

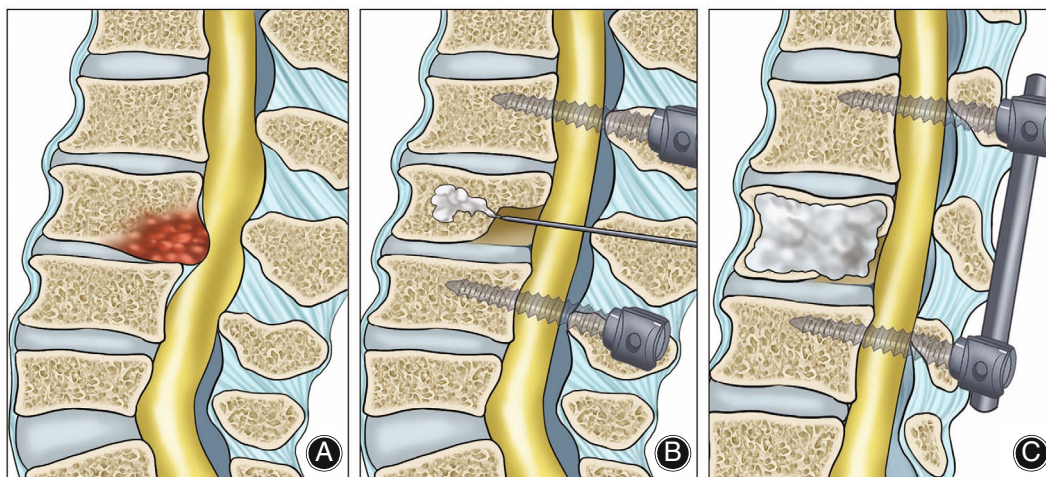


Fig. 1 (A) The tumor tissue at the posterior wall invading the vertebral canal to compress the spinal cord. (B) The pedicle screws were placed at the levels above and below the targeted vertebra. VP was then performed using a transpedicular approach. (C) The sextant rods were placed, and the nut was locked

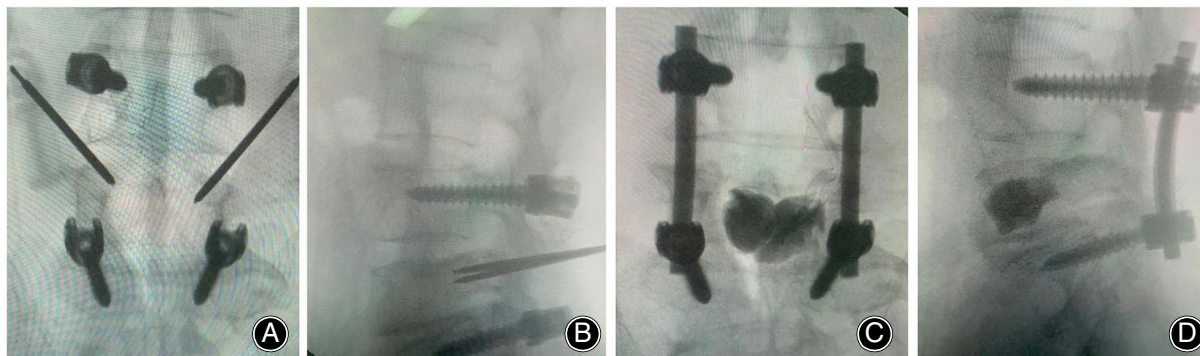


Fig. 2 (A) Placement of four pedicle screws using a C-arm machine at L5. (B) The screws accurately penetrate the pedicle into the vertebral body. (C) Polymethylmethacrylate (PMMA) was injected into the L5 diseased vertebral body. (D) No leakage of PMMA was observed after surgery

Frankel Grades

This system provides an assessment of spinal cord function at five grades. Grade A: complete loss of motor and sensory function, Grade B: incomplete sensory but no motor function, Grade C: preserved nonfunctional motor, Grade D: preserved functional motor, and Grade E: normal motor and sensory function.

Visual Analogue Scale (VAS)

This is the most commonly used questionnaire to assess the degree of pain. The degree of pain was evaluated by a 10-point VAS scoring system. A score of 0 represents no pain and a score of 10 represents the most severe pain.

Short Form-36 (SF-36)

This questionnaire is a comprehensive tool for assessing health-related quality of life. The 10-item SF-36 physical

function (PF), two-item SF-36 body pain (BP), four-item SF-36 vitality (VT), and two-item SF-36 social function (SF) was used to evaluate the quality of life of the patients. The higher the score, the better is the quality of life.

Vertebral Height

Changes in MVH and PVH were measured in lateral X-ray films. The MVH and PVH represented the distance between the upper and lower endplates in the center of the vertebra and at the posterior, respectively (Figure 3A). Two observations were made at an interval of at least 2 weeks by two orthopedic surgeons, and mean values were used for the study.

Statistical Analysis

All data were collected and analyzed using IBM SPSS software (SPSS 23.0, Armonk, NY, USA). All results are presented as

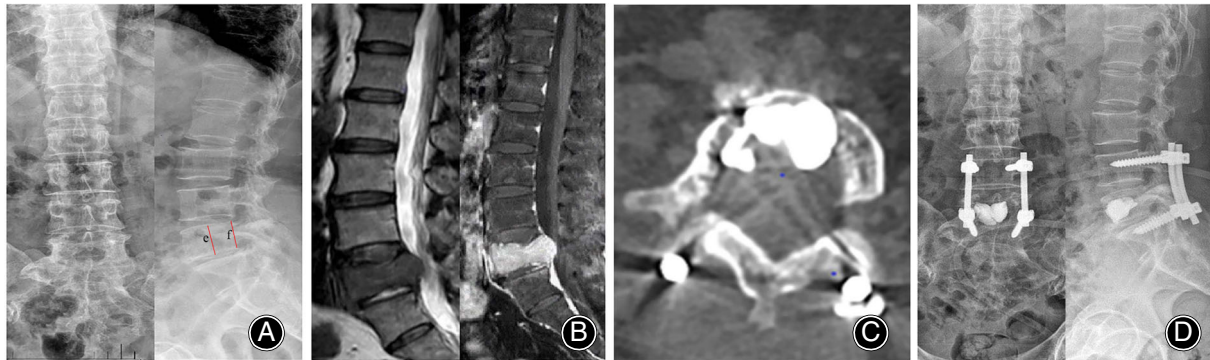


Fig. 3 Case A. Results obtained in a 71-year-old female with a history of thyroid cancer who presented with unbearable back pain. (A) Preoperative X-ray examination showed that the vertebral body of L5 was demolished. (B) Sagittal MR image showed cord compression at L5 caused by a metastatic lesion. We performed short posterior instrumentation at L4-S1 and vertebroplasty at L5 with cement augmentation. (C) Postoperative CT showed that the turgor of bone cement was good with no leakage. (D) Postoperative X-ray examination demonstrated well-fixed cement and stable spine alignment

mean \pm standard deviation. Student's *t*-test or analysis of variance was used for measurement data including VAS, SF-36 score, MVH, and PVH. The Pearson's chi-square test and the Fisher's exact test were used for categorical data, including gender, primary tumor, and complications. $P < 0.05$ was considered statistically significantly.

Results

Demographic Data

Sixty patients with metastatic spinal tumors were followed up for 1 year, of which five were excluded from the analysis (two died, and three were lost to follow-up). Thus, our study cohort consisted of 55 adult patients (27 in the VP group and 28 in the KP group). No significant difference was observed in the general data (age, gender, primary tumors, treatment level) between these two groups (Table 1).

Surgical Outcomes

The VP group had a surgery time of 172.63 ± 40.28 min, amount of bleeding of 284.82 ± 156.19 mL, volume of bone cement of 4.51 ± 0.96 mL, and time from surgery to discharge of 6.93 ± 3.04 days. Complications included deep wound infections ($n = 2$, 7.4%), neurologic deterioration ($n = 2$, 7.4%), and cement leakage ($n = 2$, 7.4%). Out of two, one case of cement leakage was into the adjacent intervertebral disc space, and the other case was anteriorly into the fractured part of the vertebra but without associated clinical symptoms. The total cost of the procedure was 8835 ± 1468 USD with a tumor recurrence rate of 3.7% ($n = 1$). The KP group had a surgery time of 187.32 ± 30.93 min, amount of bleeding of 281.80 ± 134.20 mL, volume of bone cement of 6.35 ± 1.09 mL, and time from surgery to discharge of 6.54 ± 2.52 days. Complications included deep wound infections ($n = 3$, 10.7%) and neurologic deterioration ($n = 1$, 3.6%). No cement leakage occurred

in these patients after surgery. The total cost of the procedure was 9540 ± 1053 USD with a tumor recurrence rate of 14.3% ($n = 4$). Significant differences in the total cost ($t = 2.025$, $P = 0.044$) and volume of bone cement after operation ($t = 6.634$, $P < 0.001$) were observed between the two groups (Table 1).

Clinical and Radiographic Evaluation

Spinal Instability Neoplastic Score

The VP and KP groups had a mean preoperative SINS of 10.93 ± 0.99 and 11.25 ± 0.97 , respectively. The postoperative SINS did not differ between the groups ($t = 1.211$, $P = 0.227$) (Table 1).

Frankel Grade

Neurologic status improved by one grade in 12 patients and by two grades in 2 patients, whereas the remaining patients had the same neurologic status in both the VP and KP groups, postoperatively. Decreased neurologic function was not noted in any patient from the VP group (Table 2) or KP group (Table 3).

Visual Analogue Scale

The VP group had preoperative VAS scores of 8.19 ± 0.98 in all patients, which decreased to 3.04 ± 0.92 postoperatively and 2.70 ± 0.80 at the final follow-up. Significant differences between preoperative and postoperative VAS scores and between preoperative and final follow-up VAS scores were noted in the VP group ($F = 298.321$, $P < 0.001$) (Table 4). Differences between postoperative and final follow-up values were not significant.

The KP group had preoperative VAS scores of 8.36 ± 0.83 in all patients, which decreased to 2.93 ± 0.86 postoperatively and 2.68 ± 0.82 at the last follow-up. Significant differences between preoperative and postoperative VAS

TABLE 1 General characteristics of the patients

Characteristic	VP	KP	t/χ^2	P
Patient				
Number	27	28		
Age	63.7 ± 11.4	61.0 ± 11.0	0.770	0.452
Gender (female/male)	10/17	8/20	0.447	0.504
Primary tumors				
Lung	8 (29.6%)	10 (35.7%)	—	0.631
Breast	6 (22.2%)	5 (17.9%)	—	0.686
Liver	3 (11.1%)	4 (14.3%)	—	1.000
Gastrointestinal	3 (11.1%)	0 (0%)	—	0.111
Colon	2 (7.4%)	4 (14.3%)	—	0.669
Kidney	1 (3.7%)	1 (3.6%)	—	1.000
Thyroid	1 (3.7%)	0 (0%)	—	0.491
Multiple myeloma	1 (3.7%)	1 (3.6%)	—	1.000
Others	2 (7.4%)	3 (10.7%)	—	1.000
Treatment level				
Thoracic	20	16		
Lumbar	11	13		
Pre-op SINS	10.93 ± 0.99	11.25 ± 0.97	1.211	0.227
Surgery				
Operative time (min)	172.63 ± 40.28	187.32 ± 30.93	1.520	0.138
Blood loss (ml)	284.82 ± 156.19	281.80 ± 134.20	0.077	0.939
Time from surgery to discharge (day)	6.93 ± 3.04	6.54 ± 2.52	0.519	0.610
Total cost (US dollar)	8835 ± 1468	9540 ± 1053	2.025	0.044
Cement volume (ml)	4.51 ± 0.96	6.35 ± 1.09	6.634	0.000
Complication				
Cement leakage	2 (7.4%)	0 (0%)	—	0.236
Infection	2 (7.4%)	3 (10.7%)	—	1.000
Neurologic deterioration	2 (7.4%)	1 (3.6%)	—	0.611
Local recurrence	1 (3.7%)	4 (14.3%)	—	0.352

Note: Bold represents there is statistical significance between the groups, $p < 0.05$.

TABLE 2 Distribution of Frankel grade pre- and postoperatively in the VP group

Preoperation	Postoperation					Total
	A	B	C	D	E	
A	2	0	0	0	0	2
B	0	0	2	0	0	2
C	0	0	1	3	2	6
D	0	0	0	3	7	10
E	0	0	0	0	7	7
Total	2	0	3	6	16	27

TABLE 3 Distribution of Frankel grade pre- and postoperatively in the KP group

Preoperation	Postoperation					Total
	A	B	C	D	E	
A	2	0	0	0	0	2
B	0	1	0	0	0	1
C	0	0	3	4	2	9
D	0	0	0	1	8	9
E	0	0	0	0	7	7
Total	2	1	3	5	17	28

scores and between preoperative and final follow-up VAS scores were noted in the KP group ($F = 414.097$, $P < 0.001$) (Table 4). Differences between postoperative and final follow-up values were not significant. The two groups did not significantly differ preoperatively, postoperatively, and at the last follow-up. Furthermore, for female patients, the VAS scores measured after surgery and at the last follow-up did not significantly differ between the groups (3.30 ± 1.16 vs 2.75 ± 0.89 , $t = 1.104$, $P = 0.286$; 2.90 ± 0.99 vs 2.50 ± 0.93 , $t = 0.890$, $P = 0.387$). For male patients, the VAS scores measured after surgery and at the last follow-up between both the groups showed no significant differences (2.89 ± 0.78 vs 3.00 ± 0.89 , $t = 0.396$, $P = 0.694$; 2.59 ± 0.71 vs 2.75 ± 0.79 , $t = 0.597$, $P = 0.525$).

SF-36

In the VP group, the SF-36 scores for BP improved from 19.63 ± 9.63 preoperatively to 52.22 ± 9.17 postoperatively ($t = 12.735$, $P < 0.001$) and to 53.33 ± 8.61 at the last follow-up. The SF-36 scores for PF improved from 27.96 ± 7.73 preoperatively to 52.40 ± 7.50 postoperatively ($t = 10.595$, $P < 0.001$) and to 53.15 ± 8.18 at the last follow-up. The SF-36 scores for VT improved from 27.59 ± 8.86 preoperatively to 51.48 ± 7.80 postoperatively

TABLE 4 Radiographic and clinical evaluation

Evaluation	VP	KP	t-Value	P-Value
VAS				
Preoperative	8.19 ± 0.98	8.36 ± 0.83	0.695	0.490
Postoperative	3.04 ± 0.92 ^a	2.93 ± 0.86 ^a	0.458	0.700
1 year postoperatively	2.70 ± 0.80 ^a	2.68 ± 0.82 ^a	0.092	0.910
F-Value ^b	298.321	414.097		
P-Value ^b	0.000	0.000		
SF-36, BP				
Preoperative	19.63 ± 9.63	17.50 ± 7.37	0.923	0.360
Postoperative	52.22 ± 9.17 ^a	51.79 ± 9.28 ^a	0.173	0.864
1 year postoperatively	53.33 ± 8.61 ^a	52.86 ± 8.39 ^a	0.205	0.838
F-Value ^b	114.152	155.291		
P-Value ^b	0.000	0.000		
SF-36, PF				
Preoperative	27.96 ± 7.73	28.57 ± 6.80	0.311	0.757
Postoperative	52.40 ± 7.50 ^a	53.21 ± 6.58 ^a	0.423	0.678
1 year postoperatively	53.15 ± 8.18 ^a	53.39 ± 8.35 ^a	0.108	0.915
F-Value ^b	87.583	103.775		
p-Value ^b	0.000	0.000		
SF-36, VT				
Preoperative	27.59 ± 8.86	28.57 ± 8.11	0.428	0.670
Postoperative	51.48 ± 7.80 ^a	51.96 ± 8.17 ^a	0.223	0.825
1 year postoperatively	52.59 ± 9.37 ^a	52.32 ± 9.30 ^a	0.107	0.915
F-Value ^b	68.559	68.490		
P-Value ^b	0.000	0.000		
SF-36, SF				
Preoperative	26.39 ± 12.42	25.89 ± 12.01	0.152	0.880
Postoperative	50.46 ± 11.53 ^a	51.79 ± 11.43 ^a	0.430	0.669
1 year postoperatively	48.61 ± 9.21 ^a	50.45 ± 9.14 ^a	0.744	0.460
F-Value ^b	37.622	48.012		
P-Value ^b	0.000	0.000		
MVH				
Preoperative	12.99 ± 3.84	13.83 ± 4.36	0.757	0.458
Postoperative	17.70 ± 3.78 ^a	20.15 ± 4.86 ^a	2.082	0.042
1 year postoperatively	17.28 ± 3.23 ^a	20.42 ± 5.59 ^a	2.538	0.018
F-Value ^b	12.508	15.807		
P-Value ^b	0.000	0.000		
PVH				
Preoperative	14.90 ± 4.22	15.51 ± 4.23	0.535	0.600
Postoperative	21.50 ± 3.13 ^a	22.66 ± 4.42 ^a	1.119	0.276
1 year postoperatively	21.10 ± 3.67 ^a	22.09 ± 4.17 ^a	0.933	0.369
F-Value ^b	26.023	24.154		
P-Value ^b	0.000	0.000		

Notes: Bold represents there is statistical significance between the groups, $P < 0.05$; Abbreviations: BP, bodily pain; KP, kyphoplasty; MVH, middle vertebral height; PF, physical function; PVH, posterior vertebral height; SF, social function; SINS, the spinal instability neoplastic score; VAS, visual analogue scales; VP, vertebroplasty; VT, vitality.; ^aStatistically significant compared with the preoperative, $P < 0.05$.; ^bBy ANOVA test.

($t = 10.694$, $P < 0.001$) and to 52.59 ± 9.37 at the last follow-up. The SF-36 scores for SF improved from 26.39 ± 12.42 preoperatively to 50.46 ± 11.53 postoperatively ($t = 8.528$, $P < 0.001$) and to 48.61 ± 9.21 at the last follow-up. All SF-36 scores significantly differed between preoperative and postoperative values and between preoperative and final follow-up values (BP, $F = 114.152$, $P < 0.001$; PF, $F = 87.583$, $P < 0.001$; VT, $F = 68.559$, $P < 0.001$; SF, $F = 37.622$, $P < 0.001$) (Table 4), whereas the differences between postoperative and final follow-up values were not significant.

In the KP group, SF-36 scores for BP improved from 17.50 ± 7.37 preoperatively to 51.79 ± 9.28 postoperatively

($t = 15.311$, $P < 0.001$) and to 52.86 ± 8.39 at the last follow-up. The SF-36 scores for PF improved from 28.57 ± 6.80 preoperatively to 53.21 ± 6.58 postoperatively ($t = 13.779$, $P < 0.001$) and to 53.39 ± 8.35 at the last follow-up. The SF-36 scores for VT improved from 28.57 ± 8.11 preoperatively to 51.96 ± 8.17 postoperatively ($t = 10.751$, $P < 0.001$) and to 52.32 ± 9.30 at the last follow-up. The SF-36 scores for SF improved from 25.89 ± 12.01 preoperatively to 51.79 ± 11.43 postoperatively ($t = 8.266$, $P < 0.001$) and to 50.45 ± 9.14 at the last follow-up. All SF-36 scores significantly differed between preoperative and postoperative values and between preoperative and final follow-up values (BP, $F = 155.291$, $P < 0.001$;

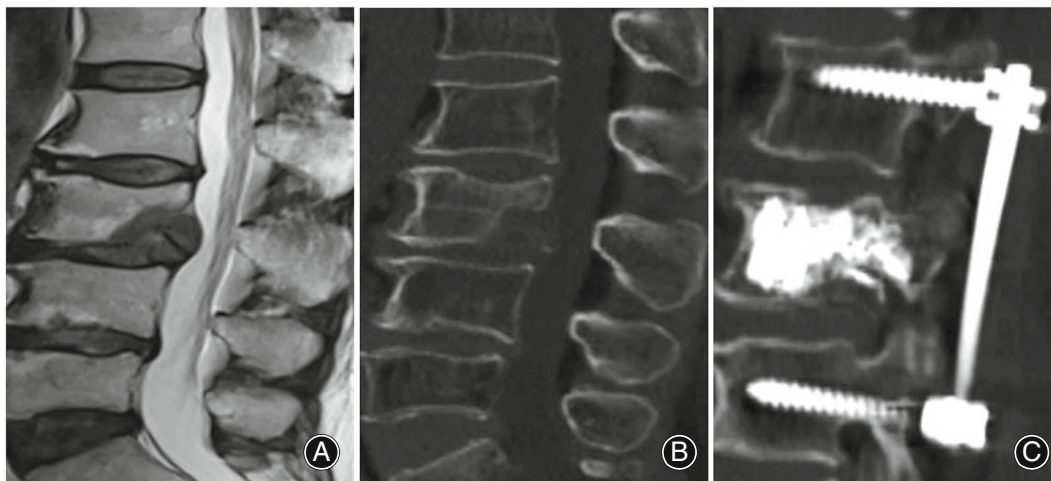


Fig. 4 Case B. A 68-year-old female with spinal metastases from lung cancer. (A) Sagittal MR image demonstrating spinal cord compression. (B) Sagittal CT reconstruction revealing VB collapse. (C) Postoperative sagittal CT reconstruction demonstrating an improvement of the collapsed VB and reduction of the local kyphosis after open KP and osteosynthesis

PF, $F = 103.775$, $P < 0.001$; VT, $F = 68.490$, $p < 0.001$; SF, $F = 48.012$, $P < 0.001$) (Table 4), whereas the differences between postoperative and final follow-up values were not significant. No significant difference was observed between two groups preoperatively, postoperatively, and at the final follow-up.

Vertebral Height

In the VP group, the MVH increased from 12.99 ± 3.84 mm preoperatively to 17.70 ± 3.78 mm postoperatively ($t = 1.997$, $P < 0.001$) and to 17.28 ± 3.23 mm at the last follow-up. The PVH increased from 14.90 ± 4.22 mm preoperatively to 21.50 ± 3.13 mm postoperatively ($t = 6.053$, $P < 0.001$) and to 21.10 ± 3.67 mm at the last follow-up. In the VP group, the MVH and PVH significantly differed between preoperative and postoperative values and between preoperative and final follow-up values (MVH, $F = 12.508$, $P < 0.001$; PVH, $F = 26.023$, $P < 0.001$) (Table 4), whereas the differences between postoperative and final follow-up values were not significant.

In the KP group, the MVH increased from 13.83 ± 4.36 mm preoperatively to 20.15 ± 4.86 mm ($t = 6.231$, $P < 0.001$) postoperatively and to 20.42 ± 5.59 mm at the last follow-up. The PVH increased from 15.51 ± 4.23 mm preoperatively to 22.66 ± 4.42 mm ($t = 5.872$, $P < 0.001$) postoperatively and to 22.09 ± 4.17 mm at the last follow-up. The MVH and PVH significantly differed between preoperative and postoperative values and between preoperative and final follow-up values (MVH, $F = 15.807$, $P < 0.001$; PVH, $F = 24.154$, $P < 0.001$) (Table 4), whereas the differences between postoperative and final follow-up values were not significant. No significant difference was observed in terms of MVH and PVH between the two groups before the surgery. However, MVH in the KP group was significantly larger than that in the VP group postoperatively ($t = 2.082$,

$P = 0.042$) (Table 4) and at the final follow-up ($t = 9.265$, $P = 2.538$) (Table 4). Furthermore, for female patients from both groups, the postoperative MVH and MVH at the last follow-up showed no significant differences (18.26 ± 3.53 vs 21.50 ± 5.38 , $t = 1.540$, $P = 0.143$; 17.88 ± 3.48 vs 21.76 ± 6.23 , $t = 1.854$, $P = 0.082$). However, for male patients from both groups, the postoperative MVH and MVH at the last follow-up significantly differed (17.37 ± 3.02 vs 19.62 ± 3.59 , $t = 2.041$, $P = 0.048$; 16.92 ± 3.89 vs 19.90 ± 4.81 , $t = 2.422$, $P = 0.021$).

Typical cases are shown in Figures 3–5.

Discussion

Spinal metastases are generally treated by chemotherapy, radiotherapy, and surgery. Surgical treatment can only be considered when the patient's expected survival time is more than 3 months.¹⁵ Complete resection seems to be the best approach for patients with spinal metastatic disease. However, complete resection of spinal lesions is typically associated with extensive dissection and blood loss, long operation time, and short expected survival. For most patients with spinal metastases, extensive surgery is not justified given their short life expectancy.^{16,17} In this study, the extent of decompression and tumor debulking was based on the range of compressive nerve instead of total removal of the pathological vertebral body and tumor mass. The objectives of the surgical procedures were to resolve neurological dysfunction, stabilize the spine, and achieve pain relief.¹⁸

Clinical Outcomes and Spinal Stability of Open VP and Open KP in the Treatment of Metastatic Spinal Tumors

The treatment plan for patients with metastatic spinal disease is generally palliative. One of the major manifestations of this disease and the first to be addressed is acute pain.

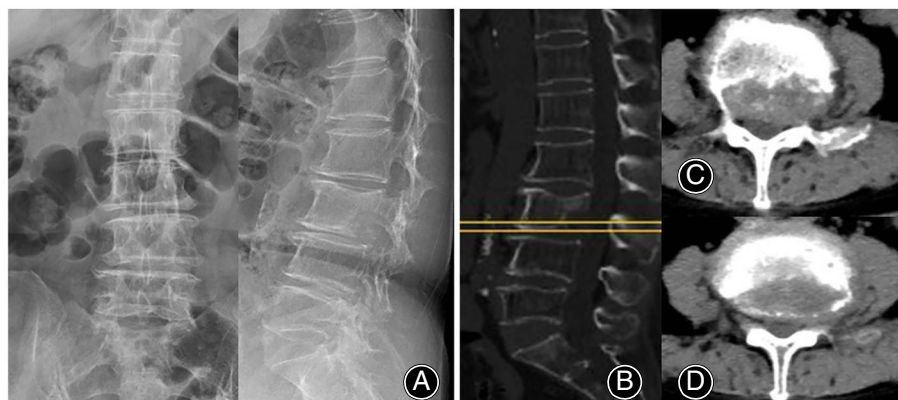


Fig. 5 Preoperative X-ray and CT examinations of the illustrative case B (A, B, C, D) Preoperative X-ray and CT examinations showed the change in the shape of the L3 vertebral body and destruction of the vertebral body bone involving posterior wall damage

This pain usually stems from tumor invasion and subsequent mechanical instability. In this study, we demonstrated that both open VP and open KP had high efficacy in alleviating pain, and this effect was maintained till the last follow-up. The enhanced spinal stability may have contributed to pain reduction along with tumor necrosis and destruction of sensory nerve endings.¹⁹ However, the difference in VAS scores between the two groups was insignificant at each follow-up assessment postoperatively, which illustrates that KP provides no better result of pain relief compared with VP in this study. In addition, significant improvement in SF-36 scores was also found in both groups for the domains of bodily pain, physical function, vitality, and social functioning. The scores of the scoring systems evaluated before and after surgery showed that patients with spinal metastases benefited from open VP/KP.

Spinal instability may lead to pathological fractures and further paraplegia. The Spine Oncology Study Group defined instability as loss of spinal integrity due to movement-associated pain, symptomatic or progressive deformity, and/or neural compromise in the presence of physiological loads.²⁰ A three-column model proposed by Denis²¹ showed that damage in two out of three columns can cause significant instability. Bone cement augmentation is capable of restoring both the anterior and middle column height of the diseased vertebra. Meanwhile, pedicle screw fixation can significantly preserve the height and physiological curvature of the spine. Hence, the combination of cement augmentation with posterior fixation not only preserves the height of the vertebral body but also strengthens the diseased vertebral body, and achieves effective spinal stabilization.

Radiographic Outcomes

KP and VP are elective alternatives in the palliative treatment of metastatic spinal disease. Height restoration with simultaneous kyphosis correction is touted as the most important feature that differentiates KP from VP. In the present study, both open VP and open KP had high efficacy in restoring vertebral body height, and this effect was maintained till the last follow-up. In addition, the mean MVH in patients who received KP was on average 3 mm

larger than that in patients who received VP, and this was a significant difference. KP corrects kyphosis of the vertebral body better than VP, which is consistent with previous studies.^{22,23} However, no difference was observed in pain alleviation and functional recovery between patients who received KP versus VP at the last follow-up. It is worth noting that height restoration is not the first priority in this population. The primary objective of the surgery was to alleviate pain and achieve effective spinal stabilization.

Comparison of Open VP and Open KP for Complications

Cement leakage is a frequent complication after VP and KP. Posterior wall defect is a relative but not an absolute contraindication of vertebral augmentation.²⁴ The major risk is the appearance or aggravation of radicular pain or medullar compression. In particular, we observed cement leakage in two patients who received VP, but none were clinically symptomatic. No cement leakage occurred in patients who received KP. There was no significant difference in cement leakage between the patients who received VP and those who received KP. In this study, the rate of cement leakage was not higher than that reported in the literature in cases of tumoral lesions involving the posterior wall. Our study had a remarkably low incidence of cement leakage, likely due to the experience and adeptness of our senior physicians. Amoretti *et al.*²⁵ demonstrated that cement leakage can be effectively reduced by augmenting cement opacity, enhancing visualization during surgery, and avoiding low viscosity cement injection while monitoring the pressure and speed of injection.

Local metastasis may be a potential iatrogenic complication of employing the cement augmentation procedure in treating spinal metastases. Needle insertion in cement augmentation is similar to biopsy, and needle tract seeding is a common post-biopsy complication. In theory, KP poses a higher risk of causing physical displacement of tumors.²⁶ Cruz *et al.*²⁷ reported two cases of iatrogenic complication after KP, characterized as “tumor extravasation.” Hence, they contraindicated the use of KP in the presence of considerable epidural tumor burden. KP utilizes a pneumatic balloon to

preserve vertebral height. The tumor tissue can be extruded by the balloon, which displaces it beyond the boundary of the vertebral body and into the adjoining soft tissues. We surmise the true incidence of this complication may be underestimated. This is because follow-up MRI evaluation is typically not done so early after surgery, and therefore, this complication may be misinterpreted as a general progression of spinal metastases. Strategies to avoid this complication include slowing balloon expansion rate or injecting appropriate amounts of bone cement to reduce the potential for mechanical tumor displacement.

Treatment of metastatic spinal tumors imposes a large economic burden on both the healthcare system and patients. Therefore, it is important to identify an economical and efficient method of treating metastatic spinal tumors. Based on our data, VP is more economical and efficacious than KP in treating metastatic spinal tumors, as seen by the values at the 1-year follow-up. Therefore, given the total cost in the KP cohort, VP appears to be superior to KP in terms of treating metastatic spinal tumors.

Limitations

There are certain limitations to our study. First, as this was a retrospective study, a randomized design may not discount

the selection bias and confounding in the study. Second, the follow-up duration was relatively short. Hence, extensive randomized prospective studies with a larger patient population are required in future.

Conclusion

In the present study, we found that posterior internal fixation with VP or KP is both effective and safe treatment for patients with MESCC and posterior wall destruction. Patients with spinal metastasis should be evaluated for eligibility for multidisciplinary therapy. After surgery, patients can quickly recover and accept postoperative anticancer therapy.

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Conflict of Interest

The authors have declared that there are no conflicts of interest.

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