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Original Article

Efficacies of percutaneous vertebral angioplasty, percutaneous kyphoplasty and conventional open operation in the treatment of spinal tumor

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Abstract: Objective: To compare the efficacies of percutaneous vertebral angioplasty (PVP), percutaneous kyphoplasty (PKP) and conventional open operation in the treatment of spinal tumor. Methods: Forty-seven patients who admitted to our hospital were divided into three groups: PVP group (treated with PVP), PKP group (treated with PKP) and control group (treated with conventional open operation). Visual analogue scales (VAS), Karnofsky Performance Status (KPS) and numerical rating scale (NRS) score were scoring methods within different groups, and X-ray examination, recurrence rate of postoperative pain, complications and other indicators were indicators for the comparisons between groups. The average follow-up period was 3~24 months with the average time of (17.61 ± 3.96) months. Results: Three months after operation, the total effective rate of PVP, PKP and control group was 86.7%, 94.4%, 57.1%, respectively, and the efficacies in the PVP group and PKP group were significantly better than that in the control group (both $P < 0.05$). All patients had significantly lower VAS score, lower NRS score and higher KPS score after the treatment compared with those before the treatment (all $P < 0.01$). Patients underwent PVP and PKP showed that the height of the vertebral body was not collapsed by X-ray examination. There were significant differences for the total recurrence rates between the PKP group and the control group, as well as between the PKP group and the PVP group (both $P < 0.05$). There were significant differences for bone cement leakage rates between the PKP group and the control group, and between the PKP group and the PVP group (both $P < 0.05$). The survival rates had significant differences between the control group and the PVP group ($P = 0.045$), as well as between the control group and the PKP group ($P = 0.035$). Conclusion: PVP and PKP can effectively relieve the pain of patients with spinal tumor, and PKP can significantly reduce the complications of bone cement leakage under the premise of ensuring the operation effect.

Keywords: Percutaneous vertebral angioplasty, percutaneous kyphoplasty, conventional open operation, spinal tumor, visual analogue scales, karnofsky performance status, numerical rating scale, bone cement leakage

Introduction

Spinal tumor is known as the growth of cells within or surrounding the spinal cord, which accounts for about 6%~10% of the whole body bone tumor [1]. Various types of bone tumors can be seen in the spine, such as osteosarcoma, osteoid osteoma, aneurysm bone cyst, and metastatic bone tumors account for more than half of spinal tumors [2]. Spinal tumors may be classified into primary tumors or secondary tumors, and benign and malignant spinal tumors are another standard of classification [3]. The causes of spinal tumors are unknown, while several factors, such as virus, chronic irritation of chemicals, ectopic or remnant embryo, genetic factor might contribute to the occurrence of spinal tumor [4]. Pain in the back and leg is the preliminary symptom for spinal tumor, followed by local pain, neurological dysfunction, local block or spinal deformity, etc. [5]. The primary treatment option for spinal tumor is open standard surgical resection, whose safety and effectiveness have been clearly documented [6]. However, because of age, recurrent nature of the tumor, medical comorbidities, or anatomical location of the lesion, open standard surgical resection is not an ideal candidate for some patients [7]. Recently, percutaneous vertebroplasty (PVP) and percutaneous kyphoplasty

(PKP), as minimally invasive techniques, have been widely used in the treatment of vertebral metastases, osteoporotic vertebral compression fractures (OVCFs) and vertebral hemangioma [8, 9].

Since its first introduction in 1984, PVP has been increasingly applied and is a relatively successful procedure in the treatment of spinal tumor, and is effective in reducing pain and reversing functional limitations [10, 11]. This technique involves percutaneous bone cement injection, generally polymethyl methacrylate (PMMA), directly into the vertebral cancellous bone, thereby contributing to bone stabilization and pain relief [12]. Nevertheless, patients underwent PVP also suffered severe complications, mainly consists of sequelae of excessive cement leakage, like neurologic deficits, cardiac perforation, paraplegia, and even death [13]. PKP was first introduced in 1998 as an improvement over the PVP method, and involves insertion of deflated balloons into the vertebral body and subsequent inflation of the balloons to restore the vertebral body height and create a cavity, achieving reduction in kyphotic angulation of the compression fracture prior to cement injection [14, 15]. PKP is able to restore the normal overall spinal sagittal alignment via reducing the fractured bone, while it also alters the shape of the vertebra in that more cements are deposited into the cavity which created by the balloon [16]. Additionally, leakage of cement is still one of the major complications for PKP, which can induce disastrous consequences, such as vascular thrombosis, bone cement toxicity, and pulmonary embolism, etc [17]. It was reported that patients underwent PVP or PKP had a better clinical and functional outcomes in comparison with those patients who underwent conservative treatments [18]. A previous study also concluded that PKP significantly decreases the incidence of bone cement leakage, compared with PVP, but the cement dosage was not mentioned in this study [19]. Despite the published benefits of PKP, some studies recommended PVP over PKP for treating spinal tumor considering the higher cost of PKP, and similar risk profiles for cement leakage and subsequent fractures [20]. For those controversial results, our study aims to compare the efficacies of PVP, PKP and conventional open operation in the treatment of spinal tumor.

Materials and methods

Ethic statement

The study was carried out with the permission of the Institutional Review Board of Affiliated Hospital of Jining Medical University. Written informed consents were obtained from all participants. Ethical approval for this study conformed to the standards of the Declaration of Helsinki [21].

Clinical data

From December 2012 to December 2015, 47 patients with spinal tumor who admitted to Affiliated Hospital of Jining Medical University for treatment were enrolled into our experiment, with totally 67 affected vertebral bodies. There were 21 males and 26 females, aged from 44~81 years old with the mean age of (66.7 ± 7.8) years old. Among these 47 patients, there were 23 cases of metastatic tumor, 2 cases of centrum angioma, 9 cases of myeloma, 5 cases of giant cell tumor of bone and 8 cases of osteosarcoma. The 23 cases of metastatic tumor included 6 cases of prostate cancer, 7 cases of breast cancer, 8 cases of lung cancer, and 2 cases of liver cancer. The lesions were in T7 for 1 case, T8 for 2 cases, T9 for 12 cases, T10 for 3 cases, T11 for 9 cases, T12 for 12 cases, L1 for 1 case, L2 for 11 cases, L3 for 2 cases, L4 for 1 case, and L5 for 13 cases. Inclusion criteria: All patients were diagnosed with spinal tumor by magnetic resonance imaging (MRI), computed tomography (CT), X-ray and clinical examination, and the posterior margins of vertebral bodies for patients were complete without nerve compression. Exclusion criteria: (1) patients didn't meet the above criteria; (2) patients who cannot accept surgical procedures; (3) patients who were allergic to anesthetics or antibiotics; and (4) patients with mental illness or other functional abnormalities in heart, liver and kidney.

Treatment methods

According to surgical indication, the number of affected vertebral bodies for patients, the histological type of primary tumor, the level of the vertebral body, diffusion degree of spinal canal, the general conditions of the patients, and the severity of pain, all the patients were divided into three groups: (1) PVP group (n = 15); (2)

PKP group (n = 18) and (3) control group (n = 14). Specific methods were as follows:

(1) PVP group: the surgical equipment included C-Arm, a set of percutaneous needles (Stryker company), and bone cement PMMA (V-max bone cement in Depuy Company). Patients lay prostrate with chest and abdomen suspended, adopted local anaesthesia and underwent vertebral pedicles anaesthesia and punctures under the guidance of C-Arm. Puncture needles were through the skin and implanted into the pedicles; this procedure was terminated when the puncture needles through the pedicles reached the vertebral body. Conducted the normal and lateral perspective to observe whether needles were located in the ideal positions, namely, the needle tip of normal perspective should be located within 0 of the pedicle projection/eye syndrome, and the needle tip of lateral perspective was located in 1/3 of anterior vertebral body. Injected 2~3 ml contrast agents to observe the dispersion of contrast agent in the vertebral body, which provided a reference basis for preventing the leakage of bone cement. Without the rapid drainage of the contrast agent into the large vein, the bone cement was modulated to adilute point for better filling of the vertebral body. However, with the rapid drainage of the contrast agent into the large vein, the bone cement was modulated to tricking condition without too high injection pressure. The disemboguements of bone cement in the vertebral body were X-rayed with the injection of bone cement. Stopped the injection when bone cement leakage exceeded the posterior margin of the vertebral body, inserted the needle core and pulled out the needle, bound up after the local oppression, finally ended the treatment.

(2) PKP group: Took out the needle core and inserted the guide needle. The needle was inserted into the expanding duct and working sleeve along the guide pin, let the front end of working sleeve located 2~3 mm in front of the posterior cortex of the vertebral body to establish working channel. The fine drill was taken out through working channel after it was accurately punctured into the right position and inserted the expandable balloon. Under the supervision of the discontinuous X-ray, the low pressure was used to slowly expand the balloon with little demand for the reduction effect. When the reduction was basically satisfactory or the balloon reached the vertebral cortex, stopped the expansion of balloon and took it out, and injected bone cement with low pressure under the supervision of the X-ray, and finally removed pushing pipe and working sleeve of bone cement after the bone cement was satisfactorily filled.

All patients underwent bilateral pedicle puncture, and the puncture needle directly reached the anterior margin of the vertebral body with no need to reach the central line of the vertebral body. One side of the retaining sleeve needle connected to the aspirator with low negative pressure, and reduced the internal pressure of vertebral body.

(3) Control group: All the patients received conventional open surgical treatment. They were treated with general anesthesia, and took prone position after the success of anesthesia. Before the treatment, the C-Arm was used for fluoroscopy location; told patients to lie prostrate with chest and abdomen suspended, cut their skin and subcutaneous tissues, and separated their erector spinae muscles. Took the affected vertebral body as the center, and exposed the upper and lower vertebrae, respectively. In the anterior approach, the vertebral bodies of all the patients were exposed through the front, and then fixed by the artificial vertebral body or titanium cage reconstruction plate after their vertebral tumors were cut off. In the posterior approach, pedicle screws were firstly screw on the upper and lower vertebrae of the affected vertebral body, resected posterior vertebral arch, small joint or part of the rib, partially or completely scraped vertebral tumors, and injected bone cement into the vertebral body. Patients were informed to lie in the hardboard bed for 4~6 weeks and get up with a waistline.

Observed indicators

After three months of treatment, the treatment effects of the three groups of patients were compared through the following indicators: visual analogue scales (VAS) score [22], Karnofsky Performance Status (KPS) score [23], numerical rating scale (NRS) score [24], X-ray examination, recurrence rate of postoperative pain, complications and other indicators. The average follow-up period was 3~24

Table 1. Comparisons for the baseline characteristics in three groups

	PVP group (n = 15)	PKP group (n = 18)	Control group (n = 14)	P
Age	65.7 ± 8.7	69.1 ± 8.6	66.4 ± 8.3	0.484
Gender				
Male	8 (53.3)	8 (44.4)	5 (35.7)	0.634
Female	7 (46.7)	10 (55.6)	9 (64.3)	
Number of lesion segments				
Section 1	9 (60.0)	9 (50.0)	11 (78.6)	0.532
Section 2	5 (33.3)	8 (44.4)	3 (21.4)	
Section ≥ 3	1 (6.7)	1 (5.6)	0 (0.00)	
Pathological types				
Metastatic tumor	5 (33.3)	11 (61.1)	7 (50.0)	0.282
Non-metastatic tumor	10 (66.7)	7 (38.9)	7 (50.0)	

Note: *P* means the values compared among three groups of patients. PVP, percutaneous vertebroplasty; PKP, percutaneous kyphoplasty.

Table 2. Comparisons of the treatment effects for spinal tumor in the three groups [n (%)]

Groups	Cure (n, %)	Effective (n, %)	Invalid (n, %)	Total effective rate (%)
PVP group (n = 15)	6 (40.00)	8 (53.33)	1 (6.67)	93.33*
PKP group (n = 18)	8 (44.40)	9 (50.00)	1 (5.56)	94.40*
Control group (n = 14)	2 (14.29)	5 (35.71)	7 (50.00)	50.00

Note: * means $P < 0.05$ when compared with the control group; PVP, percutaneous vertebroplasty; PKP, percutaneous kyphoplasty.

months with the average time of (17.61 ± 3.96) months.

Criterion of therapeutical effect

Cure: the tumor symptoms of patients were disappeared, and the postoperative examination results showed that the tumors have been completely removed; effective: tumor symptoms were significantly reduced, postoperative examination results showed that the volume of tumors decreased more than 50%; invalid: tumor symptoms did not reduced, postoperative examination results showed that the volume of tumors decreased less than 50%. The total effective rate was calculated as follows: the cure rate plus the effective rate [25].

Statistical analysis

Using SPSS 10.0 statistical software for analysis, data were expressed as mean ± standard deviation (SD). *t* test was used for the measurement data, and chi-square test was used for the enumeration data. $P < 0.05$ showed statistically significant.

Results

Comparisons for the baseline characteristics in three groups

No significant difference in age, gender ratio (male/female), number of lesion segments ratio (section 1, section 2 and section more than 3), pathological types (metastatic tumor/non-metastatic tumor) ratio was found in PVP group, PKP group and the control group (all $P > 0.05$), and all these indexes were comparable among these three groups (**Table 1**).

Treatment effect

The total effective rates of the treatment effect for spinal tumor for three groups were displayed in **Table 2** (control group: 50%; PVP group: 93.33%; PKP group: 94.4%). There was no significant difference for the total effective rate between PVP group and PKP group ($P > 0.05$); the efficacies in the PVP group and PKP group were significantly better than that in the control group (both $P < 0.05$).

Preoperative and postoperative pain scores

All patients had significantly lower VAS score, lower NRS score and higher KPS score after the treatment compared with those scores before the treatment (all $P < 0.01$). There was no significant difference for the indicators among the three groups before the treatment, and for the postoperative scores between the PVP group and the PKP group (all $P > 0.05$). There were significant differences for the indicators between the control group and the PVP group as well as between the control group and the PKP group (all $P < 0.01$) (**Table 3**).

X-ray examination

As shown in **Figure 1**, X-ray examination was performed in three groups at 3 months after

Table 3. VAS, NRS and KPS scores before treatment and after treatment in the three groups [n (%)]

Groups	Case	Time	VAS score	NRS score	KPS score
PVP group	15	Before treatment	7.67 ± 0.98	9.47 ± 0.74	64.24 ± 7.49
		After treatment	2.53 ± 0.92$^{*,\#}$	2.47 ± 1.06$^{*,\#}$	88.60 ± 5.80$^{*,\#}$
PKP group	18	Before treatment	7.94 ± 1.39	9.56 ± 0.70	65.22 ± 8.45
		After treatment	2.83 ± 1.04$^{*,\#}$	1.89 ± 0.96$^{*,\#}$	90.17 ± 5.03$^{*,\#}$
Control group	14	Before treatment	7.55 ± 1.04	9.45 ± 0.82	66.91 ± 6.99
		After treatment	5.91 ± 1.14*	8.36 ± 1.43*	80.64 ± 6.17*

Note: *refers to $P < 0.01$ when compared with before treatment of the same group; $^{\#}$refers to $P < 0.01$ when compared with after treatment of the control group. PVP, percutaneous vertebroplasty; PKP, percutaneous kyphoplasty; VAS, visual analogue scales; KPS, Karnofsky Performance Status; NRS, numerical rating scale.

treatment. The X-ray examination results for patients underwent PVP and PKP showed that the heights of the vertebral bodies were not collapsed, the bone cement filling was good, and the recovery effect was satisfactory.

Comparison of incidence of bone cement leakage and other complications

Forty-seven patients after treatment were followed up for 24 months, 24 (51.06%) of them suffered pain recurrence. After further analyzing the reasons for pain recurrence, 13 cases (27.66%) was found for bone cement leakage, 4 cases (8.51%) for ipsilateral lumbar and leg pain, 7 cases (14.89%) for secondary fracture for adjacent vertebral body, and 2 cases (4.26%) for nerve injury caused by puncture injury of nerve root, as shown in **Table 4**. All patients had no abnormal cardiovascular manifestations and pulmonary embolism. Five cases (29.41%) showed bone cement leakage in the PVP group, 1 case (5.56%) in the PKP group, and 7 cases (50%) in the control group. There were significant differences for bone cement leakage rates between the PKP group and the control group, and between the PKP group and the PVP group (both $P < 0.05$), while no such an association was found between the PVP group and the control group ($P > 0.05$). In the PVP group, 1 case (6.67%) showed ipsilateral lumbar and leg pain, 1 case (6.67%) for secondary fracture for adjacent vertebral body, and 0 case (0.00%) for nerve injury; in the PKP group, 2 cases (11.11%) showed ipsilateral lumbar and leg pain (one case with secondary fracture for adjacent vertebral body), 2 cases (11.11%) for secondary fracture for adjacent vertebral body, and no patient with nerve injury; in the control group, 1 case (7.14%) showed ipsilateral lumbar and leg pain (one case with secondary fracture for adjacent vertebral body), 4 cases (28.57%) for secondary fracture for adjacent vertebral body, and 2 cases (14.29%) for nerve injury. There was no significant difference for these three groups in the pairwise comparisons (all $P > 0.05$). There was no statistical significance for the total recurrence rates between the PVP group (46.67%) and the control group (92.86%) ($P > 0.05$), while there were significant differences for the total recurrence rates between the PKP group (22.22%) and the control group, as well as between the PKP group and the PVP group (both $P < 0.05$).

Survival rate analysis

In the control group, 1 case died at 7 months, 12 months, 21 months after treatment, respectively, and 2 cases were lost at 5~6 months. In the PVP group, 1 case was lost at 16 months and 22 months after treatment, respectively; In the PKP group, 1 case was lost at 6 months after treatment, and 1 case died of other diseases at 10 months after treatment. Among 47 patients, the average survival time of lung cancer and liver cancer was 20.90 months, breast cancer and prostate cancer was 21.15 months, osteosarcoma and myeloma was 21.94 months and giant cell tumor of bone and angeioma was 22.86 months. The survival rates had significant differences between the control group and the PVP group ($P = 0.045$), as well as between the control group and the PKP group ($P = 0.035$). However, no significant difference was found between the PKP group and the PVP group ($P > 0.05$) (**Figure 2**).

Discussion

Our study suggested that three months after operation, the total effective rate in the PVP

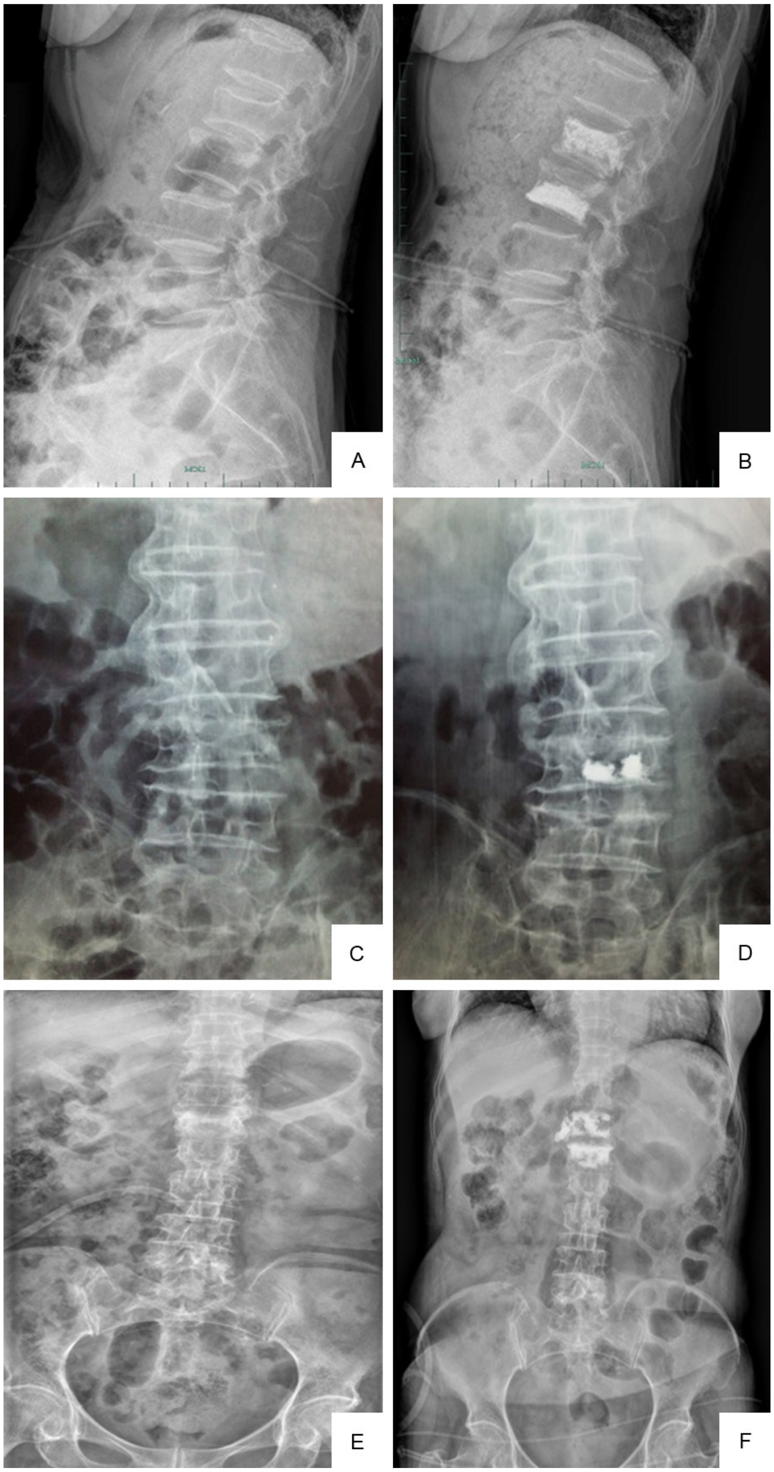

Figure 1. X-ray films of patients with spinal tumor. (A: PVP group before treatment; B: PVP group after treatment; C: PKP group before treatment; D: PKP group after treatment; E: Control group before treatment; F: Control group after treatment). (PVP: percutaneous vertebral angioplasty; PKP: percutaneous kyphoplasty).

group and PKP group were significantly better than that in the control group, and all patients had significantly lower VAS score, lower NRS score and higher KPS score after the treatment when compared with those before the treatment, implying that both PVP and PKP can effectively relieve the pain, and have better performance in postoperative functional recovery for patients with spinal tumor. It was reported that the postoperative functional recovery might assessed by various factors such as normal vertebral function, effective pain relief, heightened awareness, vertebral deformity correction and safety, as well as other scoring rules [26]. PVP and PKP procedures have gained widespread acceptance and implementation for their relatively effective functions in reducing fracture-related pain, diminishing disability, and accelerating complete recovery of orthopedic injuries [27]. It has been shown that after PVP and PKP, immediate pain relief, improvement of patients' mobility, function, as well as stature are significantly improved in the short term in comparison with optimal pain medication treatment [28]. The possible analgesic mechanism are: 1) thermal effect: bone cement in the process of polymerization produces heat with the temperature reaching 80~90°C, and the heat can cause damage and necrosis to tumor tissues, which has a certain degree of burn damage to the sensory nerve endings of the lesions; 2) mechanical property: bone cement can be evenly distributed within the lesions, thus playing a mechanical support role in reducing the pain resulting from the subtle bone of the vertebral body; 3) chemical toxicity:

Table 4. Postoperative complications in the three groups of patients [n (%)]

Groups	PVP group (n = 15)	PKP group (n = 18)	Control group (n = 14)	P^*	$P^\#$	$P^\&$
Bone cement leakage	5 (29.41)	1 (5.56)	7 (50.00)	0.039	0.004	0.363
Ipsilateral lumbar and leg pain	1 (6.67)	2 (11.11)	1 (7.14)	0.658	0.702	0.960
Secondary fracture for adjacent vertebral body	1 (6.67)	2 (11.11)	4 (28.57)	0.658	0.209	0.119
Nerve injury	0 (6.67)	0 (0.00)	2 (14.29)	-	-	-
Total	7 (46.67)	4 (22.22)	13 (92.86)	0.138	0.000	0.007

*: PKP group vs. PVP group; #: PKP group vs. control group; &: PVP group vs. control group. PVP, percutaneous vertebroplasty; PKP, percutaneous kyphoplasty.

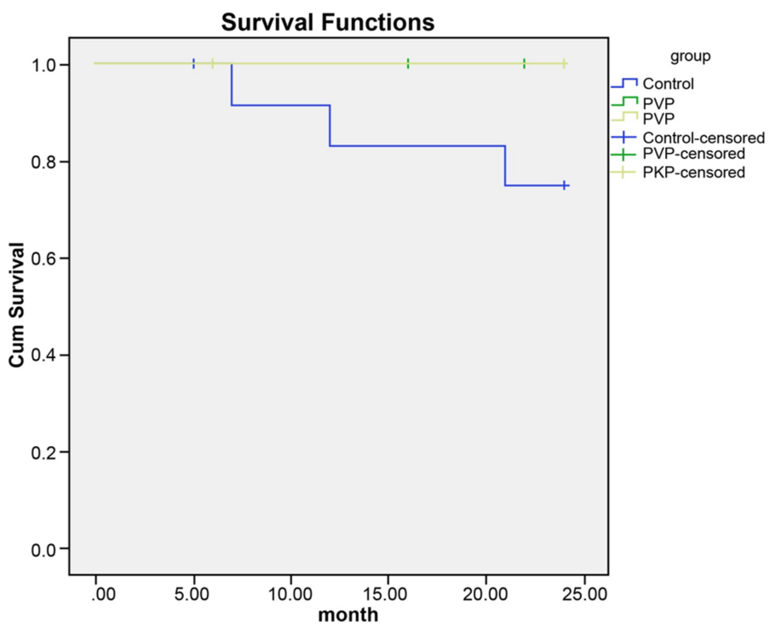

Figure 2. Kaplan-Meier survival curve. (PVP: percutaneous vertebral angioplasty; PKP: percutaneous kyphoplasty).

the monomer toxicity of bone cement can be capable of acting on nerve cells and tumor cells; 4) bone cement shoulders a quite portion of the axial stress, which reduces the stimuli on the extrapyramidal nerves; and 5) bone cement infusion gets the vertebral body microfractures fixed and increases the spinal stability [29]. Clinical study showed that PVP or PKP can be performed on cervical, thoracic and lumbar fractures and thoracic and lumbar metastatic tumors, and they can relieve most of the pain at 6~72 h after operation, and 83% patients with pain can be relieved, more than half of patients with active ability to recover [30]. Both operations showed great superiority in the restoration of all regular spinal sagittal alignment via the decrease of fractured bone on a weakened fractured bone, and they were capable of restoring diminished vertebral height along with correcting kyphotic deformity [31].

Our study also suggested that PKP can significantly reduce the complications of bone cement leakage under the premise of ensuring the operation effect when compared with PVP. Although PVP has been reported to be an effective method in the improvement of short-term outcomes and in the reduction of pain for patients, it still has some complications [32]. It was well-known that (extravertebral or vascular) cement leakage is the main complication associated with PVP and PKP, which might contribute to longer hospitalizations, more patient morbidity, the use of pain medications and the need for open surgery, all of which have related costs; extravertebral cement leakage even can result in some neurological complications, such as nerve root compression, spinal cord compression, and radiculopathy [33]. However, the rate of cement leakage seems much lower after PKP than after PVP, and the neurological complications which were seen with PVP have not seen in the study of PVP [34]. In our study, there was significant difference of bone cement leakage rate between PKP group and PVP group, and the reason for patients in PVP group has a higher bone cement leakage rate was that there were still a part of the bone cement injected into the vertebral body due to high pressure after the injection, which caused a more obvious leakage and complications. Therefore, in order to avoid leakage, bone cement should be fractionatedly injected at a volume of 0.5~1.0 ml each time, and additionally, the injection should be immediately stopped if there were any signs of leakage [35].

In conclusion, PVP and PKP can effectively relieve the pain of patients with spinal tumor, and PKP can significantly reduce the complications of bone cement leakage under the premise of ensuring the operation effect when compared with PVP. Thus, consideration should be given to reducing the bone cement leakage rate after PVP and PKP.

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Disclosure of conflict of interest

None.

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