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Cause Analysis of Open Surgery Used After Percutaneous Vertebroplasty and Kyphoplasty

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Background: The aim of this study was to analyze reasons why open surgery was done after percutaneous vertebroplasty and kyphoplasty.

Material/Methods: Patients (587 vertebral bodies) treated with percutaneous vertebroplasty or kyphoplasty in the Xi'an Honghui Hospital of Shanxi Province from January 2008 to January 2012 were retrospectively analyzed and 13 patients were enrolled in the study. These 13 patients had serious adverse events after percutaneous vertebroplasty or kyphoplasty. Their average age was 64.5 years old. Nine patients had spinal cord injury and 4 had nerve root injury. All the patients underwent open surgery within 4–12 h after definitive diagnosis.

Results: All 13 cases were followed up (average time 14.1 months, range 3–47 months). Reasons for open surgery included cement extravasation (6 cases, 46.2%), puncture mistake (3 cases, 23.1%), and false selection of indications (4 cases, 30.8%). At last follow-up, skin feeling was better than that before open surgery in 4 cases with nerve root injury, and muscle strength recovered to grade 5 (3 cases) and grade 4 (1 case). In 9 cases with spinal cord injury, 7 patients improved and 2 remained at the same ASIA level.

Conclusions: The main reasons for open surgery after percutaneous vertebroplasty and kyphoplasty were cement extravasation (the most common reason), puncture mistake, and false selection of indications.

MeSH Keywords: Conversion to Open Surgery • Postoperative Complications • Spinal Injuries • Vertebroplasty

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Background

Vertebroplasty has been performed as an open procedure for many decades to secure pedicle screws and fill tumorous voids [1]. However, the results were not always worth the risk involved with an open procedure, which was the reason for the development of percutaneous vertebroplasty (PV) and percutaneous kyphoplasty (PK) [2]. PV and PK are minimally invasive procedure and have been widely used for the treatment of osteoporotic compression fractures and vertebral tumors [3,4]. Although with the characteristics of small wound, sample operation, and good effect, PV and PK have 2 main complications – spinal cord injury(SCI) and nerve root injury(NRI) – which include pulmonary cement embolism [5] and thermal cement damage [6].

Cement extravasation is the most frequent complication of PV and PK, with incidence rates of 4–65% [7,8]. When bone cement leaks into the spinal canal and nerve root canal, typically, if there are no symptoms, there are no long-term issues [9], but if there are symptoms showing acute compression of the spinal cord or nerve root, open surgery may be required [10]. In addition, other factors can also lead to acute SCI or NRI. Open surgery has to be done in patients are not helped by drug therapy.

At present, there have been few reports of open surgery for SCI or NRI caused by PV and PK [11]. In the present study we analyzed the causes and calculated incidence of SCI or NRI caused by PV and PK. The corresponding prevention measures were put forward according to the different reasons and we discuss the significance of early open surgery on the recovery of nerve function.

Material and Methods

General data

Data of 516 patients (587 vertebral bodies) treated with PV or PK in the Xi'an Honghui Hospital of Shanxi Province from January 2008 to January 2012 were retrospectively analyzed and 13 patients were enrolled in the study. These 13 patients (13/516, 2.52%) had serious adverse events after PV or PK and underwent open surgery. Their average age was 64.5 years, range 53–72 years, and the male: female ratio was 5: 8. Injured segments were in 9 locations, including T7, T8, and T9. Nine patients had SCI and 4 patients had NRI. Ten patients underwent PK and 4 underwent PV. Their specific data are shown in Table 1 (Figure 1).

The bone cement used in this study was produced by Tianjin Institute of Synthetic Materials Industry, and was injectable a crylic type III. The blending ratio of powder and liquid was 2 g: l ml. Average injected volume of bone cement was 7.8 ml

Table 1. Information of 13 patients and recovery of neurological function.

No.	Gender	Age	Cause	Reason of open surgery	Segment
1	M	61	Vertebral fracture	Compression of fractured lamina when the puncture	T11
2	F	59	Vertebral fracture	Compression of fractured lamina when the puncture	T8
3	M	68	Vertebral fracture	Cement extravasation to thoracic vertebra canal	T9
4	F	70	Vertebral fracture	Cement extravasation to thoracic vertebra canal	T12
5	F	66	Vertebral fracture	Balloon dilatation causing backward shift of vertebra body	T12
6	M	65	Vertebral fracture	Balloon dilatation causing backward shift of vertebra body	L3
7	F	69	Vertebral fracture	Puncture injured spinal cord	T10
8	M	61	Vertebral metastases	Tumor tissue shift back after injection of bone cement	T7
9	F	53	Vertebral metastases	Tumor tissue shift back after injection of bone cement	T9
10	F	70	Vertebral fracture	Cement extravasation to nerve root canal	L1
11	F	59	Vertebra angeioma	Cement extravasation to nerve root canal	L1
12	M	72	Vertebral fracture	Cement extravasation to nerve root canal	L1
13	F	65	Vertebral fracture	Cement extravasation to nerve root canal	L4

Segment means vertebral segment.

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(range 6–9 ml) to every single vertebral body. American Spinal Injury Association (ASIA) assessment was used to document sensory and motor impairments in 9 patients with SCI [12], and 4 patients with NRI were evaluated by muscle strength (Table 2). These patients had no symptoms of SCI and NRI before PV or PK. Laboratory and systemic examinations showed no clear surgical contraindication.

Imaging examinations

After PV or PK, these 13 patients all had neurological symptoms and were checked by CT scan and MRI.

Open surgery

These 13 patients all underwent open surgery under general anesthesia within 4–12 h after definitive diagnosis. After successful anesthesia, patients were in prone position. Those with SCI caused by cement extravasation underwent bilateral laminectomy and parts of the condyloideus mandibulae processus were excised to remove bone cement. Patients with SCI

Figure 1. Lamina reduced pressure after open surgery, shown by X-ray. * Patient is female, 70 years old, and T12 was an osteoporotic compression fracture. Cement extravasation leaked to spinal canal after percutaneous vertebroplasty.

Table 2. ASIA evaluation or muscle strength of 13 patients.

No.	Former ASIA* or muscle strength	Latter ASIA# or muscle strength
1	C	D
2	C	E
3	C	E
4	C	D
5	B	D
6	C	E
7	A	A
8	A	A
9	C	D
10	Unable hip flexion, Grade 2, skin numbness in front of the thigh	Grade 4, sensory recovery
11	Unable hip flexion, Grade 2, skin numbness in front of the thigh	Grade 5, sensory recovery
12	Unable knee flexion, Grade 2, knee numbness	Grade 5, sensory recovery
13	Unable knee flexion, Grade 2, knee numbness	Grade 5, part reduction of feeling

*ASIA before open surgery; # ASIA after open surgery; ASIA – American Spinal Injury Association.

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Figure 2. Spinal canal stenosis caused by cement extravasation to spinal canal by CT scan at horizontal position. * Patient is female, 70 years old, and T12 was osteoporotic compression fractures. Cement extravasation leaked to spinal canal after percutaneous vertebroplasty.

Figure 3. Compression of spinal cord shown by MRI T2-weighting image after percutaneous vertebroplasty. * Patient is female, 70 years old, and T12 was an osteoporotic compression fracture. Cement extravasation leaked to spinal canal after percutaneous vertebroplasty. # Low signal at back and upper edge of T12 vertebral body and high signal in the spinal cord.

caused by compression of fractured lamina underwent bilateral vertebral lamina fenestration, those with NRI underwent symptomatic side partial vertebral lamina fenestration and nerve root canal decompression, and those with tumors underwent palliative decompression surgery.

After open surgery, internal fixation was done in some patients, depending on the stability of the spine. The treatment of internal fixation was done if the condyloideus mandibulae processus was broken more than 1/2. In this study, 4 patients underwent fusion-stabilization after open surgery and the other 9 cases underwent only open surgery.

Results

The 13 patients were all followed up, with an average time of 14.1 months (range 3–47 months). Six patients (46.2%, 6/13) underwent open surgery for cement extravasation, with an overall incidence of 1.02% (6/587). Two patients (No. 3 and 4) had cement extravasation to the thoracic vertebra canal, causing SCI (Figures 2, 3) and the other 4 had cement extravasation to the nerve root canal, causing NRI. In these 4 patients, 3 (No. 10, 12, and 13) had lumbar vertebra fractures with incomplete paries posterior. One patient had vertebra angioma and the lining of the radix arcus vertebrae was broken because the angle of the hemi-puncture was too large. In patients with cement extravasation to the nerve root canal, bone cement was taken out, and spinal canal decompression was used for those with compression of the spinal cord caused by cement extravasation.

Three patients (23.1%, 3/13) had SCI due to a puncture mistake, with an overall incidence of 0.51% (3/587). Two patients (No. 1 and 2) had SCI due to compression of the fractured lamina when the puncture was performed during PV. In 1 patient (No. 7), the spinal cord was directly damaged by a puncture mistake during PV, involving the thoracic vertebra body and cacoepy of the radix arcus vertebrae.

Four patients (30.8%, 4/13) had SCI due to false selection of indications, with an overall incidence of 0.68% (4/587). Two (No. 5 and 6) of these had spinal cord compression leading to nerve damage for balloon dilatation causing a backward shift

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of the vertebral body at the back edge. CT scan results before PK showed unstable fracture blocks at the back edge of the vertebral body, which was diagnosed as a blowout fracture. Two patients (No. 8 and 9) had spinal metastases and part of the paries posterior of the vertebral body had been broken by tumor tissue before PK, with tumor tissue invading the spinal canal and a constricted spinal cord. After the injection of bone cement, tumor tissue further shifted backward and constricted the spinal cord, leading to neurological symptoms.

After open surgery 2 patients (No. 7 and 8) remained at the same ASIA-evaluated level, but the other 7 with SCI had improved 1–2 levels in ASIA evaluation compared with the former result (Table 2). The skin sensation of 4 patients with NRI were better than before open surgery. Muscle strength of 3 patients recovered from grade 3 to grade 5 and another 1 patient recovered to grade 4 (Table 2).

Discussion

PV and PK are similar medical spinal procedures in which bone cement is injected through a small hole in the skin into a fractured vertebra with the goal of relieving back pain caused by vertebral compression fractures [13–15]. However, serious adverse effects may appear after PV or PK, such as SCI and NRI, in which case open surgery is often used to relieve neurological symptoms. We discuss the reasons and the corresponding prevention measures.

Cement extravasation and its prevention measures

In this study, the overall incidence of cement extravasation was 1.02% (6/587) and it accounted for the most (46.2%) complications. Thus, the pressure and the dose of bone cement injection should be carefully monitored during the entire operation. Studies show the injected pressure and the dose are positively correlated with cement extravasation rate [7]. The average injected volume in this study was 7.8 ml, which was significantly higher than the optimal reported in the literature [16]. In addition, although leaked volume accounted for only 6% of injected volume, serious neurological symptoms appeared, which may be related to spinal canal stenosis and nerve root canal stenosis of elderly patients. It is important avoid injecting too much bone cement to reconstruct mechanical properties of the injured vertebral body. Unilateral kyphoplasty was not advised for beginners because the large angle of the needle makes it easy to harm the lining of the radix arcus vertebrae, causing cement extravasation. The tip position of the needle should be located as the first 2/3 of the vertebral body to distribute the bone cement in the former middle part of the vertebral body. Imaging examinations of these 6 patients all showed significant spinal canal stenosis and nerve root canal stenosis, as well as compression of the spinal cord and nerve root. Nerve damage was mainly caused by mechanical agents, not the burning of cement extravasation. Therefore, open decompression surgery was used and patients obtained good neurological function improvement.

Puncture mistake and its prevention

The overall incidence of puncture mistakes in this study was 0.51% (3/587). Because of more serious consequences, puncture mistakes should receive careful attention. One patient in this study had cacoepy of the radix arcus vertebrae, so recognition of anatomic landmarks was not clear and the entry point of the needle caused harm to the spinal cord. Thus, we advise that the needle entry point should be outside of the radix arcus vertebrae and the angle of the needle should be reduced during the operation, with special attention to the screw position in the entopic X-ray. If the puncture needle is found to be close to or located at the midline when the needle is not deep enough, the needle may enter the spinal canal. Therefore, imaging examinations should be carefully evaluated before PV or PK. For patients with injured lamina, the puncture point should be pinpointed and the needle gently inserted, trying to avoid stimulating the broken end of the fracture and unnecessary damage.

False selection of indications and its prevention measures

The overall incidence of false selection of indications in this study was 0.68% (4/587). CT scan of 2 patients with fracture before PV showed free bone blocks at the back edge of the vertebral body, which was diagnosed as a blowout fracture. Although blowout fracture of the thoracic and lumbar vertebrae were relative contraindications of PK, 2 patients showed free bone blocks shifted to the inside of the spinal canal after balloon dilatation, causing neurological symptoms. Therefore, we think PK should be used cautiously for patients with blowout fracture, especially with free bone blocks at the back edge of the vertebral body and occupying some space in the vertebral body. At this time, posterior open surgery of radix arcus vertebrae screws and internal fixation with bone cement augmentation are better choices [17].

PV is becoming more commonly used in the treatment of vertebral metastases, which can improve the mechanical strength and stability of the vertebral body, easing the pain, and also breaks the tumor tissue by mass effect of bone cement and cytotoxicity, reducing the sensitivity of nerve endings in the tissue around the tumor. Thus, PV can have a good effect. The other 2 patients in this group had vertebral metastases. Before PV, tumor tissue had broken part of the paries posterior of the vertebral body and tumors had invaded the spinal canal, leading to spinal cord compression. When bone cement

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was injected, tumor tissue further shifted backward and constricted the spinal cord, causing neurological symptoms. After posterior open decompression surgery, 1 patients had better recovery, but another patient had no improvement of symptoms. Therefore, for patients who had serious broken paries posterior of the vertebral body and compression of spinal cord before PV or PK, treatments should be chosen carefully [14]. When the channel is established, entry points of needles should be at the former 1/3 of the vertebral body to reduce the compression of tumor tissue by bone cement.

The importance and curative effect of open surgery

The main reason why open surgery was done after PV and PK in this study was nerve damage after PV or PK. The causes of nerve damage were mainly mechanical factors. Imaging examination showed clear nerve compression or abnormal signal in the intramedullary. Thus, posterior open decompression surgery was adopted to save the neural function with the largest possible. We were treated by posterior and open operation, the maximum possible. Although there is no conclusive evidence to show the exact effect of nerve decompression surgery [18], the results in this study suggest that early decompression surgery is beneficial to the recovery of nerve function. Serious nerve dysfunction appeared in 13 patients in this study after PV or PK. After being diagnosed by physical examination and imaging examination, these patients were operated on with posterior open decompression surgery within the shortest time possible. During follow-up, except for 2 patients with complete spinal cord function injury, the rest of the patients had no deterioration of nerve function and had good improvement. Therefore, early diagnosis and early treatment should be applied for patients with deterioration of nerve function after PV or PK, while early posterior open decompression surgery can improve patient prognosis.

Conclusions

This study showed that the reason why open surgery was done after PV and PK was mainly related to worsening neurological symptoms. The major factors causing worsened neurological symptoms include cement extravasation, puncture mistake, and false selection of indications, of which cement extravasation was the most important. Once the situation was confirmed, we suggest a positive treatment of surgical intervention, which can generally obtain good prognosis after the surgery. It should be noted that proper selection of the cases before surgery, detailed imaging evaluation, localization accuracy during surgery, and controlling the depth and angle of the needle are the keys to reducing the need for open surgery after PV or PK.

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Competing interests

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