CASE REPORT

Cardiac Perforation Caused by Cement Embolism after Percutaneous Vertebroplasty: A Report of Two Cases

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Background: Percutaneous vertebroplasty (PVP) is a minimally invasive surgical technique in which polymethyl methacrylate (PMMA) is injected into the weakened vertebral body to strengthen it. However, this procedure is associated with various complications, the most common being cement leakage. Cardiac perforation caused by cement escape into the venous system is another complication, which is rare but potentially life-threatening even if not treated promptly.

Case Presentation: Here, we report two elderly patients who developed cardiac perforation caused by cement escape into veins following PVP. Both patients had a history of severe osteoporosis. On admission, they presented with lower back pain and limited movement. MRI revealed vertebral bodies compression fracture in both patients. Considering the advanced age of the patients, PVP was performed to avoid the risk of potential complications associated with nonoperative therapy. Unfortunately, the rare and fatal postoperative complication, cardiac perforation caused by cement escape into veins, occurred in both patients. Emergency open-heart surgery was performed to remove cement material and repair the heart, both patients recovered well and were discharged.

Conclusions: Although PVP is a safe and minimally invasive surgical technique, it is associated with various serious complications as seen in the present cases. We therefore recommend that surgeons should be aware of such complications. Appropriate timing of surgical operation, meticulous surgical procedures, early intraoperative and postoperative monitoring of cement leakage may improve outcomes of patients with such complications.

Key words: Cardiac perforation; Complication; Open-heart surgery; Percutaneous vertebroplasty

Introduction

Osteoporosis is the most common metabolic bone disease characterized by low bone mineral density and microarchitectural deterioration of bone tissue[1]. Patients with osteoporosis have high risks of fragility and fracture. Given the rising aging population, cases of osteoporosis and osteoporotic fractures have become a serious public health problem. Each year, approximately 8.9 mn fractures due to osteoporosis are reported worldwide[2]. Vertebral body is the most common site of osteoporotic fractures, and it accounts for approximately 50% of all osteoporotic fractures. Nonoperative treatment may not effectively relief pain and its usage has been shown to induce complications due to prolonged bedrest. Consequently, there is a growing demand for effective vertebral augmentation of osteoporotic fractures, such as percutaneous vertebroplasty (PVP) and balloon kyphoplasty (BKP). PVP is a minimally invasive surgical technique developed in 1987 by Galibert to treat vertebral

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Disclosure: The authors declare no conflict of interest. No benefits in any form have been, or will be, received from a commercial party related directly or indirectly to the subject of this manuscript.

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Received 7 January 2021; accepted 19 November 2021

Orthopaedic Surgery 2022;14:456-460 • DOI: 10.1111/os.13192

hemangioma. The technique involves injection of polymethyl methacrylate (PMMA) into affected vertebrae using a transpedicular approach. This technique effectively stabilizes the weakened vertebral body and relieves pain from various vertebral disorders, including osteoporotic vertebral compression fractures, osteolytic metastases, and myeloma. Currently, PVP is widely applied in the treatment of osteoporotic fractures.

Although PVP is a safe and minimally invasive procedure, it is associated with several serious complications linked to cement leakage. For patients with osteoporotic vertebral compression fractures, the incidence of cement leakage after PVP is in the range of 30% to 65%[3]. One of the most serious complications is cement escape into the venous system causing cardiac embolism, pulmonary embolism, and cerebral embolism. Previous studies have reported that cement in a semi-fluid state may enter the inferior vena cava *via* vertebral veins system and migrate to the right side of the heart. The cement solidifies in the heart leading to cardiac embolism. The needle-shaped cement embolus potentially increases the risk of cardiac perforation, which is a fatal condition that requires urgent management.

Here, we describe two elderly patients with cardiac perforation caused by cement escape into the venous system following PVP and propose several recommendations to reduce the risk of cement leakage. Surgeons should more cautiously perform PVP procedure by ensuring appropriate timing of surgical operation, meticulous surgical procedures, early intraoperative and postoperative monitoring of cement leakage. This would improve clinical outcomes of PVP.

This case report received ethical approval by the Affiliated Hospital of Jining Medical University ethics committee. Written informed consent for publication was obtained from the patients and their families.

Case Presentation

Patient 1

History and Preoperative Work Up

A 78-year-old female presented at our outpatient department with a 7-day history of lower back pain and limited movement. The patient had a history of atrial fibrillation, nephropyelitis, and serious osteoporosis. Magnetic resonance imaging (MRI) revealed a compression fracture of the L_4 vertebral body (Fig. 1B).

Surgical Procedure

The patient underwent PVP, in which 6 mL of PMMA cement was directly injected into the fractured vertebral body. Side and anteroposterior monitoring revealed venous and spinal canal without cement leakage.

Postoperative Complications and Management

Seventeen hours later, the patient experienced retrosternal pain with epigastric pain. Electrocardiogram (ECG) analysis showed ST-segment elevation of the inferior and anterior wall. Computed tomography (CT) and transthoracic echocardiography (TTE) analyses revealed a hyperechoic linear foreign object in the inferior vena cava and right atrium, which were accompanied by massive pericardial effusion associated with cardiac tamponade (Fig. 1C–E). ECG monitoring revealed tachycardia (140 beats/min) and a blood pressure drop to 76/36 mm Hg (1 mmHg = 0.133 kPa). During urgent open-heart surgery, pericardium opening revealed about 300 mL of blood. After opening the atrial surface, a needle-shaped cement (about 50 mm) abutting the right atrial surface inferior vena cava was revealed and removed. Opening the pleura revealed 1100 mL of blood, which was evacuated. Symptomatic treatments like blood volume supplementation and homeostasis maintenance were given after surgery, and dopamine continuously pumped to improve heart function. The patient recovered well and was discharged 33 days after the operation.

Patient 2

History and Preoperative Work Up

A 79-year-old female presented at our outpatient department, with a 5-day history of lower back pain and limited movement. The patient had a history of hypertension and serious osteoporosis. MRI revealed the T_7 and T_{11} vertebral bodies compression fracture (Fig. 2A).

Surgical Procedure

The patient underwent PVP, in which 2 and 5 mL of PMMA cement were injected into the T_7 and T_{11} vertebral bodies, respectively. Side and anteroposterior monitoring found no venous or spinal canal cement leakage.

Postoperative Complications and Management

Fourteen hours later, the patient suddenly drifted into unconsciousness associated with incontinence and limb dyspraxia. Subsequent ECG revealed a blood pressure drop to 55/38 mmHg and a saturation level of 85%, accompanied by low cardiac sound and moist cold skin. ECG also revealed frequent ventricular extrasystole. TTE revealed abnormal echo and small pericardial effusion. CT scanning revealed a hyperechoic linear foreign object in the right atrium, and multiple linear hyperdensities within remote pulmonary arteries (Fig. 2B,C). Brain CT revealed ischemic necrosis and cerebral malacia. During urgent open-heart surgery, pericardium opening revealed massive hemorrhaging. After opening the right atrial surface, a U-type cement (about 60 mm) perforating the ventricular wall on the right side of right atrioventricular groove was revealed and removed. Postsurgical arterial blood gas analysis revealed a pH of 7.49, PaO_2 of 47 mmHg, $PaCO_2$ of 41 mmHg, and an oxygenation index (OI) of 220, which is attributable to the patient's pulmonary embolism. The patient entered hypoxemia and failed to wean from mechanical ventilation. Endotracheal intubation was removed upon OI improvement on the day 7 after the

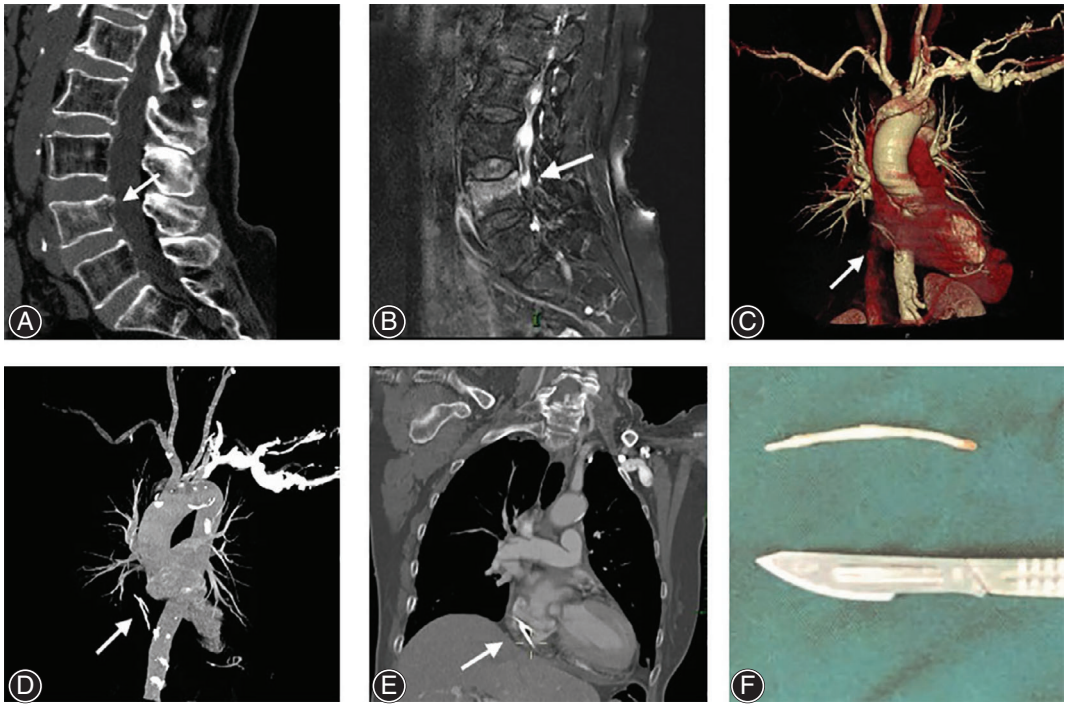

Fig. 1 The imaging findings from patient 1, a 78-year-old female with cardiac perforation following percutaneous vertebroplasty (A–E). Lumbar computed tomography revealed a compression fracture of the L_4 vertebral body (A). T2-weighted magnetic resonance image revealed a new compression fracture of the L_4 vertebral body (B). Multidetector computed tomography with three-dimensional reconstruction shows that cement is located within the cardiac contour (C). Arrows indicate cement (D). Coronal computed tomography image of the chest shows a hyperechoic linear foreign object in the right atrium (E). Gross specimen of the PMMA cement measuring 50 mm in length (F).

operation. The patient recovered well and was discharged 24 days after the operation.

Discussion

PVP is a procedure through which vertebral disorders like osteoporotic vertebral compression fractures, osteolytic metastases, and myeloma are treated by injecting PMMA into affected vertebrae. However, in rare cases, PVP may result in serious complications due to cement leakage. It is estimated that the risk of cement leakage after PVP in patients with malignant lesions or osteoporotic vertebral compression fractures is 38%–72.5%[4,5] or 30%–65%[3], respectively. Cement may escape into various anatomical sites, including needle track, the prevertebral soft tissue in 6%–52.5% of patients, the spinal canal in up to 37.5% of patients, the intervertebral disc in 5%–25% of patients, and the venous system in up to 24% of patients. The vertebral veins system, a widespread venous network that includes internal vertebral venous plexus and external vertebral plexus, surrounds and permeates the vertebral body. Its diameter and blood-flow largely depend on changing position, as well as intra-abdominal and intrathoracic pressure[6]. Thus, if an operation causes high pressure in the vertebral body, cement may leak into it. CT scan and chest X-ray (Fig. 2E) of the second showed that retained cement (63.5 mm) was attached to the T11 vertebral body and revealed leakage into the hemiazygos vein. To the best of our knowledge, this is the first reported case of cement escape into the hemiazygos vein.

A meta-analysis found that cement leakage was associated with severe vertebral collapse, cortical disruption, cement viscosity, and high volume of injected cement. Age, sex, fracture type, and operation level are not significant risk factors[7]. In the cases presented here, both patients had a history of severe osteoporosis, and the vertebral bodies formed had a degree of vertebral collapse. In the first patient, 6 mL of PMMA cement with toothpaste-like consistency was injected into the L_4 vertebral body. In the second patient, 2 and 5 mL of PMMA were injected into the T_7 and T_{11} vertebral bodies, respectively. Two of the vertebrae were injected with >4 mL cement. There are few known cardiac perforation cases caused by cement escape into the venous system upon PVP. A study involving >1500 patients and >3500 vertebral bodies identified intracardiac cement embolisms in 72 patients (3.9%) and found that having many treated vertebral bodies in a single PVP is an independent risk factor for intracardiac cement embolism[8]. This is probably due to use of a larger amount of cement and the increased complexity and duration of the operation. Even if cement escaped into venous system and caused slight pulmonary embolism, most patients are asymptomatic. Early identification of

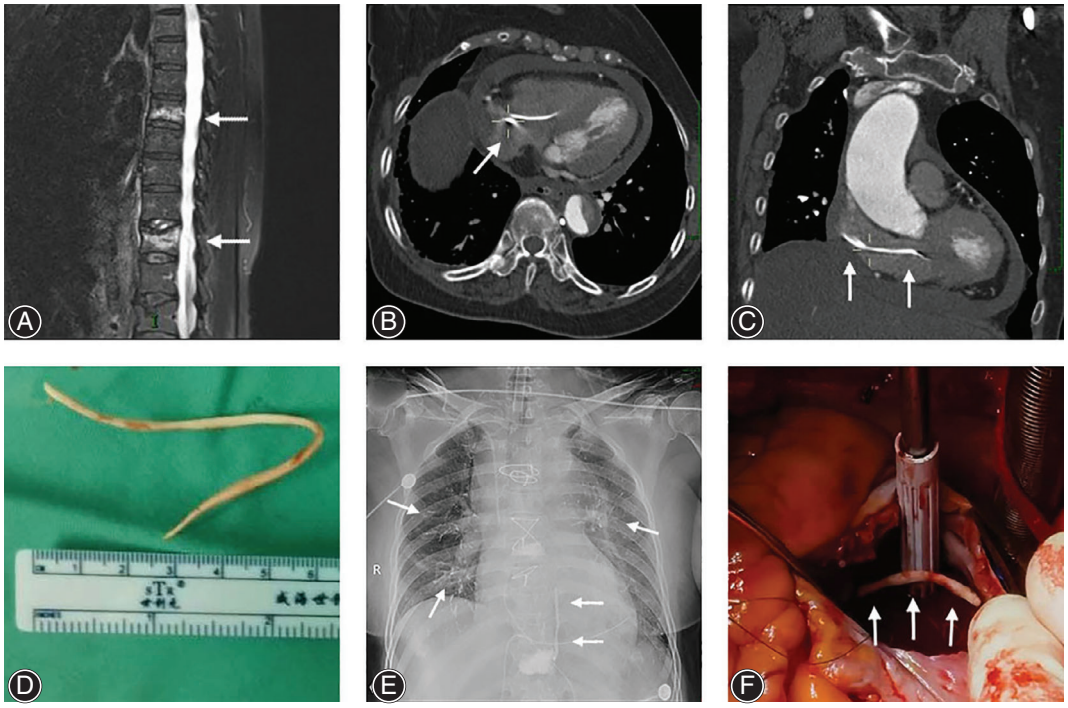

Fig. 2 The imaging findings from patient 2, a 79-year-old female with cardiac perforation following percutaneous vertebroplasty (A, B, C, E). T2-weighted magnetic resonance image revealed the new compression fracture of the T_7 and T_{11} vertebral bodies (A). Transverse computed tomography image of the chest shows a U-type hyperechoic linear foreign object in the right atrium (B). Coronal computed tomography image of the chest shows a hyperechoic linear foreign object in the right atrium (C). Gross specimen of U-type PMMA cement, measuring 60 mm in length (D). Chest X-ray reveals retained cement (63.5 mm) which was attached to T_{11} vertebral body and diffuse pulmonary embolism (E). An intra-operative photograph of open-heart surgery. A U-type cement can be revealed after the right atriotomy, the tip of which had penetrated the right ventricular wall from the right ventricular side of anterior tricuspid leaflet to the right ventricular side of interatrial septum. The end was located in the right atrium (arrows indicate cement) (F).

asymptomatic patients is challenging, and symptoms vary with migration of leaked cement into the right heart and pulmonary arteries *via* the vertebral veins system. Symptoms range from asymptomatic to symptomatic and include sudden chest pain or syncope and life-threatening events like cardiac tamponade due perforation and acute respiratory distress syndrome (ARDS) due to pulmonary embolism[9]. Although the two cases reported here were of cardiac perforation upon PVP, symptoms did not indicate this. The first patient had sudden retrosternal pain, epigastric pain, severe dyspnea, and cardiac tamponade. The second had sudden syncope followed by cardiogenic shock, including hypotension, hypoxemia, and moist cold skin. Relatively small round endocardial cement can be removed by percutaneous endovascular procedure[10]. Thomas *et al.* reported a case of cement in the pericardium being removed using an endoscopic robotic-assisted approach[11]. Park *et al.* reported a case of embolus in which a 2.1 × 6.3-cm long cement was removed *via* inferior vena cava exploration[12]. Here, CT found hyperechoic linear foreign objects in right atria of both patients and open-heart surgery was unavoidable given that the sizes and positions of the cement also caused cardiac perforation.

In the second patient, pulmonary embolism caused an arterial blood pH of 7.49, PaO_2 of 47 mmHg, $PaCO_2$ of 41 mmHg, an oxygenation index (OI) of 220, and hypoxemia after surgery. According to 2019 European Society of Cardiology (ESC) guidelines for diagnosis and management of acute pulmonary embolism[13], intravenous anticoagulation with unfractionated heparin is recommended for patients at high-risk of pulmonary embolism with hemodynamic instability. They should then be encouraged to continue on anticoagulants for 3–6 months, which prevents other thrombotic events and promotes reendothelialization of the embolic surface, minimizing risk of thrombosis. For patients with a SaO_2 level <90% in the acute phase, supplemental oxygen is indicated. To delay pulmonary embolism progression and prevent thrombosis due to the cement retained in the hemiazygos vein, low-molecular weight heparin and aspirin were given as anticoagulation therapy and warfarin continue for 3 months as maintenance therapy.

Among the multiple risk factors for cement leakage, cement viscosity and injected cement volume are actively controllable factors[14]. It has been suggested that only injection of cement above a certain volume will be able to restore the strength and stiffness of the vertebra and relieve pain[15,16]. But this increased volume of cement injection increased the risk of cement leakage. A recent study has suggested that injecting more than 4 mL of cement could provide good levels of pain relief and prevent vertebral body re-collapse, and it does not increase the risk of cement leakage[14]. Apart from that, risk of cement leakage can be minimized by using cement with a toothpaste-like consistency. Thus, injected cement should have an appropriate viscosity and volume. For cement injection, a bilateral transpedicular approach, which applies less pressure and avoids the central part where risk of leakage is higher, may be superior to the unilateral transpedicular approach in patients with severe vertebral collapse or central disk herniation[3].

The timing of when PVP is optimal has been long debated[17]. Thus, it may also have been an additional risk factor for leakage caused by overtreatment. The role of PVP in patients with osteoporotic vertebral compression fractures and chronic pain is indisputable. A treatment plan should be selected after detailed consideration for patients in the acute phase[18]. Patients with milder symptoms and those without nerve compression should be treated with nonoperative treatment that consists of bedrest, orthopaedic brace, and narcotic analgesia. Elderly patients who are not suitable for prolonged bedrest and those who fail nonoperative therapy should be treated with surgical therapy as early as possible. Application of high-resolution fluoroscopy and mixing PMMA with barium or tungsten for opacification may be crucial for early detection of leakage[6], and will have a positive impact on reducing the incidence of serious complications. Furthermore, single-level vertebroplasty poses lower risk of embolism relative to multilevel vertebroplasty. Thus, the number of vertebrae treated per vertebroplasty should be as low as possible. It is suggested that no more than three vertebrae should be injected in a single procedure[19]. If vertebral venography identifies a direct approach from the needle tip to the venous system intra-operatively, repositioning of the needle tip and pre-injection gelfoam embolization may help avoid leakage[20].

Even if PVP is safe and minimally invasive, surgeons should pay more attention to leakage-associated complications as PVP use increases. PMMA cement escape into the cardiac system may trigger life-threatening complications. Thus, timely testing during the operation is crucial. For patients with chest pain and tachypnea, chest radiographs should be performed immediately to determine if there is cement leakage and begin treatment as early as possible.

Acknowledgements

This work was supported by the Teacher-Supporting Science Foundation of Jining Medical University (JYFC2018FKJ170) and Key Research and Development Program of Jining (2020JKNS007) and Natural Science Foundation of Shandong Province (ZR2021MH346)

An Authorship Declaration

All authors listed meet the authorship criteria according to the latest guidelines of the International Committee of Medical Journal Editors. All authors read and approved this manuscript.

References

1. Sözen T, Özışık L, Başaran NÇ. An overview and management of osteoporosis. Eur J Rheumatol, 2017, 4: 46–56.
2. Lin X, Xiong D, Peng YQ, *et al*. Epidemiology and management of osteoporosis in the People's Republic of China: current perspectives. Clin Interv Aging, 2015, 10: 1017–1033.
3. Laredo JD, Hamze B. Complications of percutaneous vertebroplasty and their prevention. Skeletal Radiol, 2004, 33: 493–505.
4. Cotten A, Dewatre F, Cortet B, *et al*. Percutaneous vertebroplasty for osteolytic metastases and myeloma: effects of the percentage of lesion filling and the leakage of methyl methacrylate at clinical follow-up. Radiology, 1996, 200: 525–530.
5. Weill A, Chiras J, Simon JM, Rose M, Sola-Martinez T, Enkaoua E. Spinal metastases: indications for and results of percutaneous injection of acrylic surgical cement. Radiology, 1996, 199: 241–247.
6. Farahvar A, Dubensky D, Bakos R. Perforation of the right cardiac ventricular wall by polymethylmethacrylate after lumbar kyphoplasty. J Neurosurg Spine, 2009, 11: 487–491.
7. Zhan Y, Jiang J, Liao H, Tan H, Yang K. Risk factors for cement leakage after vertebroplasty or kyphoplasty: a meta-analysis of published evidence. World Neurosurg, 2017, 101: 633–642.
8. Fadili Hassani S, Cormier E, Shotar E, *et al*. Intracardiac cement embolism during percutaneous vertebroplasty: incidence, risk factors and clinical management. Eur Radiol, 2019, 29: 663–673.
9. Hatzantonis C, Czyz M, Pyzik R, Boszczyk BM. Intracardiac bone cement embolism as a complication of vertebroplasty: management strategy. Eur Spine J, 2017, 26: 3199–3205.
10. Bassawon R, Sirajjudin S, Martucci G, Shum-Tim D. Snare or scalpel: challenges of intracardiac cement embolism retrieval. Ann Thorac Surg, 2021, 04.
11. Molloy T, Kos A, Piwowarski A. Robotic-assisted removal of intracardiac cement after percutaneous vertebroplasty. Ann Thorac Surg, 2016, 101: 1974–1976.
12. Park JS, Kim J, Lee Y, Gwon JG, Park YS. Intra-cardiac embolism of a large bone cement material after percutaneous vertebroplasty removed through a combination of an endovascular procedure and an inferior vena cava exploration: a case report. J Korean Med Sci, 2018, 33: e141.
13. Konstantinides SV, Meyer G, Becattini C, *et al*. 2019 ESC guidelines for the diagnosis and management of acute pulmonary embolism developed in collaboration with the European Respiratory Society (ERS). Eur Heart J, 2020, 41: 543–603.
14. Wang M, Zhang L, Fu Z, Wang H, Wu Y. Selections of bone cement viscosity and volume in percutaneous vertebroplasty: a retrospective cohort study. World Neurosurg, 2021, 150: e218–218e227.
15. Fu Z, Hu X, Wu Y, Zhou Z. Is there a dose-response relationship of cement volume with cement leakage and pain relief after vertebroplasty. Dose Response, 2016, 14: 1559325816682867.
16. Miao F, Zeng X, Wang W, Zhao Z. Percutaneous vertebroplasty with high- versus low-viscosity bone cement for osteoporotic vertebral compression fractures. J Orthop Surg Res, 2020, 15: 302.
17. Shah LM, Jennings JW, Kirsch C, *et al*. ACR appropriateness criteria® management of vertebral compression fractures. J Am Coll Radiol, 2018, 15: S347–S364.
18. Barr JD, Jensen ME, Hirsch JA, *et al*. Position statement on percutaneous vertebral augmentation: a consensus statement developed by the Society of Interventional Radiology (SIR), American Association of Neurological Surgeons (AANS) and the Congress of Neurological Surgeons (CNS), American College of Radiology (ACR), American Society of Neuroradiology (ASNR), American Society of Spine Radiology (ASSR), Canadian Interventional Radiology Association (CIRA), and the Society of NeuroInterventional surgery (SNIS). J Vasc Interv Radiol, 2014, 25: 171–181.
19. Liu FJ, Ren H, Shen Y, Ding WY, Wang LF. Pulmonary embolism caused by cement leakage after percutaneous kyphoplasty: a case report. Orthop Surg, 2012, 4: 263–265.
20. Bhatia C, Barzilay Y, Krishna M, Friesem T, Pollock R. Cement leakage in percutaneous vertebroplasty: effect of preinjection gelfoam embolization. Spine (Phila Pa 1976), 2006, 31: 915–919.