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Research Article

Influence Factors of Bone Cement Distribution in Percutaneous Kyphoplasty for Osteoporotic Vertebral Compression Fracture

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Abstract

To determinate the influence factors of bone cement distribution in Percutaneous Kyphoplasty (PKP) for Osteoporotic Vertebral Compression Fracture (OVCF). The medical records of patients with OVCF were reviewed and collected from January 2013 to December 2019. Body Mass Index (BMI) was calculated. The Anterior Vertebral Height (AVH) and Middle Vertebral Height (MVH) were measured on the preoperative and postoperative X-ray. The preoperative and postoperative Anterior Vertebral Height Compression Ratio (AVHCR) and Middle Vertebral Height Compression Ratio (MVHCR) were calculated. The area, Bone Mineral Content (BMC), bone mineral density (BMD), T score and Z score of injury vertebrae body were measured by Dual-Energy X-Ray Absorptiometry (DXA) tested. Visual Analogue Scale (VAS) and Oswestry Function Index (ODI) were used to evaluate the effect of surgical treatment. The factors related to the different distribution patterns of bone cement were analyzed statistically. According to bone cement distribution the patients were divided into two groups including dispersive type (Group A) and clumpy type (Group B). There were 365 patients including 111 male and 254 female. The mean age was 73.22 ± 8.33. There were significant differences on mean age, gender distribution, preoperative AVH and MVH, postoperative AVH and MVH between two groups. Correlation analysis showed that the distribution of bone cement was negatively correlated with preoperative MVH, but positively correlated with age and preoperative AVHCR. Binary logistic regression analysis showed that the distribution of bone cement was related to preoperative AVH, MVH, AVHCR and MVHCR. The distribution of bone cement was related to AVH, MVH, AVHCR and MVHCR. The MVH is closer to normal, the lower AVHCR level, which may facilitate better diffusion of bone cement in the vertebral body.

Keywords: Osteoporosis; Vertebral compression fracture; Percutaneous kyphoplasty; Bone cement; Distribution

Introduction

Osteoporotic vertebral compression fracture (OVCF) is a common fracture among elder people. With aging population coming in global, the incidence of OVCF will increase. According to the reports, about 40% of women at the age of over 80 years old suffer from OVCF in America [1], and in UK the incidence of OVCF is nearly eightfold higher in women aged 85-89 years compared to those aged 60–64 years [2]. In over 50 years people the prevalence of OVCF was reported as high as 20% [3]. The OVCF can cause a serious of severe symptoms including back pain, physical disability spinal deformities, reduced pulmonary function, and restriction of the abdominal and thoracic contents, even clinical depression. In order to improve life quality of patients with OVCF the minimal invasive operation, such as percutaneous balloon kyphoplasty (PKP), is an available treatment.

PKP has demonstrated the efficiency on pain relief, restore of vertebral body height, decrease of kyphosis angles and correction of spinal deformities [4,5]. The achievement and sustaining of the above effectiveness rely on bone cement that is injected into vertebral body during the operation. Then the intravertebral bone cement distribution is very important. There were some studies about the distribution of bone cement during the operations including PKP, percutaneous vertebroplasty (PVP) and comparison of PKP and PVP [1,6-8]. All above the researches had demonstrated that distribution of bone cements were correlations with treatment result or chance of recompression after surgery, but influence factors of bone cement distribution is still no clear.

In our study, in order to confirm the influence factors of bone cement distribution in bilateral PKP implementation for OVCF. We classified patients into two groups according to the shapes of intravertebral bone cement on the radiographic findings after operation and collected relative parameters before and after surgery. Using the statistical approach evaluated the relationship between distribution of bone cement and those parameters.

Materials and Methods

This article was a retrospective study and ethical approval exemption by the Medical Ethics Committee of hospital.

Patients

The medical records of consecutive patients admitted for OVCF to hospital from 2013 to 2019 were collected. Diagnosis of OVCF was confirmed by two senior doctors according to standard of compressed vertebrae showing high signal on MRI-T2 weighted image and X-ray examination indicating the presence of OVCF.

Inclusive and exclusive criteria

Inclusive criteria: 1. age ≥ 60 years; 2. first single segment OVCF at thoracolumbar spine; 3. PKP performed under local anesthesia, using bilateral pedicle puncture technique; 4. no allergic reactions

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and cardiac toxicity to bone cement; 5. no bone cement leakage in the spinal canal and out of vertebrae body; 6. no postoperative complications; and 7. completion of at least 3 months of follow-up.

Exclusive criteria: 1. Primary tumor or metastases of spine combination with OVCF; 2. bone metabolic diseases; 3. hemorrhage diseases like hemophilia; 4. symptoms of spinal cord or nerve root before surgery; 5. concomitant use of hormone; 6. infection at sites of surgery; 7. intravertebral cleft; 8. Kümmell's Disease and 9. insufficient data or loss to follow-up.

Classification according to bone cement distribution

The bone cement distribution was divided into two types. One was dispersive type that bone cement dispersed into bone trabeculae, staggered distribution and the periphery is irregular Group A. (Figure 1) and was assigned 1 point [9]. The other was clumpy type that bone cement was lumped that bone cement was solid and compact mass Group B. (Figure 2) and was assigned 2 point [10].

Figure 1: The bone cement distribution was dispersive type.

Figure 2: The bone cement distribution was clumpy type.

Surgical Procedure

Patient was in prone position. The location of fracture was identified using C-arm fluoroscopy. 1% lidocaine was used for local anesthetic before surgical operation. Under guidance of C-arm fluoroscopy, the needles were inserted at positions 11 o'clock of the left pedicle and 1 o'clock of the right pedicle at the craniolateral edge of the pedicle. The needle was inserted to the one-third of the anterior part of the injury vertebral body. The PMMA bone cement was injected. The injection process was monitored under lateral C-arm fluoroscopy to achieve appropriate site in the injury vertebral body. After 24 hours of surgery, patients move freely with the aid of a waist protector.

Imaging findings

The preoperative and postoperative anterior vertebral height and middle vertebral height of injury vertebrae body were measured on the X-ray or CT pictures in the Group A (Figures 3-5) and Group B (Figures 6-8). The normal anterior and middle height of injured vertebrae body was calculated according to the formula (V1+ V3/2, where V1 indicates the anterior vertebral height above the injured vertebra and V3 indicates the anterior vertebral height below the injured vertebra [10]. The anterior vertebral height compression ratio were calculated according to formula [(V1+ V3/2–V2]/(V1+ V3/2, where V1 indicates the anterior vertebral height above the injured vertebra, V2 indicates the height of injured vertebra and V3 indicates the anterior vertebral height below the injured vertebra. According to the above the formula the middle vertebral height and the middle vertebral height compression ratio were measured and calculated.

Parameters about bone mineral

DXA was used to detect bone mineral of patients' injured vertebrae body. The results included area, BMC, BMD, T score and Z score of injured vertebrae body.

Clinical treatment

Assessment of clinical outcome: Clinical outcomes were assessed using VAS scores and ODI questionnaire at preoperative, 1 day after surgery and 3 months after surgery.

Statistical analysis

SPSS Statistics 19.0 was adopted on data analysis. All data were presented as mean ± standard deviation (SD) or frequencies. Level

Figure 3: Patient's MRI picture in the Group A before operation.

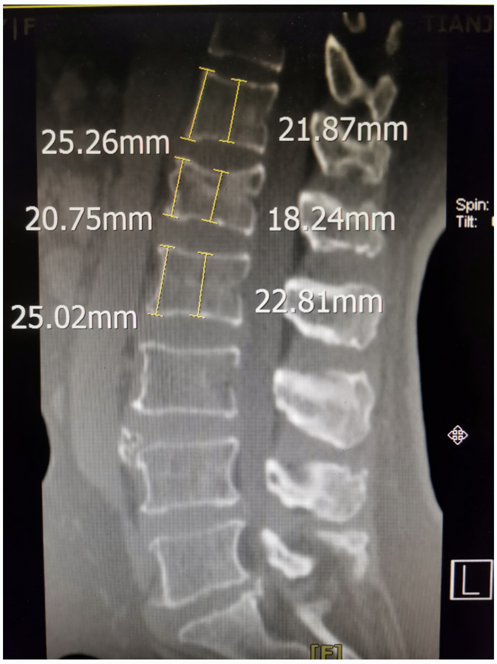

Figure 4: Preoperative measurement results in the Group A.

Figure 5: Postoperative measurement results in the Group A.

Figure 6: Patient's MRI picture in the Group B before operation.

of statistical significance was defined as P value <0.05. Analysis of variance (ANOVA) was used to compare the differences of patients' demographic characteristics, radiological parameters and DXA results between groups. The chi-square test was conveyed to analyze the difference of occurrence of male and female patients' distribution between groups and in the different injury vertebral bodies. Spearman correlation coefficient test was used to analyze the multivariate correlation between age, imaging parameters, DXA results and bone cement distribution, and binary logistic regression was used to analyze the factors affecting bone cement distribution.

Results and Discussion

Demography

There were 365 patients in this study that included 111 males and 254 female. The mean age was 73.22 ± 8.33 (range: 60-96 years). The mean BMI was 23.96 ± 3.65. T_{11} accounted for 18.6%, T_{12} for 25.5%, L_1 for 46.0% and L_2 for 9.9%. Table 1 displayed male and female patients' distribution between two groups and in the different injury vertebral bodies.

Comparison of parameters between two groups

There were significant differences on preoperative AVH,

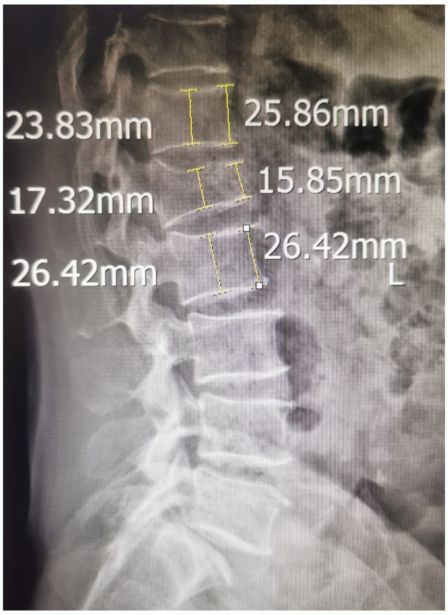

Figure 7: Preoperative measurement results in the Group B.

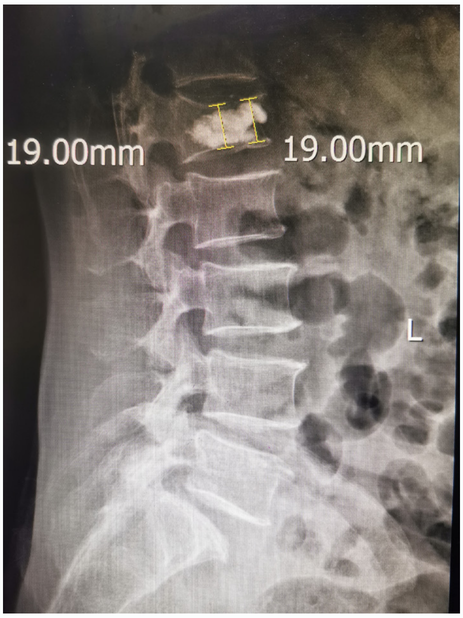

Figure 8: Postoperative measurement results in the Group B.

MVH and postoperative AVH, MVH between two groups, but no preoperative and postoperative AVHCR and MVHCR (Table 2). There were no significant differences on area, BMC, BMD, T score and Z score of injury vertebral body between two groups (Table 3). Bone cement volume was also no significant difference between two groups.

Correlations between distribution of bone cement and preoperative imaging findings and DXA results

Bone cement distribution correlates with preoperative MVH negatively, but showed significant positive correlations with age and preoperative AVHCR. No correlation was found between bone cement distribution and other parameters (Table 4). The logistic regression results displayed that preoperative AVH, AVHCR, MVH and MVHCR are correlation with bone cement distribution (Table 5).

Clinical outcomes

There were significant differences on visual analogue scale (VAS) score and Oswestry Disability Index (ODI) questionnaire between the thorn-ball and blocky groups at 1day and 3 months after surgery. Also there were significant differences on VAS score and ODI questionnaire between the pre-operation and post-operation in the two groups. There was a significant difference between the two groups (Table 6).

Table 1: Demographic characteristic of patients with OVCF (n=365)

Characteristics	Group A (n=152)	Group B (n=213)	*P*
Mean age(yr)	72.05±8.40	74.05±8.19	<0.05
Sex, M/F	33/119	78/125	<0.05
Sites			
T_{11}(M/F, n=68)	6/14	16/32	>0.05
T_{12} (M/F, n=93)	7/39	20/27	<0.05
L_1(M/F, n=168)	17/53	33/65	<0.05
L_2(M/F, n=36)	2/11	10/13	>0.05
P	>0.05	>0.05	
BMI	24.21±3.60	23.79±3.69	>0.05
Time of symptoms (days)	1.5±0.2	1.6±0.3	<0.05

Table 2: Comparison of parameters of compression vertebrae between different groups (n=365)

	Group A (n=152)	Group B (n=213)	*P*
Preoperative AVH (mm)	22.52±3.61	21.58±4.03	<0.05
Postoperative AVH (mm)	24.63±3.58	23.81±4.10	<0.05
P	<0.05	<0.05	
Preoperative AVHCR (%)	19.71%±13.97%	21.81%±15.01%	>0.05
Postoperative AVHCR (%)	11.09%±9.71%	12.86%±13.03%	>0.05
P	<0.05	<0.05	
Preoperative MVH (mm)	20.69±3.80	19.49±4.04	<0.05
Postoperative MVH (mm)	24.22±3.04	23.26±3.73	<0.05
P	<0.05	<0.05	
Preoperative MVHCR (%)	22.61%±14.42%	24.30%±15.95%	>0.05
Postoperative MVHCR (%)	8.09%±7.28%	8.72%±13.63%	>0.05
P	<0.05	<0.05	

Table 3: Comparison of DXA results between different groups (n=365)

	Group A (n=152)	Group B (n=213)	*P*
Area of injury vertebral body (cm^2)	14.66±2.72	14.92±3.06	>0.05
BMC of injury vertebral body (g)	11.74±4.37	12.11±4.06	>0.05
BMD of injury vertebral body (g/cm^2)	0.79±0.21	0.80±0.17	>0.05
T score of injury vertebral body	-2.50±1.33	-2.42±1.42	>0.05
Z score of injury vertebral body	-0.68±1.12	-0.61±1.29	>0.05
Bone cement volume (ml)	5.32±0.18	5.35±0.15	>0.05

Discussion

OVCF is a health threat to the elder patient. According to the research the prevalence of OVCF was reported as high as 20% in people aged over 50 [3]. It causes acute or chronic back pain and physical disability. The clinical management of OVCF includes conservative and operative treatment. Conservative treatment may cause some complications such as deep vein thrombosis, pendant pneumonia and bedsores due to physical disability that was caused by lied in bed for a long time. Operation such as PKP has a better clinical effect than conservative treatment. It has great efficiency in pain relief and functional improvement. So PKP is the first treatment choice for OVCF.

Table 4: Correlations of parameters with distribution of bone cement (n=365)

	P	Correlation coefficient
Age	0.016	0.126
BMI	0.343	-0.050
Preoperative AVH (mm)	0.061	-0.099
Preoperative MVH (mm)	0.011	-0.134
Preoperative AVHCR (%)	0.047	0.104
Preoperative MVHCR (%)	0.145	0.076
Area of injury vertebral body (cm^2)	0.330	0.051
BMC of injury vertebral body (g)	0.251	0.060
BMD of injury vertebral body (g/cm^2)	0.251	0.060
T score of injury vertebral body	0.490	0.036
Z score of injury vertebral body	0.492	0.036
Bone cement volume (ml)	0.488	0.035
Time of symptoms (days)	0.558	0.049

Table 5: Binary logistic regression analysis of bone cement distribution correlation factors (n=365)

	Wald	*P*	95%CI
Age	3.134	0.077	0.997-1.052
BMI	0.402	0.526	0.922-1.042
Preoperative AVH (mm)	4.186	0.041	1.008-1.451
Preoperative MVH (mm)	8.659	0.003	0.645-0.916
Preoperative AVHCR (%)	6.081	0.014	4.146-4.695
Preoperative MVHCR (%)	5.944	0.015	0.058-0.295
Area of injury vertebral body (cm^2)	0.021	0.885	0.856-1.143
BMC of injury vertebral body (g)	0.474	0.491	0.896-1.256
BMD of injury vertebral body (g/cm^2)	0.061	0.805	0.066-2.987
T score of injury vertebral body	0.012	0.912	0.729-1.424

Table 6: Comparison of clinical outcomes between the two groups (n=365)

	Group A (n=152)	Group B (n=213)	*P*
Pre-operative VAS score	7.26±1.86	7.24±1.77	>0.05
1 day after surgery VAS score	2.32±0.83	2.32±0.96	>0.05
3 months after surgery VAS score	1.19±0.76	1.54±0.98	<0.05
P	<0.05	<0.05	
Pre-operative ODI	47.35 ± 4.23	47.96 ± 3.88	>0.05
1 day after surgery ODI	20.73 ± 1.14	20.85 ± 1.66	>0.05
3 months after surgery ODI	8.03 ± 0.83	9.94 ± 0.96	<0.05
P	<0.05	<0.05	

During the treatment it is common that the intravertebral bone cement distribution after PKP procedure varies among different vertebral bodies. According to the study bone cement distributed around both the upper and lower endplates had a lower risk of recompression when compared to patients with bone cement distributed in the middle of vertebral body [6]. Besides, some studies showed that the bone cement volume and filling patterns correlated with surgical complications and curative effects [11-15]. Some studied suggested that cement volume and distribution in treated vertebral body were potential risk factors for recompression [16-19]. All above researches revealed that bone cement distribution was very important to treatment efficiency, but there was a little research about influence factors of bone cement distribution. One research showed bone cement distribution was associated with anterior vertebral height restoration rate and bone cement volume [6], but there was no report about correlations between preoperative parameters and bone cement distribution.

In our study imaging, DXA parameters and bone cement volume were analyzed. The bone cement distribution was divided into two groups including thorn-ball and lumped according to the shape. There were significant differences on preoperative AVH, MVH and postoperative AVH, MVH between two groups, but no differences on other imaging findings, DXA results and bone cement volume. The correlations analysis showed the age, preoperative MVH and AVHCR were relationship with bone cement distribution. Of which age and preoperative AVHCR were positive correlation with bone cement distribution and negative with preoperative MVH. It meant that the distribution of bone cement tended to be more concentrated with increasing age, higher preoperative AVHCR and smaller preoperative MVH during the operation. This result can be understood as smaller preoperative MVH impeding bone cement dispersing. In the same way higher preoperative AVHCR was also disadvantage to bone cement dispersing. As to age, this result showed trabeculae becames parser with increasing age; bone cement can disperse freely but there were no adequate trabeculaein the vertebrae body; only when there were appropriate trabeculae and space, the bone cement could disperse into space and interlace with trabeculaeto form a solid structure. In this study, correlation analysis and binary logistic regression statistical analysis were used to find that some parameters were correlated with bone cement distribution. The parameters related to bone cement distribution in the two statistical analysis results were determined to be the final parameters.

In some studies better distribution of bone cement was very important. For example, bone cement distributed below the upper endplate and above the lower end plate to reduce the risks of recompression after PVP treatment in patients with OVCF [1]. Bone cement distribution is a potential predictor to the reconstructive effects in unilateral PKP for OVCF and greater bone cement distribution may indicate better vertebral restoration along with a higher BE risk [6]. Both "H" and "O" shaped distribution pattern can improve radiographic data and clinical outcomes effectively. However, "H" shaped distribution can achieve better clinical recovery at short-term follow-up [7].

In the clinical work, bone cement is generally injected in the drawing period, which is conducive to avoiding the leakage of bone cement and reducing the risk of nerve damage. The bone cement used in this study was low-viscosity bone cement with a long working time, which gave us a relatively loose time for bone cement injection. Meanwhile, in the surgical process of this study, the injection time of bone cement was in the early stage of wire drawing, that is, the bone cement was injected immediately after the phenomenon of wire drawing began. In this study, bilateral injection of bone cement was adopted. For the possible problem of insufficient injection time of bone cement, the solution of this study is as follows: after the bone cement is thoroughly mixed, the bone cement pusher is injected immediately and inserted into the working channel. When the bone cement starts to draw in vitro, the bone cement is pushed into the vertebra, and the process is carried out alternately on both sides to ensure that the bone cement is pushed into the vertebra with full flow performance. In addition, before the configuration of bone cement, it must be ensured that the bone cement is refrigerated in the refrigerator before operation. Although some bone cements show that refrigeration is not necessary, this study still refrigerates the bone cement before operation to ensure that its working time is long enough.

Conclusions

The distribution of bone cement was related to AVH, MVH, AVHCR and MVHCR. The MVH is closer to normal, the lower AVHCR level, which may facilitate better diffusion of bone cement in the vertebral body.

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Not applicable.

References

1. Zhang L, Wang Q, Wang L, Shen J, Zhang Q, Sun C. Bone cement distribution in the vertebral body affects chances of recompression after percutaneous vertebroplasty treatment in elderly patients with osteoporotic vertebral compression fractures. Clin Interv Aging. 2017;12:431-6.
2. Musbahi O, Ali AM, Hassany H, Mobasheri R. Vertebral Compression Fractures. Br J Hosp Med (Lond) . 2018;79(1):36-40.
3. Kendler DL, Bauer DC, Davison KS, Dian L, Hanley DA, Harris ST, et al. Vertebral fractures: clinical importance and management. Am J Med . 2016;129(2):221.e1-10.
4. Santiago FR, Abela AP, Alvarez LG, Osuna RMA, García MMC. Pain and functional outcome after vertebroplasty and kyphoplasty.A comparative study. Eur J Radiol . 2010;75(2):e108-13.
5. Saxena BP, Shah BV, Joshi SP. Outcome of percutaneous balloon kyphoplasty in vertebral compression fractures. Indian J Orthop. 2015;49(4): 458-64.
6. Lin J, Qian L, Jiang C, Chen X, Feng F, Lao L. Bone cement distribution is a potential predictor to the reconstructive effects of unilateral ercutaneous kyphoplasty in OVCFs: a retrospective study. J Orthop Surg Res . 2018;13(1):140.
7. He S, Zhang Y, Lv N, Wang S, Wang Y, Wu S, et al. The effect of bone cement distribution on clinicalefficacy after percutaneous kyphoplasty for osteoporotic vertebral compression fractures. Medicine (Baltimore). 2019;98(50):e18217.
8. K-Z Hu, S-C Chen, L Xu. Comparison of percutaneous balloon dilation kyphoplasty and percutaneous vertebroplasty in treatment for thoracolumbar vertebral compression fractures. Eur Rev Med Pharmacol Sci. 2018;22(1 Suppl):96-102.
9. Yang D-H, Cho KH, Chung YS, Kim YR. Effect of vertebroplasty with bone filler device and comparison with balloon kyphoplasty. Eur Spine J. 2014;23(12):2718-25.
10. Hashimoto T, Kaneda K, Abumi K. Relationship between traumatic spinal canal stenosis and neurologic deficits in thoracolumbar burst fractures. Spine. 1988; 13(11):1268-72.
11. Kim SH, Kang HS, Choi JA, Ahn JM. Risk factors of new compression fractures in adjacent vertebrae after percutaneous vertebroplasty. Acta Radiol . 2004;45(4):440-5.
12. Li Q, Xiao L, Zhang J, Fan J, Zhou W, Yin G, et al. The impact of endplate fracture on postoperative vertebral height loss and kyphotic deformity during treatment of osteoporotic vertebral compression fractures with balloon kyphoplasty. J Biomed Res. 2016;30(5):419-26.
13. Lin D, Hao J, Li L, Wang L, Zhang H, Zou W, et al. Effect of bone cement volume fraction on adjacent vertebral fractures after unilateral percutaneous kyphoplasty. Clin Spine Surg . 2017;30(3):E270-E275.
14. Yang S, Liu Y, Yang H, Zou J. Risk factors and correlation of secondary adjacent vertebral compression fracture in percutaneous kyphoplasty. Int J Surg. 2016;36(Pt A):138-42.
15. Yu W, Liang D, Yao Z, Qiu T, Ye L, Huang X, et al. Risk factors for recollapse of the augmented vertebrae after percutaneous vertebroplasty for osteoporotic vertebral fractures with intravertebral vacuum cleft. Medicine (Baltimore). 2017;96(2):e5675.
16. Liebschner MA, Rosenberg WS, Keaveny TM. Effects of bone cement volume and distribution on vertebral stiffness after vertebroplasty. Spine. 2001; 26(14):1547-54.
17. Kim J-M, Shin DA, Byun D-H, Kim H-S, Kim S, Kim H-I. Effect of bone cements volume and stiffness on occurrences of adjacent vertebral fractures after vertebroplasty. J Korean Neurosurg Soc. 2012; 52(5): 435-40.
18. Sun Y-C, Teng MMH, Yuan W-S, Luo C-B, Chang F-C, Lirng J-F, et al. Risk of post-vertebroplasty fracture in adjacent vertebral bodies appears correlated with the morphologic extent of bone cement. J Chin Med Assoc. 2011;74(8):357-62.
19. Molloy S, Mathis JM, Belkoff SM. The effect of vertebral body percentage fill on mechanical behavior during percutaneous vertebroplasty. Spine. 2003; 28(14): 1549-54.