Original Article

Depression of the Thoracolumbar Posterior Vertebral Body on the Estimation of Cement Leakage in Vertebroplasty and Kyphoplasty Operations

Hao Chen, Pu Jia, Li Bao, Fei Feng, He Yang, Jin-Jun Li, Hai Tang
Department of Orthopaedics, Beijing Friendship Hospital, Capital Medical University, Beijing 100050, China

Abstract

Background: The cross-section of thoracolumbar vertebral body is kidney-shaped with depressed posterior boundary. The anterior wall of the vertebral canal is separated from the posterior wall of the vertebral body on the lateral X-ray image. This study was designed to determine the sagittal distance between the anterior border of the vertebral canal and the posterior border of the vertebral body (DBCV) and to analyze the potential role of DBCV in the estimation of cement leakage during percutaneous vertebroplasty (PVP) or percutaneous kyphoplasty (PKP).
Methods: We retrospectively recruited 233 patients who had osteoporotic vertebral compression fractures and were treated with PVP or PKP. Computed tomography images of T11–L2 normal vertebrae were measured to obtain DBCV. The distance from cement to the posterior wall of the vertebral body (DCPW) of thoracolumbar vertebrae was measured from C-arm images. The selected vertebrae were divided into two groups according to DCPW, with the fracture levels, fracture grades and leakage rates of the two groups compared. A relative operating characteristic (ROC) curve was applied to determine whether the DCPW difference can be used to estimate the degree of cement leakage. The data were processed by statistical software SPSS version 21.0 using independent sample *t*-test and Chi-square tests.
Results: The maximum DBCV was 6.40 mm and the average DBCV was 3.74 ± 0.95 mm. DBCV appeared to be longer in males than in females, but the difference was not statistically significant. The average DCPW of type-B leakage vertebrae (2.59 ± 1.20 mm) was shorter than that of other vertebrae (7.83 ± 2.38 mm, $P < 0.001$). The leakage rate of group DCPW ≤6.40 mm was lower than that of group DCPW >6.40 mm for type-C and type-S, but much higher for type-B. ROC curve revealed that DCPW only has a predictive value for type-B leakage (area under the curve: 0.98, 95% confidence interval: 0.95–0.99, $P < 0.001$), and when the cut-off value was 4.05 mm, the diagnostic sensitivity and the specificity were 94.87% and 93.02%, respectively.
Conclusions: Depression of the thoracolumbar posterior vertebral body may be informative for the estimation of cement location on C-arm images. To reduce type-B leakage, DCPW should be made longer than DBCV on C-arm images for safety during PVP or PKP.

Key words: C-arm Image; Complications; Kyphoplasty; Vertebrae; Vertebroplasty

Introduction

Percutaneous vertebroplasty (PVP) and percutaneous kyphoplasty (PKP) are effective treatments for painful vertebral diseases such as osteoporotic vertebral compression fracture (OVCF), vertebral metastasis, and angiomas. Among all the clinical complications, 66% cases of PVP or 73% cases of PKP are associated with cement leakage.[1,2] Therefore, cement leakage is the focus of attention by clinicians in these patients. It is important to establish the moving trend of the cement, its location, and its relationship to the spinal canal during an operation to prevent vertebral canal leakage and possible spinal cord injury.

The thoracolumbar spine (T11–L2) is the connecting point of moving lumbar vertebra and fixed thoracic vertebra, bearing the stress of physical activity. The cross-section of the thoracolumbar vertebral body is kidney-shaped with a depressed posterior vertebral body.

Access this article online
Quick Response Code:
Website: www.cmj.org
DOI: 10.4103/0366-6999.170264

Address for correspondence: Dr. Hai Tang, Department of Orthopaedics, Beijing Friendship Hospital, Capital Medical University, Beijing 100050, China
E-Mail: tanghai@medmail.com.cn

Received: 29-07-2015 **Edited by:** Qiang Shi
How to cite this article: Chen H, Jia P, Bao L, Feng F, Yang H, Li JJ, Tang H. Depression of the Thoracolumbar Posterior Vertebral Body on the Estimation of Cement Leakage in Vertebroplasty and Kyphoplasty Operations. Chin Med J 2015;128:3158-62.

The bony vertebral canal is elliptical in shape. Due to these anatomic characteristics, the anterior wall of the vertebral canal does not fully match the posterior wall of the vertebral body on lateral X-ray images. Indeed, the real anterior wall of the vertebral canal is located in front of posterior wall of the vertebral body on a lateral image [Figure 1].

The present study was designed to determine the sagittal distance between the anterior border of the vertebral canal and the posterior border of the vertebral body (DBCV) on images, and to analyze the influence of DBCV on the estimation of cement leakage during PVP or PKP.

Methods

Patients

The study cohort was comprised of 233 patients (86 males, 147 females) who had OVCF. The patients were treated in our hospital from August 2012 to August 2014 and had a mean age of 67.2 ± 3.7 years. In preoperative clinical examinations, the patients exhibited no symptoms or signs of spinal cord or nerve root damage. The fat suppression images of magnetic resonance imaging before the operation showed hyperintense signals in the damaged vertebral bodies and normal spinal signals. This study was approved by the hospital ethics committee, and participating patients provided written informed consents.

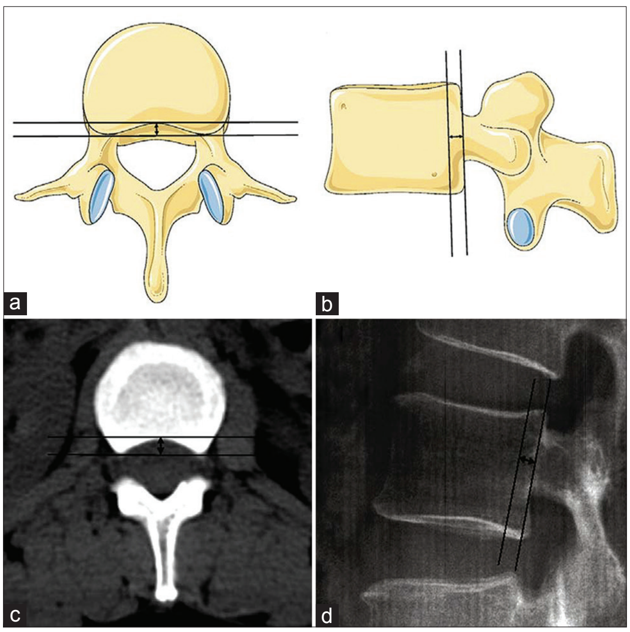

Figure 1: The depression of the thoracolumbar posterior vertebral body. (a and b) The cross-section of the thoracolumbar vertebral body is kidney-shaped, so the anterior border of the vertebral canal does not fully match the posterior border of the vertebral body (the original vector images were copied from: http://smart.servier.info/UK/images/Bones/08.gif, the last time to visit the page was July 28, 2015). (c) In the computed tomography image of the thoracolumbar spine, the anterior border of the vertebral canal does not fully match the posterior border of the vertebral body. (d) In the lateral C-arm image of thoracolumbar spine, it is important to discern that anterior border of the vertebral canal, which does not fully match the posterior border of the vertebral body.

Operative methods

Based on loss of vertebral body height, either PVP or PKP was performed under local anesthesia through a unilateral puncture with the patient in the prone position. The percutaneous puncture needle was centered at 10–11 o'clock over the left pedicle or 1–2 o'clock over the right pedicle on the anteroposterior view under the fluoroscopic guidance. Bone cement was then injected slowly into the vertebral body under the fluoroscopic guidance. The C-arm scanner was orientated perpendicularly to the thoracolumbar spine, and the intensifier was pressed closely against the patients. Rotation of vertebrae on the lateral C-arm image was avoided as far as possible.

Image analysis

A Philips BV Libra C-arm X-ray System Monitor (Philips Medical Systems, Amsterdam, The Netherlands) was used during the operations. The GE Light Speed 16 slice plain computed tomography (CT) scan (General Electric Company, Fairfield, USA) with a slice thickness of 1 mm and intervals of 1 mm was used to examine thoracolumbar vertebrae 1–3 days after the operation. Digital imaging and communication in medicine images in picture archiving and communication systems were extracted by remote terminal, read, and measured through Electronic Medical Record Image Processing System Uniweb version 4.0 (EBM Technologies Incorporated, Beijing, China).

The study had two components: First, to obtain DBCV from CT images of normal thoracolumbar vertebrae. Two doctors familiar with vertebral anatomy and PVP/PKP procedures measured CT images of T11–L2 normal vertebral bodies in order to determine DBCV. Vertebrae whose anatomic form had changed because of a previous operation, old fracture, severe degenerative changes, or other reasons were excluded from the study [Figure 2a]. The results from the two doctors were averaged to reduce bias and potential errors. Second, C-arm and CT images of the vertebrae were analyzed. We selected vertebrae which were at the thoracolumbar level and excluded vertebrae that had a posterior cortical fracture or if the C-arm images were imperfect. From each lateral C-arm image of all the selected vertebrae, the distance from the cement to the posterior wall of the vertebral body (DCPW) was measured [Figure 2b]. The postoperation CT images of selected vertebrae were analyzed. The fracture grade, DCPW, cement leakage type, and complications of all selected vertebrae were recorded. The fracture grade was defined according to the Genant semi-quantitative method and the type of cement leakage using the Yeom method.[3] DCPW of the leakage vertebrae and other vertebrae of three leakage types were compared. All of the selected vertebrae were divided into two groups depending on whether the DCPW was longer than the maximum DBCV or not. The level, fracture grade and leakage rate in the two groups were compared to analyze whether the leakage rate would increase if cement was positioned too close to the posterior vertebral body border.

Statistical analysis

The data were processed by statistical software SPSS version 21.0 (IBM Inc., Chicago, USA) using independent sample *t*-test and Chi-square tests. A relative operating characteristic (ROC) curve was applied to determine whether the DCPW difference can be used to estimate the degree of cement leakage. The statistical significance of data was determined by two-sided tests, α = 0.05 and $P < 0.05$.

Results

Sagittal distance between the vertebral canal anterior border and the posterior vertebral body border

There were 593 thoracolumbar vertebrae measured in part 1 of the study. The maximum DBCV was 6.40 mm in T11, and the minimum was 0.20 mm in L2 while the average DBCV of thoracolumbar vertebrae was 3.74 ± 0.95 mm. Because all vertebrae and vertebrae whose anatomic form had changed were excluded from measurements, not all cases were analyzed, and the number of each level was not the same. The results appeared to indicate that DBCV was longer in males than in females, but statistical significance was not reached [Table 1].

Cement leakage

In part 2, a total of 168 vertebrae met the requirements of the study. When the average DCPW between type-B leakage vertebrae (2.59 ± 1.20 mm) and other vertebrae (7.83 ± 2.38 mm) were compared, the former were found to be much shorter ($P < 0.001$). A comparison of the average DCPW between type-C leakage vertebrae (8.53 ± 1.63 mm) and other vertebrae (6.38 ± 3.16 mm) showed that the former was much longer ($P = 0.005$); similar results were obtained for type-S leakage vertebrae (8.83 ± 2.17 mm) and other vertebrae (6.38 ± 3.09 mm, $P = 0.005$). As the maximum DBCV found was 6.40 mm, we divided all vertebrae that met our criteria into two groups according to whether the DCPW was >6.40 mm, to analyze the potential role of depression of the thoracolumbar posterior vertebral body in the estimation of cement leakage [Table 2].

Relative operating characteristic curve

The ROC curve on data for 168 vertebrae showed that DCPW only had a predictive value for type-B leakage, with the area under the curve being 0.98 (95% confidence interval [*CI*]: 0.95–0.99, $P < 0.001$) [Figure 3]. The cut-off point was determined according to the Yuden index. When the cut-off value was 4.05 mm, the diagnostic sensitivity and the specificity of cement leakage were 94.87% and 93.02%, respectively.

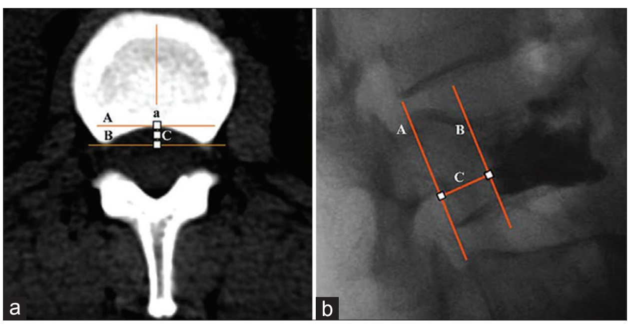

Figure 2: Measurement methods of computed tomography image and C-arm image. (a) Select the computed tomography image that shows the vertebral body instead of pedicles. Draw line “A” through anterior vertebral canal. Draw line “B” through both sides of the posterior border of the vertebral body. The intersection point of line “A” and the vertebral sagittal axis is the vertebral canal vertex, point “a”. Along the sagittal axis, draw a plumb line “C” from point “a” to line “B”. The length of “C” is the sagittal distance between the anterior border of the vertebral canal and the posterior border of the vertebral body). (b) Draw line “A” along the posterior border of the vertebral body, drawing line “B” parallel to line “A” at the cement posterior border. Then draw a vertical line “C” from line “A” to line “B” and the length of “C” is the distance from the cement to the posterior wall of the vertebral body.

Discussion

The thoracolumbar vertebral body has a kidney shape that bulges outward.[4] Previous studies have reported detailed measurements of the thoracolumbar vertebra.[5-7] However,

Table 1: Thoracolumbar vertebrae DBCV of different genders

Gender	Vertebral level	*n*	DBCV (mean ± SD, mm)	*t*	*P*
Male	T11	46	4.11 ± 0.85	1.433	0.151
Female		101	3.87 ± 0.98		
Male	T12	50	4.08 ± 0.85	0.432	0.666
Female		107	4.01 ± 0.92		
Male	L1	52	3.97 ± 0.61	0.998	0.320
Female		95	3.84 ± 0.77		
Male	L2	49	3.23 ± 0.76	1.807	0.073
Female		93	2.95 ± 0.94		

DBCV: Sagittal distance between the vertebral canal anterior border and the posterior vertebral body border. SD: Standard deviation.

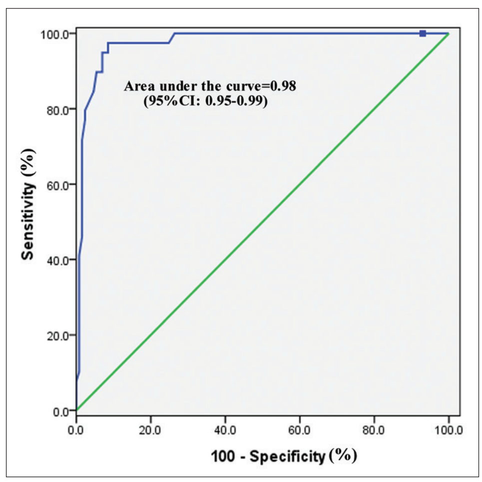

Figure 3: Relative operating characteristic curve of the distance from cement to the posterior wall of the vertebral body. The gold standard is leakage of type-B. When the cut-off value was 4.05 mm, the sensitivity and specificity were 94.87% and 93.02%, respectively. *CI*: Confidence interval.

there is no further quantitative analysis of the posterior vertebral body depression on C-images. Yeom *et al*.[3] found that lateral C-arm images revealed that cement was in vertebral body while the CT-scan showed cement leakage within the vertebral canal and also an influence of depression in the posterior vertebral body on the degree of type-B cement leakage. There is a paucity of data on how the depression in the posterior vertebral body influences the estimation of cement leakage on lateral C-arm images during PVP and PKP. Our study has confirmed the kidney-shape of the thoracolumbar vertebral body and obtained definitive DBCV values in men and women. The latter parameter enables us to better understand the anatomical characteristics of thoracolumbar vertebrae and contributes to our understanding of X-ray image interpretation. However, our data are limited to elderly Asian patients (mean age: 67.2 ± 3.7 years) and, therefore, may not be representative for all people. More data collected from different hospitals including younger patients are needed to get a complete and accurate picture.

We divided all vertebrae that met our criteria into two groups; the DCPW >6.40 mm (the maximum DBCV) or not, because we wanted to know whether the leakage rate would increase especially in type-B if the DCPW was shorter than DBCV. The results showed that the total leakage rate was 43.45%, lower than the 63–87% reported in previous literature, but the leakage rate of group DCPW ≤6.40 mm agreed well with previously published papers.[3,8,9] The leakage rate of group DCPW ≤6.40 mm was lower than that of group DCPW >6.40 mm for type-C and type-S, but much higher for type-B. Differences of the level and fracture grade between two groups had no statistical significance. Further analysis on all vertebrae showed that

Table 2: Comparison of two vertebrae groups divided by whether DCPW was longer than DBCV

Items	DCPW ≤6.40 mm (*n* = 68)	DCPW >6.40 mm (*n* = 100)	Statistical values	*P*
DCPW (mean ± SD, mm)	3.36 ± 1.46	8.82 ± 1.61	−22.346*	<0.001
Leakage type, *n*				
Type-B	38	1	68.396†	<0.001
Type-C	1	17	10.204†	0.001
Type-S	1	15	8.598†	0.003
Vertebral level, *n*				
T11	16	23	1.242†	0.743
T12	18	32		
L1	19	29		
L2	15	16		
Genant score, *n*				
0–0.5	1	3	0.808†	0.848
1	30	41		
2	34	53		
3	3	3		

DCPW: Distance from cement to posterior wall of the vertebral body; DBCV: Sagittal distance between the anterior border of the vertebral canal and the posterior border of the vertebral body. SD: Standard deviation. *: *t* values, †: χ^2 values.

compared with the no leakage group the DCPW of the type-C and type-S groups was significantly longer while in the type-B group significantly shorter. The DCPW of the type-B group was even shorter than the DBCV. The above results suggest that if DCPW is less than DBCV during operations that surgeons often mistakenly believe that the cement is still in the vertebral body, although it has leaked within the vertebral canal [Figure 4]. Because type-B leakage often occurred with the surgeon being unaware of it, the depression of the thoracolumbar posterior vertebral body is worthy of our attention. Tomé-Bermejo *et al*.[10] also noticed that the proportion of type-B leakage in the thoracolumbar spine was higher in their research, but

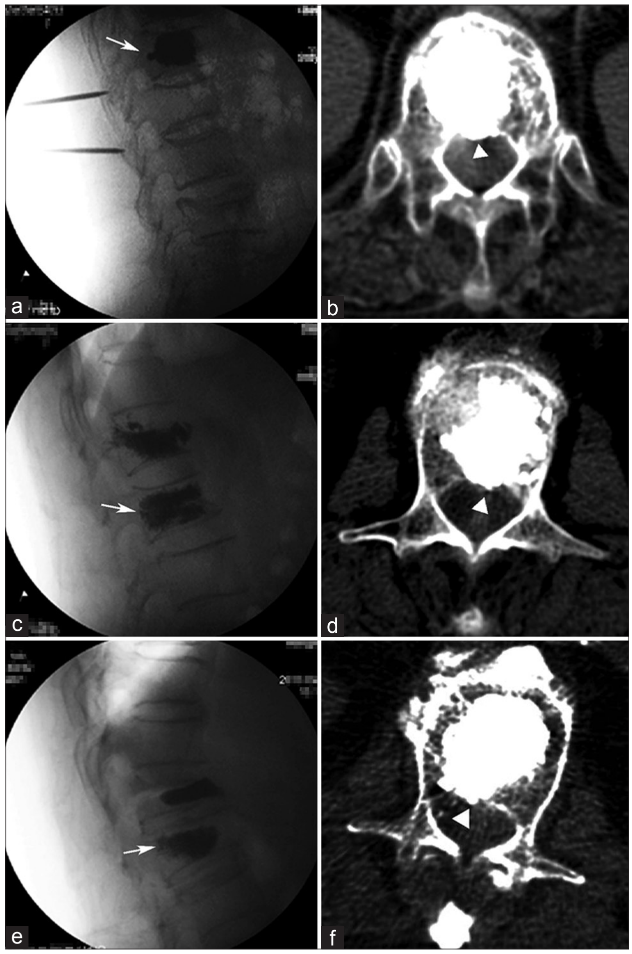

Figure 4: Computed tomography image and C-arm image that showed cement leakage of patients. (a and b) Female, 63-year-old, T12 treated with PKP. The DCPW was 2.11 mm. No cement leakage was found on lateral C-arm images (arrow). Type-B leakage was found after the operation on computed tomography images (triangle). (c and d) Male, 53-year-old, L2 treated with PVP. The DCPW was 1.04 mm. No cement leakage was found on lateral C-arm images (arrow). Type-B leakage was found after the operation on Computed tomography images (triangle). (e and f) Female, 76-year-old, L2 treated with PVP. The DCPW was 2.49 mm. No cement leakage was found on the lateral C-arm images (arrow). Type-B leakage was found after the operation on computed tomography images (triangle). PKP: Percutaneous kyphoplasty; PVP: Percutaneous vertebroplasty; DCPW: The distance from cement to the posterior wall of the vertebral body.

they did not give a definite explanation. This could have been due to the influence of the anatomical form of the thoracolumbar spine vertebral body, and is in consistence with our findings.

In order to further verify the potential role of depression of thoracolumbar posterior vertebral body in the estimation of cement leakage, we carried out an analysis of DCPW values using an ROC curve. The ROC curve of the data revealed that only DCPW had a predictive value for type-B leakage. We found that when the distance was 4.05 mm, both the diagnostic sensitivity and the specificity of cement leakage were relatively high. Thus, we can clinically speculate the possibility of type-B leakage in terms of whether the DCPW reached 4.05 mm when cement was injected. A value of 4.05 mm is much closer to the average DBCV that we found in part 1 of our study. Although we tried our best to make the measurement more accurate, the DBCV values obtained from the CT images were only similar to the real DBCV values on images. The results of this study suggest that the depression of the thoracolumbar posterior vertebral body has a potential role in the estimation of type-B leakage. Surgeons need to keep DCPW to a safe distance longer than DBCV, which we obtained from CT images during PVP or PKP to avoid type-B leakage, even though there is no evidence of leakage on C-arm images. The results of our work are probably only applicable when a unipedicular approach is used, because cement is located in the center of the vertebral body instead of on both sides of the vertebral body when a bipedicular approach is used.

Correct estimation of the stereoscopic form of cement is a real challenge. Currently, the single-plane C-arm X-ray, or bi-plane G-arm X-ray machine was used to monitor cement injection, however, they do not accurately reveal the stereoscopic form of cement in the vertebral bodies, therefore, it is rather difficult to estimate cement leakage, especially vertebral canal leakage. Schmidt *et al*.[9] reported that among the leaks in vertebral bodies examined by CT scan, only 34% were discovered by X-ray radiographs and Yeom *et al*.[3] found an even lower number of 31%. C-arm X-ray monitoring during an operation yields an even lower value, only 21%, possibly due to its low resolution ratio and the time doctors spent on observing fluoroscopy images during the procedure, although less time was spent than that of carrying out postoperative X-ray radiography analysis.[9,11] Although the incidence of complications caused by cement leakage was not high in our study, it is important to perfect the operation techniques in order to minimize complications. It is important to remember that ignorance about the depression of the thoracolumbar posterior vertebral body during PVP or PKP can lead to an increase in type-B leakage. Operations conducted under CT scan guidance may have advantages in discovering the leaks and even lung embolism at an earlier stage.[11] With the advent of three-dimensional C-arm and other new imaging equipments,[12,13] this problem may be eventually resolved.

In conclusion, the depression of the thoracolumbar posterior vertebral body may be informative for the estimation of the cement location on C-arm images. In order to reduce the type-B leakages, we should keep DCPW longer than DBCV, even though we do not find any leakage on C-arm images during PVP or PKP.

Financial support and sponsorship

This study was supported by a grant from the National Natural Science Foundation of China (No. 81472086).

Conflicts of interest

There are no conflicts of interest.

References

1. Lieberman IH, Togawa D, Kayanja MM. Vertebroplasty and kyphoplasty: Filler materials. Spine J 2005;5 6 Suppl: 305S-16S.
2. Hulme PA, Krebs J, Ferguson SJ, Berlemann U. Vertebroplasty and kyphoplasty: A systematic review of 69 clinical studies. Spine (Phila Pa 1976) 2006;31:1983-2001.
3. Yeom JS, Kim WJ, Choy WS, Lee CK, Chang BS, Kang JW. Leakage of cement in percutaneous transpedicular vertebroplasty for painful osteoporotic compression fractures. J Bone Joint Surg Br 2003;85:83-9.
4. Standring S. Gray's Anatomy. 4th ed. London: Churchill Livingstone; 2008.
5. Kang KS, Song KS, Lee JS, Yang JJ, Song IS. Comparison of radiographic and computed tomographic measurement of pedicle and vertebral body dimensions in Koreans: The ratio of pedicle transverse diameter to vertebral body transverse diameter. Eur Spine J 2011;20:414-21.
6. Panjabi MM, Goel V, Oxland T, Takata K, Duranceau J, Krag M, *et al.* Human lumbar vertebrae. Quantitative three-dimensional anatomy. Spine (Phila Pa 1976) 1992;17:299-306.
7. Panjabi MM, Takata K, Goel V, Federico D, Oxland T, Duranceau J, *et al.* Thoracic human vertebrae. Quantitative three-dimensional anatomy. Spine (Phila Pa 1976) 1991;16:888-901.
8. Muijs SP, Nieuwenhuijse MJ, Van Erkel AR, Dijkstra PD. Percutaneous vertebroplasty for the treatment of osteoporotic vertebral compression fractures: Evaluation after 36 months. J Bone Joint Surg Br 2009;91:379-84.
9. Schmidt R, Cakir B, Mattes T, Wegener M, Puhl W, Richter M. Cement leakage during vertebroplasty: An underestimated problem? Eur Spine J 2005;14:466-73.
10. Tomé-Bermejo F, Piñera AR, Duran-Álvarez C, López-San Román B, Mahillo I, Alvarez L. Identification of risk factors for the occurrence of cement leakage during percutaneous vertebroplasty for painful osteoporotic or malignant vertebral fracture. Spine (Phila Pa 1976) 2014;39:E693-700.
11. Pitton MB, Herber S, Koch U, Oberholzer K, Drees P, Düber C. CT-guided vertebroplasty: Analysis of technical results, extraosseous cement leakages, and complications in 500 procedures. Eur Radiol 2008;18:2568-78.
12. Nakashima H, Sato K, Ando T, Inoh H, Nakamura H. Comparison of the percutaneous screw placement precision of isocentric C-arm 3-dimensional fluoroscopy-navigated pedicle screw implantation and conventional fluoroscopy method with minimally invasive surgery. J Spinal Disord Tech 2009;22:468-72.
13. Citak M, Stubig T, Kendoff D, Citak M, O'Loughlin PF, Hüfner T, *et al.* Navigated minimally invasive thoracolumbar pedicle screw placement with flat panel 3-D imaging. A feasibility study. Technol Health Care 2010;18:101-10.