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ORIGINAL ARTICLE

Hidden blood loss of percutaneous vertebroplasty for osteoporotic vertebral compression fractures

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ABSTRACT

Objectives: The aim of this study was to evaluate the amount of hidden blood loss (HBL) in patients treated with percutaneous vertebroplasty (PVP) for thoracolumbar osteoporotic vertebral compression fractures (OVCFs) and to compare the HBL between unilateral extrapedicular approach and unilateral transpedicular approach.

Patients and methods: Between February 2022 to February 2023, a total of 136 patients (49 males, 87 females; mean age: 76.4±9.5 years; range, 55 to 100 years) with thoracolumbar OVCFs treated with PVP were retrospectively analyzed. Patients who underwent unilateral transpedicular approach were divided into Group A (n=62) and patients who underwent unilateral extrapedicular approach were divided into Group B (n=74). Demographic results and clinical data were collected and compared between the two groups. The HBL was calculated according to the Sehat formula.

Results: The mean operation duration was 31.7±9.9 min in Group A and 29.1±11.1 in Group B, indicating no statistically significant difference between the groups (p=0.159). The mean volume of bone cement instilled was 4.4±0.4 mL in Group A and 4.7±0.6 mL in Group B. The volume of cement injected in Group A was less than that of Group B (p=0.001). The mean hemoglobin loss and the amount of HBL were significantly lower in Group A than Group B (p=0.001 and p=0.040, respectively).

Conclusion: Our study results suggest that perioperative HBL cannot be ignored in PVP for thoracolumbar OVCFs, regardless of the surgical approach chosen. We should be more concerned about anemia in patients with thoracolumbar OVCFs after unilateral extrapedicular approach compared to the unilateral transpedicular approach.

Keywords: Hematocrit, hemoglobin, hidden blood loss, osteoporotic vertebral compression fractures, percutaneous vertebroplasty, surgical approach.

Thoracolumbar osteoporotic vertebral compression fractures (OVCFs) have become one of the most common fragility fractures in the elderly.[1] It can cause severe back pain and spinal deformity, affecting patients' quality of life.[2] However, in most cases, it can be treated safely and effectively using conservative or surgical treatment. Percutaneous vertebroplasty (PVP) is a minimally invasive procedure which has become increasingly popular in the treatment of OVCFs in recent years, mainly due to its advantages in providing short-term pain relief and improving physical function.[2,3]

In clinical practice, we have noticed a very common phenomenon that a significant proportion of patients develop anemia postoperatively, despite the short duration of PVP and the low amount of intraoperative visible bleeding. We speculate that perioperative hidden blood loss (HBL) may explain this phenomenon. The concept of HBL was first proposed by Sehat et al.[4] and refers to blood loss due to spreading of blood into tissues, residual dead space or hemolysis. It is often overlooked by

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most spine surgeons due to “zero” intraoperative blood loss. However, numerous studies have shown that HBL is an important component of total blood loss (TBL) in orthopedic surgery, whether minimally invasive or open spine surgery.[5-8] Therefore, clarifying HBL can more accurately estimate perioperative TBL, which can also help to improve clinical assessment and ensure patients’ safety in the perioperative period.

For thoracic OVCFs, the approach for injecting polymethylmethacrylate (PMMA) has evolved from bilateral transpedicular-to-unilateral transpedicular to unilateral-to-extrapedicular approaches.[9,10] Compared to the unilateral transpedicular approach, the unilateral extrapedicular approach has the advantages of shorter operation duration, uniform cement distribution, and lower cement leakage rate.[11,12] In recent years, several studies have reported the use of unilateral extrapedicular approaches for the treatment of lumbar OVCFs.[13-15] However, it is still unclear whether the unilateral extrapedicular approach is totally safe and more advantageous in reducing the incidence of HBL and anemia. In the present study, we, therefore, aimed to evaluate the amount of HBL in patients undergoing PVP surgery and to compare HBL in patients treated with unilateral extrapedicular approach and transpedicular approach.

PATIENTS AND METHODS

This single-center, retrospective study was conducted at the Third People’s Hospital of Chengdu, Department of Orthopaedics between February 2022 and February 2023. Initially, patients with thoracolumbar OVCFs treated with PVP were screened. Inclusion criteria were as follows: age over 55 years old; fresh thoracolumbar OVCFs clearly identified by magnetic resonance imaging (MRI), and all of them were one level vertebral fracture; obvious pain in the thoracolumbar back and obvious localized percussion pain in the responsible vertebrae; and bone mineral density (BMD) in accordance with the diagnostic criteria of osteoporosis (BMD <80 mg/cm^3). Quantitative computed tomography (CT) was used to measure BMD in our unit.[16] Exclusion criteria were as follows: the presence of serious underlying diseases, such as severe heart, lung, liver and kidney dysfunction; serious systemic infectious diseases or local infection in the operation area; abnormal coagulation function or serious bleeding tendency; severe spinal stenosis at the corresponding level of fracture, or the fracture of the posterior wall of the vertebral body moved back to cause intradural occupancy and with the symptoms of nerve root, spinal cord compression; Pathological fracture caused by tumor, tuberculosis; and multiple injuries. Finally, a total of 136 patients (49 males, 87 females; mean age: 76.4±9.5 years; range, 55 to 100 years) who met the inclusion criteria were recruited. A written informed consent was obtained from each patient. The study protocol was approved by the Third People’s Hospital of Chengdu Ethics Committee (date: 23.01.2022, no: 2022-S-09). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Surgical process

All surgeries were performed under local anesthesia by two surgeons from the same surgical team who have similar years of work and experience. Both surgeons were familiar with the two surgical approaches of PVP. We divided the patients with PVP treated by unilateral transpedicular approach into Group A (n=62, Figure 1a) and the patients with PVP treated by unilateral extrapedicular approach into Group B (n=74, Figure 1b). The choice of surgical approach was related to the size of the pedicle, the characteristics of the fracture, and the preference of the surgeons.

In Group A, in the prone position, the C-arm machine was used to determine the injured vertebrae under fluoroscopic guidance and to determine the projection point for the puncture of the injured vertebrae. The left pedicle projection at 10 points and the right pedicle projection at two points were selected as the anchoring points of the puncture needle on the bone surface, which were moved outward about 5 mm as the entry points for skin puncture and marked well. Routine disinfection and local anesthesia were applied. The needle was inserted from the marked point of the skin puncture, and the angle of the needle's abduction increased gradually from the thoracic to the lumbar vertebrae, from the upper to the lower. When the tip of the puncture needle touched the anchoring point of the bone surface to the middle and root of the pedicle, and when the puncture entered the vertebral body for about 0.5 cm, fluoroscopy with a C-arm machine was used to confirm that the tip of the needle was located in the pedicle, and that it did not break through the inner wall of the pedicle, respectively. As the needle continued to enter, fluoroscopy was used to confirm that the needle had reached the vertebral body's midline in the anteroposterior position, and that the needle was close to the anterior edge of the vertebral body in

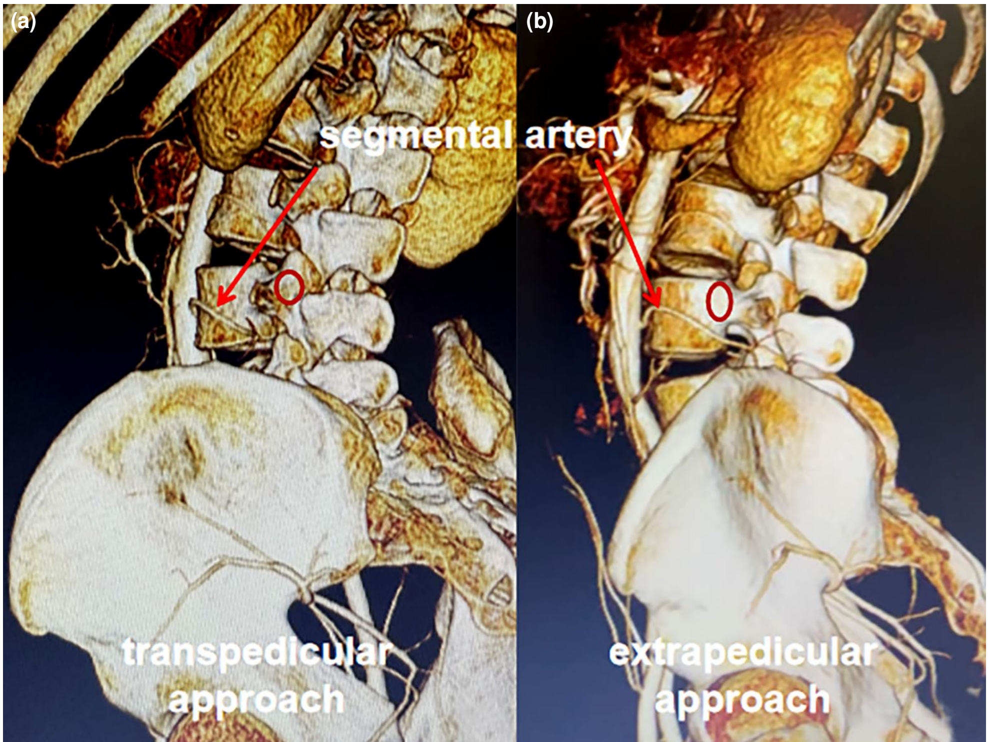

FIGURE 1. Anatomical landmarks of the two surgical approaches of PVP. **(a, b)** Red circles indicated the anchoring points of the puncture needle on the bone surface for the transpedicular approach and the extrapedicular approach, respectively; **(b)** compared to the transpedicular approach, the extrapedicular approach carried a risk of segmental arterial injury.

the lateral position. Subsequently, the core of the puncture needle was withdrawn, and the cement was injected under fluoroscopy until the cement dispersed approximately 5 mm from the posterior wall of the vertebral body. If the cement leaked out of the vertebral body during the injection process, the injection was stopped, waiting for 3 to 5 min until the cement was initially solidified. Finally, the pusher and the working trocar were withdrawn, and the incision was locally pressed to stop bleeding for 3 min.

In Group B, in the prone position, the junction between the upper edge of the pedicle projection and the outer edge of the vertebral body was selected as the anchoring point of the puncture needle under fluoroscopy of the C-arm machine. The entry point of skin puncture was marked by a lateral translation of about 5 mm. Routine disinfection and local anesthesia were applied. The needle was inserted from the marked skin puncture point, and the puncture needle arrived at the anchoring point and was further confirmed by fluoroscopy with a C-arm machine. The tip of the puncture needle was located at the junction between the outer edge of the root of the pedicle and the vertebral body in the anteroposterior position, and the tip of the puncture needle was located at the upper edge of the pedicle in the lateral position. The puncture needle penetrated the posterior lateral wall of the vertebral body and was continued, until it entered the vertebral body about 1.5 cm and then stopped. Fluoroscopy confirmed that the puncture needle was at or near the midline of the vertebral body in the anteroposterior position and near its anterior margin in the lateral position. The core of the puncture needle was withdrawn and the probe was placed to touch and confirm that the cortex of the anterior wall of the vertebral body was not breached. The subsequent operations were carried out according to the routine steps of PVP.

The patients' vital signs were closely monitored for 24 h. After 24 h, they were discharged from bed under the protection of a waist cuff to avoid excessive spinal movement. All patients were treated with regular anti-osteoporosis medication. Patients in both groups were followed for more than 12 months.

TABLE I
Characteristics of the patients

	Group A		Group B		
Variables	n	Mean±SD	n	Mean±SD	*p*
Age (year)		76.1±9.3		76.7±9.7	0.719
Sex					
Male	23		26		
Female	39		48		
Height (m)		1.61±0.06		1.61±0.07	0.445
Weight (kg)		52.0±5.7		53.6±6.4	0.121
BMI (kg/m^2)		20.2±1.7		20.6±2.2	0.204
BMD (mg/cm^3)		42.6±15.2		44.4±15.7	0.494
Comorbidity					
Hypertension	9		8		
Diabetes mellitus	20		21		
Coronary heart disease	8		7		
Fracture segment					
Thoracic vertebrae (T7-T12)	30		46		
Lumbar vertebra (L1-L5)	32		28		
Time from injury to surgery (days)		5.1±2.0		5.0±2.0	0.657
Visual Analog Scale		6.5±1.1		6.6±0.9	0.712
ASA classification					
I	5		11		
II	45		52		
III	12		11		
Total	62		74		

SD: Standard deviation; BMI: Body mass index; BMD: Bone mineral density.

Data collection

Preoperative variables were assessed and recorded, including age, sex, height, weight, body mass index (BMI), BMD, underlying comorbidity, fracture segment, time from injury to surgery, and Visual Analog Scale (VAS) score. Intra- and postoperative data included the American Society of Anesthesiologists (ASA) classification, operation duration, number of fluoroscopy, amount of cement injected, cement leakage, length of stay and follow-up time. In addition, laboratory data (hemoglobin [Hb], albumin [ALB], and hematocrit [Hct]) were documented. The above parameters could be obtained from the patients' routine blood and liver function tests on the first preoperative day and the third postoperative day. None of the patients received preoperative blood transfusion.

Calculation of hidden blood loss

We used the complete blood count on the third postoperative day as a reference, mainly because by this time, the patient's hemodynamics were stabilized and any fluid transfer was largely complete.[4]

Firstly, the Nadler formula was used to calculate patient blood volume (PBV):[17] PBV (L) = k1 × height (m)^3+ k2 × weight (kg) + k3; where k1 = 0.3669, k2 = 0.03219, and k3 = 0.6041 for males and k1 = 0.3561, k2 = 0.03308, and k3 = 0.1833 for females.

Secondly, the Gross formula was used to calculate the TBL:[18] TBL (L) = PBV (L) × (Hct_{pre} - Hct_{post})/Hctave; where Hct_{pre} was the preoperative Hct, Hct_{post} was the Hct on the third postoperative day, and Hctave was the average of Hct_{pre} and Hct_{post}.

Thirdly, based on the Sehat formula,[4] HBL was calculated: HBL=TBL - Visible blood loss (VBL). The HBL and TBL were roughly equal due to the negligible amount of VBL. The HBL was finally calculated as follows: HBL=TBL.

Statistical analysis

Statistical analysis was performed using the IBM SPSS version 26.0 software (IBM Corp., Armonk, NY, USA). Descriptive data were expressed in mean ± standard deviation (SD), median (min-max) or number and frequency, where applicable. The independent t-test was used to compare the groups. The chi-square test was used to analyze categorical data. A p value of <0.05 was considered statistically significant.

RESULTS

Of a total of 136 patients, the majority (76) of the fractures were thoracic spine fractures. There was no significant difference in the demographic and baseline characteristics of the two groups (Table I).

The mean operation duration was 31.7±9.9 min in Group A and 29.1±11.1 in Group B, indicating no statistically significant difference between the groups (p=0.159). The mean volume of bone cement instilled was 4.4±0.4 mL in Group A and 4.7±0.6 mL in Group B. The volume of cement injected in Group A was less than that of Group B (p=0.001). Fourteen patients (22.6%) in Group A had cement leakage. Patients with cement leakage in both groups did not experience complications and related symptoms such as spinal cord and nerve root compression, and the difference in cement leakage rate between the two groups was not statistically significant (p=0.957). There was no significant difference between the two groups in

TABLE II
Comparison of intraoperative and postoperative parameters between the two groups

	Group A		Group B		
Variables	n	Mean±SD	n	Mean±SD	p
Surgical time (min)		31.7±9.9		29.1±11.1	0.159
Number of fluoroscopy		6.8±1.3		6.9±1.2	0.695
Amount of cement injected (mL)		4.4±0.4		4.7±0.6	0.001
Cement leakage					
Yes	14		17		
No	48		57		
Length of stay (day)		5.1±1.3		5.1±1.1	0.730
Follow-up time (month)		15.3±2.3		15.8±2.8	0.284
Total	62		74		

SD: Standard deviation; ASA: American Society of Anesthesiologists.

TABLE III
Laboratory and HBL-related parameters

	Group A		Group B		
Variables	n	Mean±SD	n	Mean±SD	p
Preoperative ALB (g/L)		34.5±3.9		34.3±4.1	0.834
Preoperative Hct (%)		0.37±0.04		0.36±0.04	0.289
Postoperative Hct (%)		0.35±0.04		0.34±0.04	0.137
Hct loss (%)		0.02±0.01		0.03±0.01	0.113
Preoperative Hb (g/L)		118.6±16.1		119.3±17.2	0.815
Postoperative Hb (g/L)		113.2±16.8		113.5±17.7	0.927
Hb loss (g/L)		5.9±2.1		7.6±3.3	0.001
PBV (L)		3.5±0.5		3.6±0.5	0.406
HBL (mL)		230.7±82.2		263.2±97.8	0.040
Mean HBL (mL)		248.4±92.2		248.4±92.2	-
Total	62		74		

HBL: Hidden blood loss; SD: Standard deviation; ALB: Albumin; Hct: Hematocrit; Hb: Hemoglobin; PBV: Patient blood volume; Hct loss referred to preoperative Hct minus postoperative Hct; Hb loss referred to preoperative Hb minus postoperative Hb.

terms of ASA classification, operation duration, number of fluoroscopy, length of stay, and follow-up time (p>0.05) (Table II).

Perioperative parameters regarding HBL are shown in Table III. In our study, the mean HBL of PVP was 248.4±92.2 mL, a value that was higher than we expected and could not be ignored. Group A was significantly lower than Group B in terms of Hb loss and HBL, indicating a statistically significant difference between the groups (p=0.001 and p=0.040, respectively).

DISCUSSION

In recent years, PVP has become the treatment of choice for thoracolumbar OVCFs not only as it can partially correct the collapse of fractured vertebral body, but also as it provides rapid relief of low back pain postoperatively and it is a minimally invasive procedure which can be performed as a day-surgery.[19] Precisely, since it is a minimally invasive operation with minimal VBL, many spine surgeons tend to ignore the effects of HBL. In addition, thoracolumbar OVCFs are mostly seen in the elderly population, which is often comorbid with some medical conditions. In our study, there were many elderly patients with comorbid hypertension, diabetes mellitus, and coronary heart disease. Therefore, enhancing perioperative blood management in elderly patients can help to reduce anemia-related complications and promote rapid recovery. In a retrospective study examining risk factors for HBL, HBL was statistically significantly higher than VBL.[6] In our study, the mean perioperative HBL and Hb loss were 248.4±92.2 mL and 6.8±2.9 g/L, respectively. These figures were much greater than that can be attributed to VBL. In contrast to the study by Cai et al.,[6] we disregarded intraoperative VBL, which may have resulted in an underestimation of HBL. Nonetheless, our study reinforced the spine surgeons' knowledge of HBL and also compared HBL between the two surgical approaches, providing guidance for the formulation of surgical strategies. In elderly patients with OVCFs, significant blood loss is secondary to the initial injury. Additional HBL in the perioperative period would have a significant impact on these patients, particularly those with underlying comorbidities. It would also increase postoperative mortality and morbidity.[20] Due to the potential adverse effects of anemia, patients must be closely monitored after surgery.

Over the past few years, the unilateral extrapedicular approach has become popular in the treatment of thoracic OVCFs.[21] Numerous studies have demonstrated that the extrapedicular approach and the transpedicular approach are equally effective and safe for pain relief in patients undergoing thoracic kyphoplasty.[22,23] In recent years, some attempts have been made to perform lumbar OVCFs for posterior kyphoplasty using a unilateral extrapedicular approach.[15] The choice of surgical approach is related to many factors. When the diameter of the pedicle is small, the fracture involves the pedicle, or the puncture via the transpedicular approach fails or the location of the puncture is unsatisfactory, the extrapedicular approach is usually considered. If the fracture is amenable to any of the approaches, the decision on the choice of surgical approach is made by a discussion among the surgeons. Compared to the unilateral transpedicular approach, the unilateral extrapedicular approach can provide good pain relief, adequate cement infusion, shorter operation duration, and less fluoroscopy exposure.[24] However, to the best of our knowledge, there are no studies comparing the extrapedicular approach with the transpedicular approach for HBL in unilateral PVP for thoracolumbar OVCFs.

In the present study, HBL was significantly less in Group A than in Group B. One explanation for this was that the extrapedicular approach had a longer puncture path than the transpedicular approach, with consequent heavier soft tissue damage. Secondly, the extrapedicular approach was more likely to access the center of the fractured vertebrae, providing a more symmetrical cement filling. As a result, a larger amount of cement was injected in Group A than in Group B. This larger dose of cement injected may cause greater damage to an otherwise fractured vertebra. In addition, the risk of segmental arterial injury was higher with the extrapedicular approach compared to the transpedicular approach. Thus, injuries to segmental artery or its branches that we did not identify may also contribute to increased HBL. Therefore, for patients using the extrapedicular approach, the operator needs to be concerned about the patients' HBL and the occurrence of postoperative anemia.

Cement infiltration in unilateral extrapedicular approach has more advantages than transpedicular approach. In the present study, more cement was injected into the fractured vertebrae in Group B compared to Group A. We believe that achieving this satisfactory cement infusion was highly correlated with a favorable puncture position and angle. In previous studies, several extrapedicular approaches have been proposed. Ryu et al.[25] proposed a far-lateral extrapedicular approach. Cho et al.[26] described an individualized approach with preoperative measurements, where the puncture was advanced to the superior edge of the transverse process. Wang et al.[27] suggested performing a puncture through the Kambin's triangle. Previous studies have found that the extrapedicular approach demonstrates a lower rate of cement leakage compared to the transpedicular approach.[11,12] However, in our study, there was no significant difference in the incidence of cement leakage, although the average amount of cement injected differed significantly between the two groups. Our report contradicted the results of other studies, and we believe that there may be several reasons for this: *(i)* This is a single-center report with the small sample size; *(ii)* the injection of a large amount of cement by the extrapedicular approach may increase the risk of cement leakage; and *(iii)* other unpredictable factors existed. The overall bone cement leakage rate was 22.8% (31/136), which is consistent with the results of previous studies.[24,28]

The most common problem with the extrapedicular approach is the segmental arterial injury. Xu et al.[29] performed spinal CT angiography and found that segmental arteries mainly pass below the midline of the pedicle. Therefore, the injury of segmental arteries can be avoided, when an extrapedicular approach was used and the puncture site was located on the superior-lateral aspect of the vertebral pedicle. In patients with hypovolemic shock and progressive Hb loss after the extrapedicular approach, the retroperitoneal hematoma can be confirmed by abdominal CT scanning.[10,29]

Nonetheless, our study has several limitations. First, as a single-center, retrospective study, the relatively small sample size may have affected statistical validity. Second, the difference in the proportions of thoracic and lumbar fracture sites between the two groups may cause selection bias. Third, we assessed HBL on the third postoperative day based on Hct, which may have led to an underestimation of HBL. In addition, postoperative rehydration may dilute the blood and lead to bias in HBL. Finally, as the choice of surgical approach is related to many factors, this may result in data bias in grouping. Further multi-center, large-scale prospective studies are needed to confirm our findings.

In conclusion, in the PVP treatment of thoracolumbar OVCFs, perioperative HBL should not be ignored. Compared to the unilateral transpedicular approach, we should pay more attention to the amount of Hb loss and the anemia status of patients after the unilateral extrapedicular approach, and formulate countermeasures in time to avoid a series of complications caused by postoperative anemia.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Conception and design: L.T., Y.Y.; Collection and assembly of data: Y.Y.; Analysis and interpretation of the data, statistical expertise: H.Z.; Drafting of the article: L.T.; Critical revision of the article for important intellectual content: H.H. All authors read and approved the final manuscript.

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REFERENCES

1. Zhang T, Peng Y, Li J. Comparison of clinical and radiological outcomes of vertebral body stenting versus percutaneous kyphoplasty for the treatment of osteoporotic vertebral compression fracture: A systematic review and meta-analysis. Jt Dis Relat Surg 2024;35:218-30. doi: 10.52312/jdrs.2023.1356.
2. Sun Y, Li X, Ma S, Chong H, Cai TC, Li KM, et al. Comparison of the efficacy and safety of unilateral and bilateral approach kyphoplasty in the treatment of osteoporotic vertebral compression fractures: A meta-analysis. Jt Dis Relat Surg 2024;35:491-503. doi: 10 .52312/jdrs.2024.1701.
3. Kim T, Park J, Cho J, Yi JS, Lee HJ. Quantitative comparison of vertebral structural changes after percutaneous vertebroplasty between unilateral extrapedicular approach and bilateral transpedicular approach using voxel-based morphometry. Neurospine 2023;20:1287-302. doi: 10.14245/ns.2346536.268.
4. Sehat KR, Evans R, Newman JH. How much blood is really lost in total knee arthroplasty? Correct blood loss management should take hidden loss into account. Knee 2000;7:151-5. doi: 10.1016/s0968-0160(00)00047-8.
5. Yang Y, Peng YX. Hidden blood loss and its risk factors in percutaneous vertebroplasty surgery for osteoporotic vertebral compression fractures. Arch Orthop Trauma Surg 2023;143:5575-81. doi: 10.1007/s00402-023-04873-3.
6. Cai T, Wang F, Nan L, Chen D, Wang S, Feng X, et al. Perioperative hidden blood loss in elderly osteoporotic vertebral compression fracture patients with percutaneous vertebroplasty and influencing factors. Geriatr Orthop Surg Rehabil 2021;12:2151459321996178. doi: 10.1177/2151459321996178.
7. Raitio A, Heiskanen S, Soini V, Helenius L, Syvänen J, Helenius I. Hidden blood loss and bleeding characteristics in children with congenital scoliosis undergoing spinal osteotomies. Int Orthop 2024;48:1569-77. doi: 10.1007/s00264-024-06090-y.

8. Yang Y, Wang F. Hidden blood loss in unilateral opendoor cervical laminoplasty for multilevel cervical spondylotic myelopathy. Jt Dis Relat Surg 2024;35:293-8. doi: 10.52312/jdrs.2024.1439.
9. Schupfner R, Koniarikova K, Pfeifer C, Grechenig P, Bakota B, Staresinic M, et al. An anatomical study of transpedicular vs. extrapedicular approach for kyphoplasty and vertebroplasty in the thoracic spine. Injury 2021;52 Suppl 5:S63-9. doi: 10.1016/j.injury.2020.11.017.
10. Zhu D, Hu JN, Wang L, Cui W, Zhu JC, Ma S, et al. A modified unilateral extrapedicular approach applied to percutaneous kyphoplasty to treat lumbar osteoporotic vertebral compression fracture: A retrospective analysis. Pain Physician 2023;26:E191-201.
11. Chen W, Xie W, Xiao Z, Chen H, Jin D, Ding J. Incidence of cement leakage between unilateral and bilateral percutaneous vertebral augmentation for osteoporotic vertebral compression fractures: A meta-analysis of randomized controlled trials. World Neurosurg 2019;122:342-8. doi: 10.1016/j.wneu.2018.10.143.
12. Zhang W, Liu S, Liu X, Li X, Wang L, Wan Y. Unilateral percutaneous vertebroplasty for osteoporotic lumbar compression fractures: A comparative study between transverse process root-pedicle approach and conventional transpedicular approach. J Orthop Surg Res 2021;16:73. doi: 10.1186/s13018-021-02219-6.
13. Qian Y, Li Y, Shen G, Zhong X, Tang C, He S. Comparison of unipedicular and bipedicular kyphoplasty for treating acute osteoporotic vertebral compression fractures in the lower lumbar spine: A retrospective study. BMC Musculoskelet Disord 2023;24:410. doi: 10.1186/s12891-023-06545-0.
14. Zhang T, Deng Y. A design of a targeted puncture trajectory applied to unilateral extrapedicular percutaneous vertebroplasty. BMC Musculoskelet Disord 2023;24:268. doi: 10.1186/s12891-023-06387-w.
15. Zhu D, Hu J, Wang L, Zhu J, Ma S, Liu B. A comparison between modified unilateral extrapedicular and bilateral transpedicular percutaneous kyphoplasty in the treatment of lumbar osteoporotic vertebral compression fracture. World Neurosurg 2022;166:e99-108. doi: 10.1016/j.wneu.2022.06.115.
16. Brunnquell CL, Winsor C, Aaltonen HL, Telfer S. Sources of error in bone mineral density estimates from quantitative CT. Eur J Radiol 2021;144:110001. doi: 10.1016/j.ejrad.2021.110001.
17. Nadler SB, Hidalgo JH, Bloch T. Prediction of blood volume in normal human adults. Surgery 1962;51:224-32.
18. Gross JB. Estimating allowable blood loss: Corrected for dilution. Anesthesiology 1983;58:277-80. doi: 10.1097/00000542-198303000-00016.
19. Nie B, Wang Q, Li B, Ou N, Yang Z. Exploration of percutaneous vertebroplasty in the treatment of osteoporotic vertebral compression fracture as day surgery: A retrospective study. Eur Spine J 2021;30:2718-25. doi: 10.1007/s00586-021-06887-0.
20. Wu YS, Zhang H, Zheng WH, Feng ZH, Chen ZX, Lin Y. Hidden blood loss and the influential factors after percutaneous kyphoplasty surgery. Eur Spine J 2017;26:1878-83. doi: 10.1007/s00586-017-4950-9.
21. Ge J, Cheng X, Li P, Yang H, Zou J. The clinical effect of kyphoplasty using the extrapedicular approach in the treatment of thoracic osteoporotic vertebral compression fracture. World Neurosurg 2019;131:e284-9. doi: 10.1016/j.wneu.2019.07.133.
22. He H, Tan Y, Yang S, Zhang C, Luo X. Study of unilateral extrapedicular and bilateral pedicle approach percutaneous kyphoplasty for osteoporotic vertebral compression fracture. J Coll Physicians Surg Pak 2022;32:924-7. doi: 10.29271/jcpsp.2022.07.924.
23. Wang W, Duan K, Ma M, Jiang Y, Liu T, Liu J, et al. Can an unipedicular approach replace bipedicular percutaneous vertebroplasty for osteoporotic vertebral compression fracture? J Back Musculoskelet Rehabil 2019;32:261-7. doi: 10.3233/BMR-170870.
24. Hong H, Li J, Ding H, Deng Y, Deng Z, Jiang Q. Unilaterally extrapedicular versus transpedicular kyphoplasty in treating osteoporotic lumbar fractures: A randomized controlled study. J Orthop Surg Res 2023;18:801. doi: 10.1186/s13018-023-04267-6.
25. Ryu KS, Park CK, Kim MK, Kim DH. Single balloon kyphoplasty using far-lateral extrapedicular approach: Technical note and preliminary results. J Spinal Disord Tech 2007;20:392-8. doi: 10.1097/BSD.0b013e31802da846.
26. Cho SM, Nam YS, Cho BM, Lee SY, Oh SM, Kim MK. Unilateral extrapedicular vertebroplasty and kyphoplasty in lumbar compression fractures: Technique, anatomy and preliminary results. J Korean Neurosurg Soc 2011;49:273-7. doi: 10.3340/jkns.2011.49.5.273.
27. Wang YF, Shen J, Li SY, Yu X, Zou TM. Kambin triangle approach in percutaneous vertebroplasty for the treatment of osteoporotic vertebral compression fractures. Medicine (Baltimore) 2019;98:e17857. doi: 10.1097/MD.0000000000017857.
28. 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;101:633-42. doi: 10.1016/j.wneu.2017.01.124.
29. Heo DH, Cho YJ. Segmental artery injury following percutaneous vertebroplasty using extrapedicular approach. J Korean Neurosurg Soc 2011;49:131-3. doi: 10.3340/jkns.2011.49.2.131.