

Hidden blood loss and its influencing factors after percutaneous kyphoplasty surgery

A retrospective study

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Abstract

Percutaneous kyphoplasty (PKP) surgery is generally accepted as a minimally invasive treatment for osteoporotic vertebral compression fractures (OVCFs). However, hidden blood loss (HBL) caused by this procedure is usually disregarded. This study aimed to investigate the amount of HBL and its influencing factors after PKP surgery.

A total of 160 patients were retrospectively examined from January 2014 to January 2016, and their clinical and radiological data were recorded and analyzed. Preoperative and postoperative hematocrit (Hct) and hemoglobin (Hb) levels were also documented. HBL was calculated using Gross formula. Different factors, including gender, age, bone mineral density (BMD), number of fracture levels, hypertension, diabetes mellitus, operative time, percentage of vertebral height loss, percentage of vertebral height restoration, and cement leakage, were examined. Multivariate linear regression analysis was performed to elucidate the related clinical or radiological factors of HBL.

A total of 122 patients with 169 levels were eligible for inclusion in the study. The mean HBL was 279 ± 120 mL, and the postoperative Hb loss was 8.2 ± 3.9 g/L. Multivariate linear regression analysis revealed that HBL was positively associated with operative time ($P = .000$), percentage of vertebral height loss ($P = .037$), and percentage of vertebral height restoration ($P = .000$). By contrast, HBL was not associated with gender ($P = .874$), age ($P = .148$), BMD ($P = .134$), number of fracture levels ($P = .079$), hypertension ($P = .259$), diabetes mellitus ($P = .495$), and cement leakage ($P = .975$). The postoperative incidence of anemia significantly increased by 39.3% compared with that of the preoperative incidence ($\chi^2 = 21.432$, $P = .000$).

For patients with OVCFs, the amount of HBL after PKP is much larger than that observed perioperatively. Operative time, percentage of vertebral height loss, and percentage of vertebral height restoration are influencing factors of HBL.

Abbreviations: ALIF = anterior lumbar fusion surgery, BMD = bone mineral density, BMI = body mass index, Hb = hemoglobin, HBL = hidden blood loss, Hct = hematocrit, HL = height loss, HR = height restoration, OVCFs = osteoporotic vertebral compression fractures, PBV = patient's blood volume, PKP = percutaneous kyphoplasty, PLIF = posterior lumbar fusion surgery, SD = standard deviation, TBL = total blood loss, THA = total hip arthroplasty, TKA = total knee arthroplasty, VAS = visual analogue score, VBH = vertebral height.

Keywords: hidden blood loss, influencing factors, multivariate linear regression analysis, osteoporotic vertebral compression fractures, percutaneous kyphoplasty surgery

1. Introduction

In clinical practice, hidden blood loss (HBL) penetrating tissues, retained in a dead space, and lost due to hemolysis is often

disregarded by orthopedic surgeons.^[1] HBL may considerably affect postoperative outcomes, such as medical complications, increased blood transfusion risks, and prolonged hospitalization time.^[2,3] HBL has been widely investigated in orthopedic surgeries since 2000,^[2,4-7] and emerging data on knee and hip replacement surgeries have revealed that HBL varies from 26% to 56% of the total blood loss (TBL).^[1,8,9] In a study on the treatment of intertrochanteric fractures, HBL was nearly 75% and 44% of the TBL in proximal femoral nail antirotation group and dynamic hip screw group, respectively.^[10] In a work on anterior/posterior lumbar fusion surgery (ALIF/PLIF), HBL was approximately 40% of TBL.^[2,4] However, few studies have considered HBL in percutaneous kyphoplasty (PKP) surgery.

PKP is a minimally invasive and effective treatment for osteoporotic vertebral compression fractures (OVCFs). It is performed by initially inserting an inflatable balloon through a pedicle and then injecting polymethylmethacrylate into a fractured vertebral body. In our clinical experience, PKP is associated with a relatively low perioperative blood loss because of small incision, reduced muscular dissection, and short operative time.

Correct information about the degree of blood loss can help prevent complications. However, HBL and its relevant influencing factors after PKP surgery have yet to be systematically

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investigated. In this study, we retrospectively reviewed patient data to determine the amount of HBL and identified the influencing factors of HBL after PKP surgery.

2. Materials and methods

2.1. Patients

The study design was reviewed and approved by the Ethics Committee of Chongqing General Hospital. Informed consent was obtained from all of the participants. A total of 160 patients, with 59 males and 101 females, with a complete disease history were analyzed between January 2014 and January 2016 in our hospital. Our inclusion criteria were age > 60 years, low-energy injury sustained within 2 weeks prior to admission, severe back pain (visual analogue score, VAS > 5), conservative treatment failures, acute OVCFs (confirmed by magnetic resonance imaging), decreased bone mineral density (BMD ≤ -2.5 standard deviation, SD), and all of the patients underwent PKP surgery. Our exclusion criteria were old OVCFs, spine infection, suspected underlying malignant disease, spinal cord compression syndrome, severe cardiopulmonary comorbidity, major coagulopathy, and patients with liver cirrhosis or uremia. Basic clinical data, including gender, age, height, weight, body mass index (BMI), BMD, hypertension, diabetes mellitus, fracture location, number of fracture levels, preoperative and postoperative hematocrit (Hct) and hemoglobin (Hb), operative time, percentage of vertebral height loss, percentage of vertebral height restoration, and cement leakage were recorded.

2.2. Surgical technique and postoperative therapy

All of the operations were primary procedures and performed by an experienced surgeon (SZ) using local anesthesia. PKP surgery was carried out in accordance with a standard published technique, namely, bilateral pedicle approach, with a C-arm fluoroscope.^[11] All of the patients were prescribed with osteoporotic medication, including calcium, vitamin D supplements, and antiresorptive agents after surgery.

2.3. Management of blood loss

No patient received blood transfusion throughout the assessment period. Low visible blood loss was detected intraoperatively but was disregarded. Therefore, HBL was approximated to TBL. No drainage was typically placed in any of the patients. All of the patients underwent a full blood count, including Hct, and Hb before the surgery and 2 or 3 days after the surgery. By this time, the patients were hemodynamically stable, and fluid shifts were largely completed.^[9]

2.4. Calculation of patient's blood volume (PBV) and HBL

PBV was estimated in accordance with the formula of Nadler et al^[12] as follows:

$PBV (L) = k_1 \times \text{height (m)}^3 + k_2 \times \text{weight (kg)} + k_3$, where $k_1 = 0.3669$, $k_2 = 0.03219$, and $k_3 = 0.6041$ for males, and $k_1 = 0.3561$, $k_2 = 0.03308$, and $k_3 = 0.1833$ for females. We assumed that the blood volume was the same on admission and on days 2 or 3 after surgery.

The TBL was calculated through the Gross formula^[13] as follows:

$$TBL (L) = PBV(L) \times \frac{Hct_{pre} - Hct_{post}}{Hct_{ave}},$$

where Hct_{pre} is the initial preoperative Hct, Hct_{post} is the Hct 2 or 3 days postoperation, and Hct_{ave} is the average of Hct_{pre} and Hct_{post} .

The preoperative and postoperative Hb levels were used to calculate Hb_{loss} in the perioperative period. Hb_{loss} was calculated as follows:

$$Hb_{loss} (g/L) = Hb_{pre} - Hb_{post}$$

2.5. Calculation of the percentages of vertebral height loss and restoration

All of the included cases were examined using plain radiographs. Vertebral height (VBH) was measured at the point of the maximal collapse of the affected vertebral body. The percentages of vertebral height loss (HL, %) and vertebral height restoration (HR, %) were calculated with the following equations:

$$VBH_{ave} = \frac{VBH_a + VBH_b}{2},$$

$$HL (\%) = \frac{VBH_{ave} - VBH_{pre}}{VBH_{ave}} \times 100\%,$$

$$HR (\%) = \frac{VBH_{post} - VBH_{pre}}{VBH_{ave}} \times 100\%,$$

where VBH_a and VBH_b are 2 adjacent vertebral heights, VBH_{ave} is the average height of the 2 adjacent vertebrae, and VBH_{pre} is the preoperative anterior or midline vertebral body height of the fractured vertebrae.

2.6. Additional measurements

According to the World Health Organization, anemia is characterized by Hb levels of < 120 g/L for women and < 130 g/L for men.^[14]

2.7. Statistical analysis

Data were expressed as means \pm standard deviation or medians (25th–75th percentile). The normality of variables was assessed, and differences in mean and median values were evaluated using Student *t* test and Mann–Whitney *U* test, respectively. A χ^2 test was adopted to compare the preoperative and postoperative incidence of anemia. Multivariate linear regression analysis was performed to evaluate the influencing factors associated with HBL. Among the qualitative variables, hypertension, diabetes mellitus, and cement leakage were set as “1,” whereas nonhypertension, nondiabetes mellitus, and nonleakage were set as “0.” A positive coefficient indicated a positive influence on the dependent variable (HBL), whereas a negative coefficient denoted a negative influence. All of the independent variables were incorporated into the model using the method of “Enter.” Data analyses were performed with SPSS version 19.0 (SPSS,

Table 1
Patient's demographic information.

Parameters	Male	Female	Total
Number of patients	39	83	122
Age, y	73 (69–82)	75 (69–80)	75 (69–80)
Height, m*	1.67 (1.63–1.70)	1.60 (1.55–1.62)	1.61 (1.55–1.65)
Weight, kg*	66 (60–69)	56 (50–60)	57 (51–66)
BMI, kg/m ²	23.2±2.4	21.7±2.5	22.2±2.5
BMD, T*	−3.1 (−3.4 to −2.8)	−3.4 (−3.8 to −3.1)	−3.3 (−3.7 to −3.0)

Values are presented as mean ± standard deviation (SD), or median (Q1–Q3).

BMD=bone mineral density, BMI=body mass index.

* $P < .05$.

Chicago, IL). A 2-sided P value of $< .05$ was considered statistically significant.

3. Results

Thirty-eight patients were excluded, 20 patients were old OVCFs, 10 patients were age ≤ 60 years, 8 patients were BMD $> -2.5SD$. As a result, a total of 122 patients with 169 levels were reviewed retrospectively. All of the patients underwent PKP for painful OVCFs. Their demographic data are summarized in Table 1. No differences in age ($P = .361$, Mann–Whitney U test) and BMI ($P = .602$, Student t test) were noted between male and female patients. Conversely, significant differences in height, weight, and BMD were found between male and female patients ($P = .000$, Mann–Whitney U test). The number of fracture levels, operation time, and HBL are shown in Table 2. The increase in operative time and amount of HBL was associated with the increasing number of fracture levels. The loss of Hb and Hct levels, operative time, percentage of vertebral height loss, percentage of vertebral height restoration, and HBL are listed in Table 3. The mean HBL was 279 ± 120 mL, and the mean Hb loss was 8.2 ± 3.9 g/L. Twenty-six patients suffered from preoperative anemia, and the number of patients with anemia increased to 74 after

Table 2
Number and involved levels.

Number of fracture(s)	Number of patients	Operative time, min	Hidden blood loss, mL
One level	86	34±8	244±117
Two level	25	43±3	328±68
Three or more levels	11	65±4	439±37

Values are presented as mean ± SD.

Table 3
Clinical results in the patients after PKP surgery.

Parameters	Mean ± SD
Number of patients	122
Hemoglobin loss, g/L	8.2±3.9
Hematocrit level loss, %	2.7±1.1
Operative time, min	39±11
Percentage of height loss, %	38.4±10.0
Percentage of height restoration, %	16.7±10.4
Hidden blood loss, mL	279±120

Values are presented as mean ± SD.

PKP=percutaneous kyphoplasty.

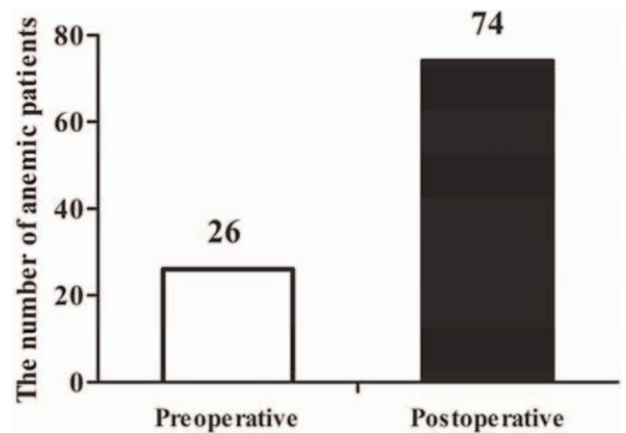


Figure 1. The number of anemic patients.

surgery (Fig. 1). This difference indicated that HBL could obviously increase the number of patients with anemia ($\chi^2 = 21.432$, $P = .000$). The operative time ($P = .000$), percentage of vertebral height loss ($P = .037$), and percentage of vertebral height restoration ($P = .000$) were positively correlated with HBL (Table 4). By contrast, gender ($P = .874$), age ($P = .148$), BMD ($P = .134$), number of fracture levels ($P = .079$), hypertension ($P = .259$), diabetes mellitus ($P = .495$), and cement leakage ($P = .975$) were not associated with HBL.

4. Discussion

Studies on HBL after orthopedic surgery have mostly focused on total hip arthroplasty (THA), total knee arthroplasty (TKA), and ALIF/PLIF surgery but have rarely explored PKP. PKP involves a smaller incision, shorter operative time, less visible intraoperative blood loss, and less hemodynamic interference than THA, TKA, and ALIF/PLIF do. HBL is often disregarded in clinical practice. In this study, 279 ± 120 mL HBL and 8.2 ± 3.9 g/L Hb were obtained in the perioperative period. In addition, 48 patients with normal preoperative Hb levels developed anemia. This result was similar to that of Wu et al.^[6] and the obtained amount was much greater than that of visible intraoperative blood loss. Excessive blood loss in the perioperative period can be associated with direct and indirect complications, especially for elderly patients with OVCFs. The correct information about HBL can improve patients' safety and decrease the potential adverse effects of anemia.

The mechanisms of HBL possibly involve extravasation into tissue compartments, blood hemolysis, and ongoing blood loss.^[1,15–17] However, influencing factors associated with the amount of HBL have yet to be elucidated. In this study, we performed multiple linear regression analysis to examine the associated factors. The results suggested that operative time, percentage of vertebral height loss, and percentage of vertebral height restoration were correlated with HBL.

Our statistical analysis showed that the patients who had long operative time suffered from more HBL than those who have short operative time. Although the duration of surgery was directly related to the number of fracture levels of the patients who underwent PKP, no correlation was noted between HBL and the number of fracture levels. This result contradicts those of Wu et al.^[6] and Ju et al.^[4] Possibly because 14 mid-thoracic vertebral

Table 4**Multiple linear regression analysis on influential factors of HBL after PKP surgery.**

	Unstandardized		Standardized		P
	β	SE	β	T	
Gender	- 0.002	0.010	- 0.007	- 0.159	.874
Age, y	- 0.001	0.001	- 0.061	- 1.458	.148
BMD (SD)	- 0.016	0.011	- 0.067	- 1.511	.134
Number of fracture level (s)	- 0.021	0.012	- 0.111	- 1.774	.079
Hypertension	0.013	0.011	0.043	1.134	.259
Diabetes mellitus	0.008	0.012	0.027	0.685	.495
Operative time, min	0.003	0.001	0.254	3.597	.000*
Percentage of vertebral height loss, %	0.110	0.052	0.091	2.115	.037*
Percentage of vertebral height restoration, %	0.847	0.065	0.733	13.059	.000*
Cement leakage	0.000	0.013	- 0.001	- 0.032	.975

BMD = bone mineral density, HBL = hidden blood loss, PKP = percutaneous kyphoplasty, SD = standard deviation.

* $P < .05$.

fractures were included in our study, the pedicle of the mid-thoracic vertebrae was smaller and the operation difficulty was higher than those of the thoracolumbar or lumbar vertebrae, the time of surgery for 1 level of the mid-thoracic vertebral fracture was often longer than that for 2 or 3 levels of lumbar fracture, and the operative time was shorter than that in the ALIF/PLIF surgery, although it had 3 levels or more of PKP surgery. In lumbar fusion surgery, the percentage of HBL was similar at 1 and 2 levels of operation and was not significantly different at 3 or more levels of operation. It increased the visible blood loss (surgery bleeding plus drainage).^[2,18] In our study, the intraoperative and postoperative visible blood loss were disregarded, thereby possible underestimating the amount of HBL.

In the present study, HBL was directly related to vertebral fracture severity and enhanced height restoration. Vertebrae involve the cancellous bone, which is rich in blood supply. When a guide cannula is fixed, the expansion of the vertebral cavity can cause internal bleeding. An enhanced vertebral height restoration may result in an enlarged cavity, and gaps around the vertebrae may widen.^[19] Vertebral cavities and intramuscular gaps also provide storage cavities for HBL.

No association was found between cement leakage and HBL. The HBL of the patients with leakage were not significantly higher than that of the patients with nonleakage. Gao et al^[20] found that cortical disruption, large cement volume, and low BMD were strong predictors of cement leakage. Pre-existing cortical defects can cause persistent vertebral bleeding, which can significantly increase the volume of HBL. Polymethylmethacrylate, the most commonly used bone cement, may be an important factor inducing hemolysis because of its toxicity to cells and heat loss during solidification may result in thermal necrosis.^[6] Our results differed from those of other studies possibly because of the decreased cement leakage (17/122) and amount of injected cement in our work. An abundant blood supply in the intravertebral body can bring large heat during cement solidification. As such, the correlation between cement and hemolysis should be further explored.

HBL seemed unaffected by age, gender, BMD, hypertension, and diabetes mellitus in this study. This result differed from those in THA, TKA, and intertrochanteric fracture surgery and treatment^[10,21–23] likely because of variations in diagnosis, incision, surgical sites, and surgical techniques.

This study had several limitations. First, our study involved a retrospective analysis and a small sample size. As such, our findings should be performed in future prospective studies with a

large number of patients. Second, the effects of hemodilution related to intravenous fluid infusion in the perioperative period were underestimated. Finally, the multilevel vertebral body fractures mainly included the thoracolumbar and lumbar areas but not the mid-thoracic vertebrae. Further research should involve more patients with mid-thoracic fractures.

5. Conclusion

PKP surgery is associated with substantial HBL. Operative time, percentage of vertebral height loss, and percentage of vertebral height restoration are the influencing factors of HBL. However, HBL seems unaffected by age, gender, BMD, number of fracture levels, hypertension, diabetes mellitus, and cement leakage. Further clinical research should focus on these factors to reduce HBL. Accurate perioperative HBL assessment can help prevent complications and improve rehabilitation.

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