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Original Article

Impact factors of perioperative hidden blood loss after total hip arthroplasty in osteoarthritis patients

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Abstract: Background: Total hip arthroplasty (THA) is a vital treatment for severe hip osteoarthritis (OA). Hidden blood loss (HBL) typically occurs following THA and is thought to contribute to postoperative anemia even after reinfusion or blood transfusion. The objective of this study was to calculate hidden blood loss and its influential factors after THA in osteoarthritis patients. Methods: From September 2010 to December 2014, 240 OA patients who underwent total hip arthroplasty, were recruited into the study. Their age, gender, body mass index (BMI), operation time, allogenic blood transfusion, preoperative and postoperative hematocrit (Hct) and hemoglobin (Hb) levels were recorded. The perioperative total blood loss and the HBL following THA were calculated with a previously validated formula. Influential factors were further analyzed by multiple and stepwise regression. Results: The mean HBL was 526 ml, which is 37.3% of the total loss (1438 ml). A remarkable fall of HB and Hct was observed after operation and the Hct value of 214 patients reached the lowest point at day 2 to day 4. Multiple and stepwise regression analysis revealed that the levels of HBL were associated with BMI, blood transfusion, operation time, fall in Hct and gender. However, age, hypertension, anesthesia method and prosthetic type were not significantly correlated with HBL. Conclusions: HBL after THA, accounting for about one third of total blood loss, is much larger than expected. Factors such as gender, BMI, operation time, blood transfusion and fall in Hct are influential causes of HBL in OA patients undergoing THA, all of which should be taken into account carefully in the perioperative blood management for osteoarthritis patients undergoing THA. Further clinical research should be performed to reduce the HBL.

Keywords: Hidden blood loss, influential factors, osteoarthritis, total hip arthroplasty

Introduction

Osteoarthritis (OA) is the most common degenerative joint disorder, afflicting mainly the weight-bearing joints, such as hips and knees. Total hip arthroplasty (THA) is a widely used surgical procedure in elderly patients with end-staged hip osteoarthritis [1]. Blood loss is a common concern of postoperative complications in patients after THA [2]. Previous studies showed that the total blood loss reached 1023 to 1758 mlaverage [3-6] and hemoglobin (Hb) level drop about 4.0±1.5 g/dl post-operation [7, 8]. In order to facilitate early rehabilitation, blood management is necessary in perioperative treatment to avoid a significant decrease in hemoglobin level post-operatively. However, patients often present with a lower post-operative Hb level than anticipated. In spite of an apparently satisfactory blood management based on the visible blood loss volume, patients still have anemia. This inconsistency may attributed to the blood loss, including extravasatd blood into the tissue compartments [9], residual blood in the joint and loss of blood due to haemolysis [10]. These aspects are widely ignored. All above maybe called as hidden blood loss (HBL).

Some studies have investigated hidden blood loss in THA. But only a few of them focused only on a specific disease of patients. Our study investigates exclusively in hip OA patients. This is important since different diseases could lead to varied amounts of hidden blood loss due to different structure change of joint and THA procedures. It has been reported that many other factors may influence the HBL in patients after THA, like gender [11], body mass index (BMI) [12], operation time [5], allogenic blood transfu-

Table 1. Calculation of total blood loss

Total RBC loss (ml) = Uncompensated RBC loss (ml) + Compensated RBC loss (ml)
Uncompensated RBC loss (ml) = Calculate RBC loss = initial RBC (ml) - Final RBC (ml)
Compensated RBC loss = Sum of RBCs received from the various sources of transfusion
initial RBC (ml) = [Estimated blood volume (ml) × initial Hct level (%)] (Hct value is one day pre-operation)
final RBC (ml) = [Estimated blood volume (ml) × final Hct level (%)] (Hct value is the lowest value post operation within 7 days)
The estimated blood volume in milliliters was calculated for women and men separately with use of the formulas:
Women: [Body surface area (m^2)] × 2430
Men: [Body surface area (m^2)] × 2530
Where body surface area was calculated as
$0.2353 \times [\text{height (cm)}]^{0.42246} \times [\text{weight (kg)}]^{0.51456}$
Finally, total blood loss at a hematocrits of pre-Hct value was of the following equation:
Total blood loss (ml) = [Total RBC loss (ml)]/Hct (pre-operation value)
Hidden blood loss = total blood loss-Visible blood loss among operation-the post operative drainage

Table 2. Patient's demographic information

Parameters	values
Mean age (years)	65.1±8.78
Gender	
Male (%)	82 (34%)
Female (%)	158 (66%)
Weight (kg)	61.0±9.36
Height (cm)	160.9±7.36
Hospitalization time (days)	8.2±1.21

sion [13] and even closed-suction drainage [14]. Miao et al. [15] suggested that HBL was significantly associated with gender, BMI, blood transfusion volume and change of levels of hematocrit (Hct) before and after operation. They also found that HBL was influenced by the types of specific diseases. Therefore, the primary aim of the study was to calculate the hidden blood loss after THA specifically in osteoarthritis patients. The secondary aim was to assess the affecting factors for HBL in patients after THA.

Patients and methods

This study was approved by the local Ethics Committee of Second Affiliated Hospital of Soochow University. From September 2010 to December 2014, 240 hip OA patients (including 82 males and 158 females) who undergoing primary THA were recruited into this study. Patients who underwent simultaneous bilateral THA or revision surgeries and patients with acquired or congenital bleeding disorders were excluded from the study.

The surgeries were performed under general anesthesia or continuous epidural anesthesia. All the operations were performed in standardized method (posterior-lateral incision, length of incision was within a range of 8 to 15 cm) by the same experienced team. The prosthetic types of implants were into cemented and uncemented. During the post-operative period, the antibiotics and thromboprophylaxis were administered with second-generation cephalosporins and low-molecular-weight heparin (LMWH). Patients were advised to take appropriate bed-related activity 24 h after the operation. After removal of drainage tube (48 h after operation), patients were encouraged to walk with a walking aid.

The total perioperative blood loss was calculated with a validated formula described previously by Rosencher et al. [16] (**Table 1**).

Statistical analysis

Statistical analyses were performed using SPSS for Windows Ver.19.0. Continuous data were presented as mean ± standard deviation (SD). Comparisons of variables were performed using unpaired Student t test. Multiple and stepwise regression analysis was used for the analysis of the influential factors of HBL. As for the categorical variables, male, hypertension, general anesthesia and uncemented prosthesis were set as "1", and, female, normal blood pressure, continuous epidural anesthesia and cemented prosthesis were set as "0". *P* value <0.05 was considered statistically significant.

Results

The Demographic data in this study are shown in **Table 2**. A total number of 240 hip OA patients who underwent unilateral primary THA were

Table 3. Perioperative blood changed in the patients after THA

Parameters	Values
Number of patients	240
Operation time (min)	104.5±37.84
Length of incision	12.1±1.4
Blood loss during operation (ml)	598±364
Blood transfusion (ml)	160±87
Wound drainage (ml)	313±148
Hematocrit (Hct) level loss (%)	14.1±3.9
Haemoglobin (Hb) level loss (g/L)	43.8±14.7
Hidden blood loss (ml)	526±336
Total blood loss (ml)	1438±412
Percentage of hidden blood loss (%)	37.3±15.6

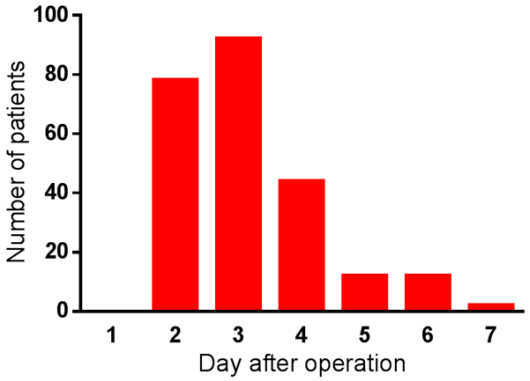

Figure 1. The day when patient reached the lowest Hct value after THA.

Table 4. Compared the change of Hb and Hct which those were transfused and those who were not

	THA with transfusion	THA without transfusion	*P* values
Number	80	160	
Pre-op Hb (g/L)	126±17	127±14	0.413
Post-op Hb (g/L)	84±16	82±13	0.225
Fall inHb (g/L)	42±19	44±12	0.122
Pre-op Hct (g/L)	38.9±3.6	38.3±4.6	0.584
Post-op Hct (g/L)	25.0±3.6	23.9±3.8	0.003
Fall in Hct (g/L)	14.0±3.7	14.4±4.4	0.004

Hct: hematocrit; Hb: hemoglobin.

consecutively enrolled in the study. **Table 3** shows the operation procedure related data. Mean HBL was 526±336 ml, which is 37.3%± 15.6% of the total blood loss (1438±412 ml). An obvious fall in Hb and Hct can be seen in **Table 3**. **Figure 1** shows that Hct value in most of the patients (214 patients) reached the lowest point at day 2 today 4 after the operation.

We also compared the change of Hb and Hct between patients administrated with transfusion and without. The results are shown in **Table 4**. There is no significant difference between pre-operative and post-operative Hb, fall in Hb or pre-operative Hct between the two groups. On the other hand, post-operative Hct was significantly increased and fall in Hct significantly decreased in patients with transfusion compared with those without transfusion.

To Evaluate the influential factors of hidden blood loss, we performed multiple and stepwise regression analysis. As shown in **Table 5**, we found that BMI (P=0.022), blood transfusion (P=0.004), operation time (P=0.003), fall in Hct (P<0.001) and gender (P=0.021) were positively correlated with HBL. Age, hypertension, type of anesthesia and prosthetic type were not significantly associated with HBL.

Discussion

Total hip arthroplasty is a vital treatment for hip joint diseases and pronounced blood loss is associated with THA [17]. In usual practice, the blood loss measured and recorded after THA is merely the intraoperative blood loss and the postoperative drainage. However, there is more blood loss that is hidden. Although there are some studies on HBL after THA, very few of them have focused on hip OA alone. In the present study, we used a reliable approach for estimating the quantity of HBL in hip OA patients undergoing THA. Furthermore, we applied multiple regression analysis to analyze the influential factors of the HBL in hip OA patients.

Emerging data have suggested that there was a significant amount of HBL after THA. However, varied results of HBL amounts were reported by different studies. Sehat et al. reported that the mean HBL after THA was 471 mL (26% of TBL) [18], while Miao et al. demonstrated a 429 ml HBL (35.4% of TBL) [15]. Moreover, Liu et al. showed a even larger amount of HBL, which was 1050 ml, accounting for about 60% of TBL [5]. Compared to these results, in our study, the volume of HBL was 526 ml, accounting for 37.3% of TBL. The reason underlying these differences might be the different types of diseas-

Table 5. Multiple linear regression analysis on influential factors of HBL after THA

Variable	Coefficients	*P* values	95% CI
Constant	-797.556	<0.001	-1214.777~-380.335
Quantitative variable			
Age (years)	3.324	0.095	-0.581~7.228
BMI (kg/m^2)	12.24	0.022	1.801~22.679
Blood transfusion (ml)	-0.219	0.004	0.367~0.071
Operation time (min)	-1.44	0.003	-2.376~-0.504
Fall in Hct (g/L)	72.961	<0.001	64.395~81.528
Qualitative variable			
Gender	83.679	0.021	12.87~154.448
Hypertension	22.682	0.508	-44.69~90.054
Anesthesia method	-3.223	0.924	-69.757~63.31
Prosthetic type	34.456	0.306	31.682~100.594

HBL: hidden blood loss, THA: total hip arthroplasty.

es studied in these researches. In most cases of earlier studies, one research would include more than on disorder, including osteoarthritis (OA), femoral neck fracture (FNF), development dysplasia hip (DDH), rheumatoid arthritis (RA) and avascular necrosis of femoral head (ANFH). In the study by Sehat et al. and Miao et al., most of the patients recruited suffered from FNF. The HBL of both studies were less than ours, indicating that the FNF patients may have smaller HBL after THA than our OA patients. This may be due to the retain and repair of articular capsule after implantation of the prosthesis (as the articular capsule in FNF patients is often normal) and preoperative blood loss caused by trauma (which may lead to lesser blood loss during the operation) in FNF patients. Liu et al. [5] indicated that retain and repair of articular capsule can significantly decrease HBL during THA. Another study by Smith et al. [19] demonstrated that a large drop in Hb was associated with the initial trauma rather than the operation. Therefore, the calculated HBL after THA in FNF may be smaller than that in OA patients.

For DDH patients, the anatomical abnormalities of hip joint often increase the complexity of hip arthroplasty. The surgeons have to remodel the acetabular fossa so that acetabular implant can be placed at or near the normal anatomical acetabular location. The action of remodeling may destroy more tissue around the joint and increase subsequent blood loss during the operation. Therefore, we assume that HBL in DDH patients should be more than that in OA patients. More HBL in OA patients than DDH patients has been shown in the study by Liu et al. (1157 ml VS 1053 ml) [5]. However, an opposite result was found by Miao et al. [15], they showed that DDH patients had the smallest amount of HBL in all patients. The limited amount of DDH patients including in Miao's study, which was only 28 patients (8.4% of all patients) might make their HBL result in DDH patients less reliable. As the final pathologic changes of hip joint is often similar in diseases of ANFH and OA, and, the surgical procedures are alike in these two diseases. Take these two points into consideration, we propose that there may not be too much difference in the amount of HBL after THA in patients of ANFH and OA. RA is a chronic disease which would lead to synovium hyperplasia, tissue contracture and osteoporotic bone. Dealing with synovium hyperplasia and loosening contracture tissue may cause quite an amount of blood loss during operation, which suggests that the HBL in RA patients would greater than that in OA patients. In consistence, we found that the HBL (608 ml) in RA patients was greater than that in OA patients. We do not show the data of HBL in RA patients, because the number of the patients was only 11 and too limited to get a reliable conclusion.

In the study of Liu et al. [5], the amount of HBL (1063 ml in OA patients) was much larger than ours. Higher rate of transfusion in their patients may account for this higher HBL. Although the mechanism of HBL is still unclear, it has been reported that hemolysis should be one of the possible explanations for HBL [10]. Our result also showed that blood transfusion increased the HBL after THA, which is probably attributed to hemolysis. We also compared the Hb level and Hct levels between the patients with blood transfusion and without blood transfusion. The level of fall in Hb and Hct in patients with blood transfusion (Hb 42±19 g/L; Hct 14.0±3.7%) were less, but was not obviously different from patients without blood transfusion (Hb 44±12 g/L; Hct 14.4±4.4%), indicating the presence of hemolysis after blood transfusion and weaken the effect of blood transfusion. Another mechanism underlying HBL is the blood infiltration

into tissue compartments [9]. Miao et al. found that the HBL was positively correlated to the length of incision [15]. The possible explanation is that, the longer the incision, the more formation of penetrable tissue compartments, and, more blood would be accumulated in these compartments and lead to an increase in HBL.

Many other factors have been reported to influence the HBL after THA, yet the results are inconsistent. For example, Zhao et al. [12] found that low BMI was associated with an increase of HBL while Hrnack et al. [20] suggested that BMI was not associated with blood loss in THA. Cushner and Friedman found that gender played a role in HBL, but age, types of disorder, operative time, and tourniquet time are not associated with HBL [21]. However Miao et al. showed that gender, age, BMI, blood transfusion, change of Hct and types of diseases are correlated with the HBL after THA [15]. In the present study, we found that gender, BMI, operation time, blood transfusion and change of Hct were positively correlated with HBL in OA patients after THA. On the other hand, age, hypertension, anesthesia method and prosthetic type were not associated with HBL. Notably, gender can affect the result of HBL, with greater HBL in men compared with women. Compared with patients of normal weight, patients of low BMI have the potential to suffer more postoperative HBL and need a higher transfusion rate [12]. Longer operating time could augment the soft tissue injury and may increase the potential blood loss after the surgery. Based on this reason, the amount of HBL was associated with duration of operation. Moreover, the change of Hct can also affect the result of HBL. The formula for calculating blood loss is based on perioperative hematocrit. Some researchers suggested the hematocrit value of second or third day after operation as an index [18, 22]. In agreement, we found that the lowest hematocrit value occur on the day 2 to day 4 after surgery in most patients.

In this study, we assess the HBL and its influential factors after THA exclusively among the osteoarthritis patients to reduce the bias caused by other diseases. However, it also limited the application of our observation of HBL to other diseases. As an offset, we compared our results with the outcomes of previous studies. Additionally, although the standardized method of THA was performed by the same experienced team, there may be some uncontrolled factors that can affect the operation time and blood loss, such as anatomic variation, different types of prosthesis used. Finally, the effects of other potential influential factors, such as some comorbidities that affected part of the patients enrolled, the cup size of implant and bone mineral density of patients need to be further determined.

Conclusion

In conclusion, HBL after THA, accounting for about one third of total blood loss, is much larger than expected. Factors such as gender, BMI, operation time, blood transfusion and change of Hct are associated with HBL in OA patients undergoing THA, all of which should be taken into account carefully perioperative blood management for osteoarthritis patients undergoing THA. Other factors, such as age, hypertension, anesthesia method and prosthetic type were not significantly correlated with HBL. More clinical research should be performed to reduce the HBL, while keeping in focusing on the factors affecting HBL mentioned above.

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Disclosure of conflict of interest

None.

Authors' contribution

J.-L. S. and J. G contributed to the conception and study design, collection, analysis and interpretation of the data, and wrote the first version of the manuscript. L.-B. L. participated in the design of the study, performed the statistical analysis and helped to revise the manuscript. S.-B. L. contributed to interpretation of the data, and revised the manuscript. Q.-R. D. conceived of the study, and participated in its design and coordination and helped to revise the manuscript. All authors read and approved the final manuscript.

Abbreviations

THA, total hip arthroplasty; HBL, hidden blood loss; OA, osteoarthritis; BMI, body mass index; Hct, hematocrit; Hb, hemoglobin; RBC, red blood cells; LMWH, low-molecular-weight heparin; SD, standard deviation; FNF, femoral neck fracture; DDH, development displasia hip; RA, rheumatoid arthritis; ANFH, avascular necrosis of femoral head.

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References

[1] Learmonth ID, Young C and Rorabeck C. The operation of the century: total hip replacement. Lancet 2007; 370: 1508-1519.

[2] Yamasaki S, Masuhara K and Fuji T. Tranexamic acid reduces postoperative blood loss in cementless total hip arthroplasty. J Bone Joint Surg Am 2005; 87: 766-770.

[3] Li J, Zhou Y, Jing J and Zhan J. [Comparison of effects of two anticoagulants on hidden blood loss after total hip arthroplasty]. Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi 2013; 27: 432-435.

[4] Lostak J, Gallo J and Mlcuchova D. [Multivariate analysis of blood loss during primary total hip or knee arthroplasty]. Acta Chir Orthop Traumatol Cech 2013; 80: 219-225.

[5] Liu X, Zhang X, Chen Y, Wang Q, Jiang Y and Zeng B. Hidden blood loss after total hip arthroplasty. J Arthroplasty 2011; 26: 1100-1105, e1101.

[6] Borgen PO, Dahl OE and Reikeras O. Blood loss in cemented THA is not reduced with postoperative versus preoperative start of thromboprophylaxis. Clin Orthop Relat Res 2012; 470: 2591-2598.

[7] Keating EM and Ritter MA. Transfusion options in total joint arthroplasty. J Arthroplasty 2002; 17: 125-128.

[8] Saleh A, Small T, Chandran Pillai AL, Schiltz NK, Klika AK and Barsoum WK. Allogenic blood transfusion following total hip arthroplasty: results from the nationwide inpatient sample, 2000 to 2009. J Bone Joint Surg Am 2014; 96: e155.

[9] McManus KT VM, Alavi A, Lotke PA. Noninvasive assessment of postoperative bleeding in TKA patients with Tc-99m RNCs. J Nuclear Med 1987; 28: 565.

[10] Faris PM, Ritter MA, Keating EM and Valeri CR. Unwashed filtered shed blood collected after knee and hip arthroplasties. A source of autologous red blood cells. J Bone Joint Surg Am 1991; 73: 1169-1178.

[11] Shen HL, Li Z, Feng ML and Cao GL. Analysis on hidden blood loss of total knee arthroplasty in treating knee osteoarthritis. Chin Med J (Engl) 2011; 124: 1653-1656.

[12] Zhao J, Li J, Zheng W, Liu D, Sun X and Xu W. Low body mass index and blood loss in primary total hip arthroplasty: results from 236 consecutive ankylosing spondylitis patients. Biomed Res Int 2014; 2014: 742393.

[13] Carling MS, Jeppsson A, Eriksson BI and Brisby H. Transfusions and blood loss in total hip and knee arthroplasty: a prospective observational study. J Orthop Surg Res 2015; 10: 48.

[14] Zhou XD and Wu LD. Do we really need closed-suction drainage in total hip arthroplasty? A meta-analysis. Int Orthop 2013; 37: 2531-2532.

[15] Miao K, Ni S, Zhou X, Xu N, Sun R, Zhuang C and Wang Y. Hidden blood loss and its influential factors after total hip arthroplasty. J Orthop Surg Res 2015; 10: 36.

[16] Rosencher N, Kerkkamp HE, Macheras G, Munuera LM, Menichella G, Barton DM, Cremers S and Abraham IL. Orthopedic Surgery Transfusion Hemoglobin European Overview (OSTHEO) study: blood management in elective knee and hip arthroplasty in Europe. Transfusion 2003; 43: 459-469.

[17] Callaghan JJ, O'Rourke MR and Liu SS. Blood management: issues and options. J Arthroplasty 2005; 20: 51-54.

[18] Sehat KR, Evans RL and Newman JH. Hidden blood loss following hip and knee arthroplasty. Correct management of blood loss should take hidden loss into account. J Bone Joint Surg Br 2004; 86: 561-565.

[19] Smith GH, Tsang J, Molyneux SG and White TO. The hidden blood loss after hip fracture. Injury 2011; 42: 133-135.

[20] Hrnack SA, Skeen N, Xu T and Rosenstein AD. Correlation of body mass index and blood loss during total knee and total hip arthroplasty. Am J Orthop (Belle Mead NJ) 2012; 41: 467-471.

[21] Cushner FD and Friedman RJ. Blood loss in total knee arthroplasty. Clin Orthop Relat Res 1991; 98-101.

[22] Sehat KR, Evans R and 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: 151-155.