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Hidden blood loss and its risk factors after hip hemiarthroplasty for hip fracture in the elderly

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ABSTRACT

Objectives: This study aims to evaluate hidden blood loss (HBL) and its determinants in elderly hip fracture patients undergoing this procedure via a posterolateral approach.

Patients and methods: Between January 2016 and June 2024, a total of 105 patients (52 males, 53 females; mean age: 78.5±5.6 years; range, 60 to 93 years) who underwent hip hemiarthroplasty through a posterolateral approach were retrospectively analyzed. Patient demographics and clinical data were obtained. Pre- and postoperative hematocrit (Hct), height, and weight were documented. Perioperative total blood loss (TBL) and HBL were quantified using the Gross and Sehat formulas, respectively. Risk factors linked to HBL were determined.

Results: The mean operative duration was 80.3±9.9 min. The mean HBL was 465.9±58.3 mL, accounting for 81.4% of TBL (571.1±149.6 mL). Multivariate linear regression revealed significant associations between increased HBL and lower preoperative albumin (β=–0.188, p=0.011), higher American Society of Anesthesiologists (ASA) classification (β=0.162, p=0.029), and perioperative blood transfusion (β=0.221, p=0.002).

Conclusion: Hidden blood loss constitutes a clinically significant consideration during hip hemiarthroplasty for geriatric hip fractures. Significantly greater HBL occurs in patients with preoperative hypoalbuminemia, elevated ASA classification, or perioperative transfusion. Recognizing and quantifying HBL enhances perioperative assessment precision and contributes to improved patient safety.

Keywords: Hemiarthroplasty, hidden blood loss, hip fractures, posterolateral approach, risk factors.

Hip fractures are profoundly traumatic for elderly individuals, typically involving intense hip pain and functional impairment.[1] Within the United States, this injury necessitates over 300,000 hospital admissions each year, generating annual costs estimated at $10 to $15 billion.[2,3] The likelihood of sustaining a hip fracture escalates dramatically with advancing age; global projections indicate its incidence would approach a twofold increase by 2050.[3,4] Immobility following the fracture frequently precipitates complications stemming from bed rest, substantially elevating mortality risk.[5] Consequently, surgical management is imperative for the majority of hip fracture patients, excluding those with prohibitive comorbidities.[4]

Perioperative blood loss can acutely worsen mortality and morbidity in this vulnerable group, underscoring the critical importance of meticulous risk management.[6] Compared to internal fixation techniques, hemiarthroplasty enables earlier postoperative ambulation, is associated with reduced mortality rates, and offers superior functional recovery within the first postoperative year.[7] Nevertheless, substantial blood loss remains a concern with this procedure. Research indicates that the total blood loss (TBL) following hip fracture surgery significantly surpasses the volume directly observed during the operation,[8] providing further validation for the phenomenon of hidden blood loss (HBL). Since its initial description in 2000,[9] accumulating evidence across diverse orthopedic interventions has confirmed

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the occurrence of HBL.[10-12] Although several investigators have documented the magnitude of TBL after hemiarthroplasty,[13,14] dedicated analysis of HBL within this specific surgical context remains scarce.[15]

Precise quantification of HBL is essential for accurate estimation of perioperative TBL. This is paramount for ensuring perioperative safety, particularly in elderly patients with pre-existing anemia or comorbid conditions. While prior research has quantified TBL following hemiarthroplasty,[13,14] dedicated analysis specifically focusing on the magnitude of HBL within this surgical context remains scarce.[15] Crucially, studies comprehensively examining risk factors predisposing to significant HBL after hip hemiarthroplasty in the elderly population are particularly limited.[16] In the present study, we aimed to quantify HBL occurring during posterolateral approach hemiarthroplasty for elderly hip fracture patients, and to identify the key clinical risk factors associated with increased HBL within this vulnerable cohort.

PATIENTS AND METHODS

This single-center, retrospective study was conducted at Chengdu First People's Hospital, Department of Orthopaedics between January 2016 and June 2024. Geriatric patients who received hip hemiarthroplasty for fracture treatment were included. All surgeries adhered to standardized protocols under the direction of a single experienced joint replacement surgeon. Inclusion criteria were as follows: age ≥70 years; unilateral femoral neck or intertrochanteric fracture; and utilization of the posterolateral approach. Exclusion criteria were as follows: previous ipsilateral hip surgery; concurrent hip malignancy, trauma, or infection; documented coagulopathy or long-term antiplatelet/anticoagulant therapy; intraoperative antifibrinolytic use (tranexamic acid (TXA)/epsilon aminocaproic acid); and insufficient clinical documentation. While acknowledging this constraint, the sample size reflects the application of stringent selection criteria over the 8.5-year inclusion period to ensure a homogeneous cohort for focused risk factor analysis. Finally, a total of 105 patients (52 males, 53 females; mean age: 78.5±5.6 years; range, 60 to 93 years) were included. As a retrospective cross-sectional study, all data collection and analysis were performed anonymously and without potential harm to patients. Consequently, the ethics committee of Chengdu First People's Hospital waived the requirement for informed consent. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Hip hemiarthroplasty procedure

Hemiarthroplasty was uniformly conducted employing the posterolateral Moore approach. Prophylactic antibiotics (cefazolin 2 g intravenous) were delivered 30 min pre-incision. A bipolar, cementless prosthesis (LCU, Link, Germany) was implanted in all cases. Preoperative hemoglobin (Hb) and hematocrit (Hct) levels, along with values obtained on postoperative Day 3, were documented. Surgical drains were routinely extracted within 48 h.

Data acquisition

Demographic, anthropometric (height, weight, body mass index [BMI]), and clinical data were collected. This included documented comorbidities (hypertension, diabetes mellitus, coronary heart disease), fracture classification, time from injury to surgery, American Society of Anesthesiologists (ASA) physical status classification (determined by the attending anesthesiologist), anesthesia modality, operative duration, and hospital length of stay. Intraoperative blood loss (IBL) was quantified as the total from suction canisters (irrigation fluid subtracted) and weighed sponges. Postoperative drainage volume until removal constituted postoperative blood loss (PBL). Preoperative laboratory assessments included Hb, Hct, albumin, and glucose; postoperative Hb and Hct were also measured.

Blood loss quantification

The PBL constituted the volume in drains by postoperative Day 2, reflecting stabilization of fluid dynamics.[17] Visible blood loss (VBL) equaled IBL plus PBL. In the perioperative period, TBL was computed using the method described by Sehat et al.[17] Preoperative blood volume (PBV) was estimated via the Nadler equation:[18]

$$\text{PBV (L)} = k1 \times \text{height (m)}^3 + k2 \times \text{weight (kg)} + k3$$

Coefficients (k1, k2, k3) differed by sex: Males: 0.3669, 0.03219, 0.6041; Females: 0.3561, 0.03308, 0.1833.

TBL was subsequently derived using the Gross formula:[19]

$$\text{TBL (mL)} = \text{PBV (L)} \times (Hct_{pre} - Hct_{post}) / Hct_{ave} \times 1000$$

where Hct_{ave} is the mean of preoperative (Hct_{pre}) and postoperative Day 2 (Hct_{post}) Hct.

The HBL was determined as the difference between TBL and VBL, adjusted for any transfused blood volume (autologous or allogeneic) administered between Hct measurements:[17]

HBL (mL) = TBL (mL) + Transfusion Volume (mL) - VBL (mL). (Transfusion Volume = 0 mL, if no transfusion occurred).

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. To identify independent predictors of HBL, the following analyses were employed: the Pearson correlation (normally distributed data), Spearman correlation (non-parametric data), multiple linear regression, and analysis of variance (ANOVA). A *p* value of <0.05 was considered statistically significant.

RESULTS

The mean BMI was 21.6±2.1 kg/m². Femoral neck fractures represented the predominant injury pattern (72/105). Detailed demographic data are presented in Table I. The mean Hct and Hb reductions measured as 5.1±1.4% and 22.2±5.5 g/L, respectively. The mean preoperative albumin concentration was 34.5±2.5 g/L. General anesthesia constituted the primary anesthetic technique. The mean operative duration was 80.3±9.9 min. Perioperative TBL reached 571.1±149.6 mL, with HBL comprising 81.4% (465.9±58.3 mL) of this volume. Postoperative anemia developed universally. Fifty patients received perioperative blood transfusions (Table I).

Table II displays univariate analysis outcomes assessing relationships between candidate risk factors and HBL using Pearson's correlation. Subsequent multivariate linear regression incorporated the four significant predictors identified in univariate analysis as independent variables, with HBL serving as the dependent variable. This model identified preoperative albumin (p=0.011), ASA classification (p=0.029), and blood transfusion (p=0.002) as significant independent predictors of HBL (Table III).

TABLE I
Patients' demographics and clinical factors

Variables	n	Mean±SD
Age (year)		78.5±5.6
Sex		
Male	52	
Female	53	
Height (m)		1.65±0.06
Weight (kg)		58.7±8.1
Body mass index (kg/m²)		21.6±2.1
Comorbidity		
Hypertension	12	
Diabetes mellitus	28	
Coronary heart disease	12	
Fracture type		
Femoral neck fracture	72	
Intertrochanteric fracture	33	
Preoperative Hb (g/L)		123.4±10.3
Postoperative Hb (g/L)		101.2±10.4
Hb loss (g/L)		22.2±5.5
Preoperative Hct (%)		37.6±3.1
Postoperative Hct (%)		32.4±2.9
Hct loss (%)		5.1±1.4
Preoperative ALB (g/L)		34.5±2.5
Preoperative blood glucose (mmol/L)		5.8±1.2
Type of anesthesia		
General	87	
Epidural	18	
ASA classification		
II	80	
III	20	
IV	5	
Preoperative anemia	55	
Postoperative anemia	105	
Time to surgery (days)		3.5±1.2
Surgical time (min)		80.3±9.9
Hidden blood loss (mL)		465.9±58.3
Intraoperative blood loss (mL)		131.8±20.8
Postoperative blood loss (mL)		113.1±22.5
Visible blood loss (mL)		244.9±28.7
Blood transfusion	50	
Total blood loss (mL)		571.1±149.6
Length of stay (day)		10.3±2.0
Total	105	

SD: Standard deviation; Hb: Hemoglobin; Hct: Hematocrit; ALB: Albumin; ASA: American Society of Anesthesiologists.

DISCUSSION

Hemiarthroplasty represents a prevalent surgical intervention for hip fractures, comprising over 50% of procedures in elderly populations.[20] This approach demonstrates reduced VBL and lower transfusion requirements compared to total hip arthroplasty.[21,22] However, geriatric hip fracture

TABLE II
Correlation analysis between related factors and hemoglobin

Variables	Pearson value	*p*
Age	0.043	0.660
Sex	–0.118	0.230
Height	0.128	0.194
Weight	0.096	0.332
Body mass index	0.046	0.644
Comorbidity	0.095	0.333
Fracture type	0.626	<0.001
Preoperative Hb	–0.086	0.385
Postoperative Hb	–0.031	0.751
Hb loss	–0.100	0.308
Preoperative Hct	0.030	0.763
Postoperative Hct	0.071	0.472
Hct loss	–0.082	0.408
Preoperative ALB	–0.215	0.028
Preoperative blood glucose	0.075	0.449
Type of anesthesia	0.048	0.624
ASA classification	–0.192	0.049
Preoperative anemia	0.120	0.222
Time to surgery	–0.073	0.462
Surgical time	0.011	0.913
IBL	0.128	0.192
PBL	–0.178	0.069
VBL	–0.053	0.594
Blood transfusion	–0.238	0.014
TBL	–0.018	0.853
Length of stay	0.078	0.430

Hb: Hemoglobin; Hct: Hematocrit; ALB: Albumin; ASA: American Society of Anesthesiologists; IBL: Intraoperative blood loss; PBL: Postoperative blood loss; VBL: Visible blood loss; TBL: Total blood loss.

patients exhibit heightened vulnerability to postoperative anemia due to advanced age, elevated ASA classifications, and significant comorbidity profiles.[23] Beyond initial fracture-related hemorrhage, surgical intervention induces additional blood loss, with HBL potentially continuing postoperatively. Previous studies have associated postoperative anemia in this cohort with compromised functional outcomes and increased mortality.[24] Guo et al.[16] reported HBL constituting 61% of perioperative TBL following hemiarthroplasty for femoral neck fractures. Our findings, derived using the same validated Gross formula but within a cohort restricted to the posterolateral approach and excluding TXA, demonstrate a significantly higher mean HBL proportion (81.4%±13.6% of TBL). This substantial difference underscores the potential impact of surgical approach and perioperative antifibrinolytic management on HBL magnitude, highlighting a key contribution of our work. Of note, the present study offers three novel advances: *(i)* the first HBL quantification exclusive to cementless posterolateral hemiarthroplasty without TXA, revealing markedly higher HBL proportions than previously reported; *(ii)* identification of preoperative hypoalbuminemia as a previously unrecognized independent risk factor for HBL; and *(iii)* quantification of ASA classification's graded impact on HBL volume. These insights refine perioperative management for the growing subset of elderly patients ineligible for TXA.

The standardized protocol (single surgeon, posterolateral approach, cementless implant) was deliberately employed to minimize technical confounders, allowing focused analysis of patient-specific determinants of HBL, a novel approach distinct from comparative studies of techniques or implants.[25,26] This study provided novel insights by specifically quantifying HBL and identifying its independent risk factors within a well-defined cohort of elderly hip fracture patients undergoing hemiarthroplasty exclusively via the posterolateral approach, without the confounding influence of antifibrinolytics. While strategies

TABLE III
Multiple linear regression analysis of influencing factors on HBL following hip hemiarthroplasty

Independent variables	B value	SE	β	t	*p*
Constant	289.62	71.34	-	4.06	<0.001
Fracture type	–23.87	17.91	–0.092	–1.33	0.185
Preoperative ALB	–4.21	1.62	–0.188	–2.60	0.011
ASA classification	25.03	11.32	0.162	2.21	0.029
Blood transfusion	0.12	0.04	0.221	3.25	0.002

HBL: Hidden blood loss; SE: Standard error; ALB: Albumin; ASA: American Society of Anesthesiologists; R^2=0.312, adjusted R^2=0.285, F=11.64, p<0.001.

minimizing IBL during hemiarthroplasty are relatively well-established, comprehensive analysis of HBL risk factors in elderly hip fracture patients remains limited. Our study, therefore, examined 105 consecutive geriatric cases. Utilizing the Gross formula, a validated orthopedic method for HBL quantification, we derived reliable estimates. Postoperative HBL averaged as 465.9±58.3 mL, representing 81.4%±13.6% of TBL (571.1±149.6 mL). These findings underscore the substantial contribution of HBL to perioperative hemorrhage, necessitating its incorporation into blood loss assessments. Notably, anemia prevalence increased from 52.4% preoperatively to universal occurrence postoperatively, highlighting the need for vigilant postoperative monitoring given adverse implications of anemia.

Transfusion occurred in 47.6% (50/105) of our cohort, aligning closely with Miao et al.'s [27] reported rate of 50.6%. Multivariate linear regression confirmed perioperative transfusion as an independent predictor of increased HBL. Pattison et al.[28] proposed postoperative hemolysis as a contributor to blood loss, while evidence indicates stored red blood cell transfusions can exacerbate hemolysis.[29] We consequently suggest that heightened HBL in transfused patients may partially stem from transfusion-associated hemolysis. Additionally, preoperative albumin concentration and ASA classification emerged as independent HBL predictors in our analysis.

Lou et al.[30] identified ASA ≥3 as an independent HBL risk factor during intertrochanteric fracture surgery. Our multivariate analysis not only confirms ASA classification as a significant predictor of increased HBL in hemiarthroplasty, but also quantifies its impact, demonstrating that each ASA grade elevation was associated with a 25.03 mL increase in HBL (β=0.162). This relationship may reflect diminished physiological reserve, impaired coagulation, and amplified surgical stress responses in higher-risk ASA patients. Collectively, these observations indicate escalating ASA classification significantly correlates with greater HBL in hemiarthroplasty.

In the current study, the preoperative albumin level was inversely associated with HBL. Each 1 g/L albumin increase corresponded to a 4.21 mL HBL reduction (β=−0.188). While Zhu et al.[31] demonstrated preoperative hypoproteinemia significantly increased TBL and transfusion requirements in elderly femoral neck fracture patients undergoing hemiarthroplasty, our study is the first, to the best of our knowledge, to specifically identify preoperative hypoalbuminemia as a significant independent predictor of HBL in this surgical context. This finding represents a distinct advancement in understanding the determinants of HBL. Mechanisms linking hypoalbuminemia to elevated HBL include reduced colloid osmotic pressure,[32] compromised coagulation, endothelial dysfunction,[33] and heightened inflammation.[34] Furthermore, hypoalbuminemic patients often require substantial postoperative crystalloid resuscitation, potentially causing hemodilution, coagulation factor dilution, and consequently increased HBL. We, therefore, suggest correcting preoperative hypoalbuminemia through nutritional optimization or albumin supplementation.

Nonetheless, this study has several limitations. First, the single-center, retrospective design with a limited sample size requires future validation through larger prospective or multi-center studies. Second, TBL calculation assumed Hct stabilization by postoperative Day 2,[17] potentially underestimating HBL if equilibrium was incomplete. Third, standardized postoperative rivaroxaban thromboprophylaxis may have influenced results, as this agent is associated with increased major/clinically relevant bleeding following hip arthroplasty,[35] potentially affecting measured HBL volumes. Fourth, the exclusion of patients receiving TXA limits the generalizability of our findings to patients managed without this antifibrinolytic agent. Tranexamic acid is known to significantly reduce perioperative blood loss, including HBL, in hip arthroplasty.[36] Consequently, our results primarily reflect HBL patterns and associated risk factors in the specific cohort of patients not administered TXA. This focus on a TXA-naive cohort, combined with the rigorous exclusion of confounding medications and standardization to the posterolateral approach, provides novel data distinct from studies where TXA was administered or surgical approach varied. Finally, while standardization minimized confounding, it limits extrapolation to diverse surgical settings. However, this design was necessary to achieve our objective: elucidating patient-specific HBL determinants. Generalizability to other approaches/implant types requires verification.

In conclusion, our study results suggest that HBL represents a substantial proportion of perioperative TBL during hip hemiarthroplasty for geriatric hip fractures. Significantly elevated HBL volumes are observed in patients presenting with preoperative hypoalbuminemia, higher ASA physical status classifications, or perioperative transfusion requirements. Comprehensive perioperative fluid management protocols must systematically account for both quantified HBL and these identified clinical risk factors.

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

Author Contributions: Wrote the draft of the manuscript, was a major contributor in design and revising: J.WZ.; Critically reviewed and revised the manuscript for important intellectual content: F.C.; Were involved in collecting data and design of the study: X.C., L.M.Y., C.J.L. All authors approved the final manuscript and agree to be accountable for all aspects of the work.

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