Dynamic Analysis of Perioperative Hidden Blood Loss in Intertrochanteric Fractures

Shuwei Tian, MD1, Hui Li, MD2, Meiyu Liu, MM3, Yanlong Zhang, MM4, and Aqin Peng, MD5

Abstract
To analyze the dynamic variation in perioperative hidden blood loss in patients with intertrochanteric fracture. From January to December 2017, 79 patients with intertrochanteric fracture were treated with proximal femoral nail antirotation. Serial complete blood count assays were performed consecutively in the 3 days after admission, on the day of surgery, and 7 days postoperatively. Blood loss during surgery, postoperative drainage, and perioperative blood transfusion volumes were recorded. Dynamic changes in hemoglobin (Hb) prior to surgery were recorded and compared between males and females. Patients were divided into the no blood transfusion group, the 400-mL blood transfusion group, and the 800-mL blood transfusion group depending on the volume of perioperative blood transfusion. Total and hidden blood loss were separately calculated according to the Gross equation. Lowest mean Hb values occurred on day 2 after admission among men (104.8 g/L) and on day 3 after admission among women (98.6 g/L). The average Hb decrease was 11.4 g/L, 11.8 g/L, and 8.9 g/L in the no blood transfusion group, the 400-mL blood transfusion group, and the 800-mL blood transfusion group, respectively. The lowest Hb value occurred on postoperative day 2. Hemoglobin increased on postoperative day 3 and stabilized by day 6. In the no blood transfusion group, the average total blood loss was 406.0 ± 255.6 mL, 628.3 ± 267.2 mL, and 759.7 ± 322.1 mL in the no blood transfusion group, the 400-mL blood transfusion, and 800-mL blood transfusion groups, respectively, and hidden blood loss was 326.0 ± 246.6 mL, 512.1 ± 247.3 mL, and 596.1 ± 306.9 mL, respectively. Perioperative hidden blood loss occurred prior to surgery for intertrochanteric fracture and ended on postoperative day 2.

Keywords
intertrochanteric fracture, hidden blood loss, PFNA

Date received: 03 June 2018; revised: 29 November 2018; accepted: 30 November 2018.

Introduction
Although surgical and anesthetic techniques have made great progress, the mortality rate of patients with intertrochanteric fracture has not significantly changed in the last 40 years.1 An important risk factor for perioperative death is anemia. Many patients have varying degrees of anemia in the perioperative period. Identifying and rectifying perioperative anemia earlier could facilitate appropriate medical optimization and reduce mortality.2 The aim of our study was to improve understanding of this issue by monitoring dynamic variations in perioperative hidden blood loss and hemoglobin (Hb) levels in patients undergoing surgery for intertrochanteric fracture.

Patients and Methods
From January to December 2017, a total of 109 surgeries for proximal femoral nail antirotation were performed in our hospital. Inclusion criteria were as follows: (1) intertrochanteric fracture patients >65 years of age and admission on the day of fracture occurrence and (2) platelet count, prothrombin time, partial thromboplastin time, and international normalized ratio within normal ranges. Exclusion criteria were as follows: (1) pathological fracture; (2) serious cardiac or respiratory disease requiring conservative treatment; (3) congenital or acquired coagulopathy; (4) history of thromboembolic disease such as...
cerebral infarction, pulmonary embolism, myocardial infarction, deep vein thrombosis, or recent thrombophilia with chronic anticoagulant drugs; and (5) hemorrhagic disease developed during hospitalization.

A total of 79 patients were included in our study. We eliminated several of the original 109 cases because they could have affected the authenticity of the results, as follows: 7 patients who were not admitted to hospital on the day of fracture occurrence, 12 who completed surgery within 48 hours, 3 cases of congenital or acquired coagulopathy, 6 with chronic anticoagulant drugs because of thrombus history, and 2 who developed hemorrhagic diseases during hospitalization (1 cerebral hemorrhage and 1 gastrointestinal hemorrhage). All patients received low-molecular-weight heparin (subcutaneous enoxaparin, 40 mg, once daily) from the time of admission (pre- and postoperatively). The day of admission was recorded as day 0. Patients had daily consecutive complete blood count assays for 3 days after admission, on the day of the operation, and on the first 7 days postoperatively. The volumes of visible blood loss in the operating room, postoperative drainage, and perioperative blood transfusion were recorded. The 79 patients were divided into male and female groups; the dynamic changes in Hb in each group prior to surgery were recorded and compared.

All of our patients followed the new blood transfusion guidelines, which stated that transfusions should occur when Hb concentrations were less than 8 g/dL. Patients were further divided into the no blood transfusion group, the 400-mL blood transfusion group, and the 800-mL blood transfusion group depending on the volume of perioperative blood transfusion. Values of perioperative variations in Hb and hematocrit (Hct) were recorded from day 1 after admission to the lowest day postoperatively in each group. Hidden blood loss and total blood loss were calculated according to the Gross formula. The dynamic changes in Hb level from the day of surgery to postoperative day 7 were analyzed for the no blood transfusion group.

Approval for our study was provided by the ethics board of the Third Hospital of Hebei Medical University [clinical trial registration code: 2016-016-1], and all patients provide their written informed consent for participation.

Calculation of Hidden Blood Loss

The patient’s blood volume (PBV) was calculated as follows:

\[ \text{PBV} = k_1 \times \text{height (m)}^3 + k_2 \times \text{weight (kg)} + k_3, \]  

where \( k_1 = .3669, \ k_2 = .03219, \) and \( k_3 = .6041 \) for men and \( k_1 = .3561, \ k_2 = .03308, \) and \( k_3 = .1833 \) for women.

Multiplying the PBV by the Hct yields the total red cell volume. Any change in red cell volume can therefore be calculated from the change in Hct. Total red blood cell (RBC) volume loss = \( \text{PBV} \times (\text{Hct}_{\text{pre-op}} - \text{Hct}_{\text{post-op}}). \)

The theoretical total blood loss was determined according to total RBC loss and Hct_{\text{pre-op}}. The formulae used were as follows:

\[ \text{Theoretical total blood loss} = \frac{\text{total RBC loss}}{\text{Hct}_{\text{pre--op}}}. \]

\[ \text{Perioperative actual blood loss} = \text{Theoretical total blood loss} + \text{transfusion} \]

\[ = \text{the hidden blood loss} + \text{visible blood loss} \]

\[ \text{Hidden blood loss} = \text{theoretical total blood loss} + \text{transfusion} - \text{visible blood loss} \]

When transfusion was performed, a unit of red cell concentrate containing the standard 200 mL of red blood corpuscles was used.

Statistical Methods

Statistical analysis was performed using SPSS 16.0 statistical software (SPSS Inc., Chicago, Illinois). Means are presented as mean (standard deviation). Numerical data were compared by \( t \) test. The significance level used for all tests was \( P < .05 \).

Results

This study comprised 37 males and 42 females with a mean age of 74.5 years (range, 67-82 years), average height of 1.61 m (range, 1.50-1.73 m), and a mean body weight of 64.4 kg (range, 50.3-81.1 kg). Fractures classified according to the orthopedic trauma association (AO/OTA) classification included 31 A1 fractures in 19 patients, 31 A2 fractures in 38 patients, and 31 A3 fractures in 22 patients. A total of 31 patients did not receive a blood transfusion, 26 received a transfusion of 400 mL, and 22 received a transfusion of 800 mL during the perioperative period. All cases of severe anemia were corrected promptly during the study, and no patient died of anemia. Patient demographic characteristics are shown in Table 1.

| Table 1. Patient Demographic Characteristics.a |
|----------------------------------------------|
| Variables      | Value                          |
|----------------|--------------------------------|
| Patients       | 79                             |
| Male           | 37                             |
| Female         | 42                             |
| Age, years (SD)| 74.5 (6.3)                     |
| Height, m (SD) | 1.61 (0.12)                    |
| Weight, kg (SD)| 64.4 (11.8)                    |
| BMI, kg/m² (SD)| 24.8 (4.52)                    |
| OTA classification (%) |                           |
| 31A1 fractures | 19 (24.05%)                    |
| 31A2 fractures | 38 (48.10%)                    |
| 31A3 fractures | 22 (27.85%)                    |
| Blood transfusion, mL (%) |                        |
| 0              | 31 (39.24%)                    |
| 400            | 26 (32.91%)                    |
| 800            | 22 (27.85%)                    |

Abbreviations: BMI, body mass index; SD, standard deviation. *n = 79.

Theoretical total blood loss = \( \text{total RBC loss/\text{Hct}_{\text{pre--op}}}. \)

Perioperative actual blood loss = Theoretical total blood loss + transfusion = the hidden blood loss + visible blood loss

Hidden blood loss = theoretical total blood loss + transfusion − visible blood loss
Mean Hb values on day 1 after admission were 111.4 g/L for men and 106.8 g/L for women, far below normal values. The lowest Hb values occurred on day 2 after admission in the male group and on day 3 after admission in the female group (104.8 g/L and 98.6 g/L, respectively). The mean serial Hb results and dynamic variation trends for the male and female groups on the first 3 days after admission are illustrated in Figure 1.

Comparisons of blood loss in each group are shown in Table 2. In the no blood transfusion group, the total blood loss was 406.0 ± 255.6 mL including overt blood loss of 80.0 ± 43.1 mL and hidden blood loss of 326.0 ± 246.6 mL; hidden blood loss was 85.1% of the total blood loss. In the 400-mL blood transfusion group, the total blood loss was 628.3 ± 267.2 mL including overt blood loss of 116.2 ± 57.6 mL and hidden blood loss of 512.1 ± 247.3 mL; hidden blood loss accounted for 78.9% of the total blood loss. In the 800-mL blood transfusion group, the total blood loss was 759.7 ± 322.1 mL including overt blood loss of 163.6 ± 62.4 mL and hidden blood loss of 596.1 ± 306.9 mL; hidden blood loss accounted for 73.9% of the total blood loss.

The mean Hb on the day of operation in the no blood transfusion group was 106.8 g/L; the lowest Hb value (100.7 g/L) appeared on postoperative day 2. Hemoglobin increased on postoperative day 3 and stabilized by day 6. The mean decrease in Hb between samples taken on the day of surgery and those taken on postoperative day 2 was 6.1 g/L for patients with intertrochanteric hip fracture. The mean serial Hb results and dynamic variation trend for the no blood transfusion group between the day of surgery and postoperative day 7 are illustrated in Figure 2.

**Table 2.** Comparison of Hb/Hct Levels and Blood Loss in the No Transfusion, 400-mL Transfusion, and 800-mL Transfusion Groups.

| Parameter                  | 0 mL, n = 31 | 400 mL, n = 26 | 800 mL, n = 22 | P Value |
|----------------------------|--------------|---------------|---------------|---------|
| Hb, g/L                    |              |               |               |         |
| Pre                        | 112.1 (8.9)  | 109.0 (10.3)  | 104.5 (6.8)   | .106    |
| Post                       | 100.7 (5.6)  | 97.2 (9.5)    | 95.5 (5.0)    | .022    |
| -                          | 11.4 (8.6)   | 11.8 (8.9)    | 9.0 (8.5)     | .004    |
| Hct, %                     |              |               |               |         |
| Pre                        | 33.5 (2.7)   | 32.5 (3.1)    | 31.2 (2.0)    | .492    |
| Post                       | 30.1 (1.7)   | 29.0 (2.8)    | 28.5 (1.5)    | .038    |
| -                          | 3.4 (1.7)    | 3.5 (2.7)     | 2.7 (2.5)     | .015    |
| Overt blood loss, mL       |              |               |               |         |
| Hidden blood loss, mL      | 80.0 (43.1)  | 116.2 (57.6)  | 163.6 (62.4)  | .009    |
| Hidden/Total, %            | 326.0 (246.6)| 512.1 (247.3) | 596.1 (306.9) | .011    |
| Total blood loss, mL       | 406.0 (255.6)| 628.3 (267.2) | 759.7 (322.1) | .005    |
| Hidden/Total, %            | 85.1         | 78.9          | 73.9          | .023    |

Abbreviations: Hb, hemoglobin; Hct, hematocrit; Pre, postoperative; Post, postoperative; - , pre-pre; Hidden/Total, hidden blood loss/total blood loss.

**Discussion**

Patients with hip fractures have a high perioperative mortality. For example, European patients with hip fracture have a 30-day mortality in excess of 10% and a 1-year mortality of more than 25%. Perioperative morbidity in surgical procedures is often multifactorial, and anemia is one such important factor. This increases the incidence of pulmonary edema and cerebral edema and breaks the balance of oxygen supply and demand in the tissues, causing other problems. In a case–control study of 125 surgical patients who refused blood transfusions, operative mortality was inversely related to the preoperative Hb level, increasing from 7.1% for patients with levels of greater than 10 g/dL to 61.5% for those with levels of less than 6 g/dL.

Previous work has put particular emphasis on analyzing the hidden blood loss related to surgery but has not addressed the hidden blood loss that occurs preoperatively. The serial Hb results from our study show that the mean decrease in Hb
blood loss results from perioperative bleeding into tissue com-
experiments using labeled RBCs demonstrated that this hidden
from the surgical wound and fracture into the tissues. Previous
loss is important to facilitate appropriate medical
with intertrochanteric fracture. A better understanding of hid-
a direct effect on the perioperative management of patients
observed during the surgical procedure. Hidden blood loss has
respectively, and was up to 3.5 to 4.4 times more than that
loss in our study was 85.1 \% , 78.9 \% , and 73.9 \% in the 3 groups,
was up to 3.5 to 4.4 times more than that
observed during the surgical procedure. Hidden blood loss has
a direct effect on the perioperative management of patients
with intertrochanteric fracture. A better understanding of hid-
hidden blood loss is important to facilitate appropriate medical
Hb decrease on this day,
and we also suggest that routine blood counts should be
rechecked many times after surgery, especially in patients
with blood transfusion. For older people with poor mobility
and decreased physiological compensation, finding and
treating perioperative anemia promptly can significantly
improve survival.\textsuperscript{10}

**Conclusions**

Our study demonstrates that hidden blood loss exists prior to
surgery and accounts for more than 80 \% of the total blood loss
in patients with intertrochanteric fracture. It also exists post-
operatively. To avoid long-term anemia after surgery, orthope-
dic staff should closely monitor dynamic changes in Hb.
Moreover, to achieve a smooth perioperative period, we should
reduce the harm caused by hidden blood loss as far as possible
by supplementing the patient’s blood circulation and correcting
anemia when necessary.

**Authors’ Note**

Hui Li and Shuwei Tian are contributed equally to this work.

**Declaration of Conflicting Interests**

The author(s) declared no potential conflicts of interest with respect to
the research, authorship, and/or publication of this article.

**Funding**

The author(s) received no financial support for the research, author-
ship, and/or publication of this article.

**References**

1. Haleem S, Mayahi R, Khanna A, Grice JE, Parker MJ. Mortality
following hip fracture: trends and geographical variations over the
last 40 years. *Injury*. 2008;39(10):1157-1163.
2. Carson JL, Poses RM, Spence RK, Bonavita G. Severity of anae-
mia and operative mortality and morbidity. *Lancet*. 1988;1(8588):
727-729.
3. Haematology TL. Updates on blood transfusion guidelines. *Lan-
cet Haematol*. 2016;3(12):e547.
4. Nadler SB, Hidalgo JU, Bloch T. Prediction of blood volume in
normal human adults. *Surgery*. 1962;57(2):224-232.
5. Gross JB. Estimating allowable blood loss: corrected for dilution.
*Anaesthesiology*. 1983;58(3):277-280.
6. Foss NB, Kehlet H. Mortality analysis in hip fracture patients:
implications for design of future outcome trials. *Br J Anaesth*
2005;94(1):24-29.
7. Roberts SE, Goldacre MJ. Time trends and demography of
mortality after fractured neck of femur in an English popu-
lation, 1968-98: database study. *BMJ*. 2003;327(7418):
771-775.
8. Heikkinen T, Parker M, Jalovaara P. Hip fractures in Finland and
Great Britain – a comparison of patient characteristics and out-
comes. *Int Orthop*. 2001;25(6):349-354.
9. Tian S, Shen Z, Liu Y, Zhang Y, Peng A. The effect of tranexamic
acid on hidden bleeding in older intertrochanteric fracture patients
withd PFNA. *Injury*. 2018;49(3):680-684.
10. Foss NB, Kehlet H. Hidden blood loss after surgery for hip fracture. *J Bone Joint Surg Br*. 2006;88(8):1053-1058.
11. Smith GH, Tsang J, Molyneux SG, White TO. The hidden blood loss after hip fracture. *Injury*. 2011;42(2):133-135.
12. Erskine JG, Fraser C, Simpson R, Protheroe K, Walker ID. Blood loss with knee joint replacement. *J R Coll Surg Edinb*. 1981; 26(5):295-297.
13. Faris PM, Ritter MA, Keating EM, 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(8): 1169-1178.
14. Vinagre Gaspar R, Cornejo Bauer C, Murillo Pérez A, et al. Diagnostic blood losses in severe trauma patients. *Enferm Intensiva*. 2010;21(3):120-125.