Injury 50 (2019) 2282–2286

Contents lists available at ScienceDirect

Injury

journal homepage: www.elsevier.com/locate/injury

Hidden blood loss after hip hemiarthroplasty using the superPATH approach: A retrospective study

Kaihang Xu[1], Dilixiati Anwaier[1], Rongzhi He, Xin Zhang, Sheng Qin, Guangchao Wang, Xuzhou Duan, Dake Tong*, Fang Ji*

Department of Orthopedics, Changhai hospital Affiliated to the Navy Military Medical University, Shanghai, China

ARTICLE INFO

Article history:
Accepted 4 October 2019

Keywords:
Hidden blood loss
Femoral neck fracture
Hemiarthroplasty;SuperPATH

ABSTRACT

Objective: The purpose of this study was to compare perioperative hidden blood loss after hip hemiarthroplasty via the SuperPATH approach and the conventional posterior approach (the Moore approach).
Patients and methods: From January 2015 to January 2017, 130 patients (80.7 ± 6.0 years) with displaced femoral neck fracture (Garden type III or IV) undergoing hip hemiarthroplasty were included in this study. As a non-randomisation study, Fifty-two patients (SuperPATH group) were operated using the SuperPATH approach, and 78 patients (Moore group) were operated with the conventional posterior approach (Moore approach). The demographic and relevant clinical information of the patients were collected. According to the combination formulas of Nadler, Gross and Sehat, the hidden blood loss (HBL) of each patient was calculated. Student's *t*-test for independent samples was used to compare the normally distributed variables and the Mann-Whitney *U* test was used to compare variables not following a normal distribution.
Results: The visible blood loss (VBL) in the SuperPATH group was 123.7 ± 47.5 ml, the hidden blood loss (HBL) was 1084.1 ± 816.8 ml and the HBL% was 82.7 ± 16.5%. In the Moore group, the VBL was 303.6 ± 139.6 ml, the HBL was 700.2 ± 563.8 ml and the HBL% was 61.5 ± 23.8%. The patients in the SuperPATH group had more HBL and HBL% ($P < 0.05$). However, no significant difference was observed of total blood loss (TBL) between the two groups ($P = 0.125$).
Conclusions: HBL should not be ignored in patients who underwent hip hemiarthroplasty for displaced femoral neck fractures, as it is a significant portion of TBL. Compared with the conventional approach, the SuperPATH approach had a greater amount of HBL. A better understanding of HBL after hip hemiarthroplasty may help surgeons improve clinical assessment and ensure patient safety.

Background

Femoral neck fracture is a common form of fracture, which often occurs in the elderly. With a steady increase of incidence, it has become a devastating injury for patients and a substantial burden for the health care system as well [1,2]. Compared with internal fixation, hemiarthroplasty is considered the preferred treatment for displaced femoral neck fractures (Garden type III or IV) for older patients, as it can promote early postoperative ambulation, lower reoperation rates, and achieve better functional outcomes in the first year after operation [3,4]. However, the conventional surgical approaches of hip hemiarthroplasty have their respective shortcomings, including longer incisions, massive tissue damage, increased perioperative blood loss, and delayed time for postoperative rehabilitation [5,6].

The supercapsular percutaneously assisted total hip arthroplasty (SuperPATH) was first reported by Dr. James Chow in 2011. The SuperPATH technique combines the percutaneous preparation of the acetabulum through a portal of the PATH approach and the femoral reaming and broaching of the SuperCap approach [7]. Through the tissue space between the gluteus medius and the piriformis to access the capsule, the SuperPATH technique does not need to release the conjoint tendons or external rotator muscles. Some studies have shown several advantages of this surgical technique, such as a low complication rate, satisfactory radiographic outcomes, shortened length of hospital stay, and excellent early functional results [8–10]. Hip hemiarthroplasty using the SuperPATH approach has been carried out in our hospital since 2015. From our experience, we have noticed that although the operation time is short with little visible blood loss (VBL) during operation, a significant

* Corresponding authors at: Department of Orthopedics, Changhai hospital Affiliated to the Navy Military Medical University, No. 168 Changhai Road, Shanghai 200433, China.
E-mail addresses: doctorxkh@163.com (K. Xu), 605752743@qq.com (D. Tong), doctorjif@126.com (F. Ji).
[1] These authors contributed equally to this article.

https://doi.org/10.1016/j.injury.2019.10.013
0020-1383/

portion of patients still suffer postoperative anemia. We hypothesize that perioperative hidden blood loss (HBL) may explain this phenomenon. Since the concept of HBL was firstly proposed by Sehat and colleagues [11], a number of studies have shown that HBL is an important component of TBL in orthopedic surgical procedures [12–14].

In this study, we suggested that the amount of HBL after hip hemiarthroplasty in elderly patients is significant, and the HBL would appear differently in patients operated with different surgical approaches. The aim of this study was to determine the proportion of HBL, and to compare HBL of patients treated with the SuperPATH approach and the Moore approach.

Patients and methods

Patients

Our study was reviewed and approved by the Medical Ethical Committee of our hospital. From January 2015 to January 2017, all patients with displaced femoral neck fractures who underwent hip hemiarthroplasty by the same senior surgeon were reviewed. The inclusion criteria were: [1] >70 years old, [2] fresh closed femoral neck fractures (Garden type III or IV), [3] low energy trauma, [4] no ipsilateral proximal femoral fracture or operation history, [5] complete medical data, including hematocrit (Hct) and hemoglobin (Hb) value on admission and 72 h after operation [HCT value at 2 to 3 days after operation was recommended as index to minimize the influence of fluid retention [15]], are available. Exclusion criteria were: [1] multiple fractures, [2] pathological fractures or American Society of Anesthesiologists (ASA) score of V, [3] neoplastic diseases, [4] severe hematologic disorders, [5] using antiplatelet drugs or non-steroidal anti-inflammatory drugs (NSAIDs) less than 1 month before operation. All patients were followed up in the same rehabilitation unit in our hospital for at least 12 months, and all complications after the hip hemiarthroplasty were recorded. Finally, a total of 130 patients were included in the analysis.

Hip hemiarthroplasty procedures

All the patients with displaced femoral neck fractures (Garden type III or IV) were treated by hip hemiarthroplasty. As a non-randomisation study, before operations, we clearly informed the patients and their families of the advantages and disadvantages of these two approaches, and the choice of the operation method mainly based on the wishes of the patients and their families. Fifty-two patients were operated by using the SuperPATH approach (Uncemented prostheses with bipolar heads, Wright, USA). The patient was positioned in the lateral position with the hip in 45° of flexion and 10–15° of internal rotation and the incision (6–8 cm) is made in-line with the femur proximal to the greater trochanter. Then the gluteus maximus is bluntly split and the Zelpi retractors is placed to visualize the piriformis. Through the interval between the gluteus medius and the piriformis, the capsule can be exposed and be opened. From the anterior portion of the piriformis fossa, the femur was reamed and broached. An entry reamer was used to open the canal, then a canal feeler was used to confirm the position. A calcar punch was used to knock out the femoral neck and head in order to insert the broaches. Consecutive broaches were used until the appropriate broach was placed. The femoral neck osteotomy was made using the superior aspect of the broach as a guide and two Schanzpins were inserted into the femoral head in order to rotate and remove the head. Following an assessment of the health of the acetabular cartilage, the trial bipolar head is placed in the acetabulum. The trial neck is inserted and reduction is then achieved through a combination of hip abduction and internal rotation. Once stability is confirmed, an intraoperative radiograph can be used to confirm restoration of leg length, offset, and appropriate canal fill. Components were then separated and removed. The definitive femoral head was inserted, and a femoral prosthesis was implanted and reduced again. The hip joint capsule was perfectly preserved and closed with a suture. Then, the gluteal fascia and skin were closed with sutures. The left 78 patients were operated with the Moore approach (Uncemented prostheses with bipolar heads, Link, Germany). All the operations were performed at the same institution by the orthopaedic surgeons with more than 15 years of clinical experience in treating femoral neck fractures. Prophylactic antibiotics (2 g cefazolin) were injected intravenously 30 min before the surgery. Postoperative intravenous cefazolin (2 g, ×3 doses) was administered within the first 24 h. Low-molecular-weight heparin was used from the time the patients were admitted until the operations were completed to prevent deep venous thrombosis. All patients received 10 mg of oral rivaroxaban per day postoperatively for at least 1 month.

Data collection

The height and weight of all patients were recorded before operation. The volume of blood loss, including the blood in suction bottles and in the weighed swabs, was recorded by anesthesiologists during the operation. Hemoglobin (Hb) and hematocrit (HCT) were measured before and 72 h after operation in all patients. The drainage tubes were removed 24 h after the operations, and the total drainage volume was recorded as part of the visible blood loss (VBL). The frequency and volume of blood transfusion were carried out according to the hospital blood transfusion policy [Hb < 90 g/L in healthy patients; for elderly patients (> 65 years old) and with destabilizing vital signs (heart rate > 100 or systolic blood pressure < 90 mmHg), the indication of blood transfusion should be relaxed].

Calculation of blood loss

(1) The patient blood volume (PBV) was calculated according to the Nadler formula [16]:

$$PBV\,(L) = height\,(m)\,3 \times 0.367 + weight\,(Kg) \times 0.032 + 0.604 \quad \text{(For male patient)}$$

$$PBV\,(L) = height\,(m)\,3 \times 0.356 + weight\,(Kg) \times 0.033 + 0.183 \quad \text{(For female patient)}$$

(2) The estimated blood loss volume (EBV) was calculated according to the Gross formula [17]:

$$EBV\,(ml) = PBV\,(L) \times (Hct_{pre}\text{-}Hct_{post})/Hct_{ave} \times 1000.$$

Multiply PBV by HCT to get the red blood cell volume, so any change in the red blood cell volume can be reflected through the change in Hct. Hct_{pre} is the initial preoperative Hct, Hct_{post} is Hct on the third day postoperatively, and Hct_{ave} is the average of Hct_{pre} and Hct_{post}.

(3) The hidden blood loss (HBL) was calculated according to the Sehat formula [18]:

HBL (ml) = EBV (ml) – visible blood loss (intraoperative blood loss + drainage volume).

When transfusion was performed during the perioperative period, the formula was calculated as follows: HBL (ml) = EBV (ml) + blood infusion (ml) – visible blood loss (ml). And 1 unit of red blood cells was recorded as 200 ml.

(4) The total blood loss (TBL) was calculated as follows [15]:

TBL (ml) = visible blood loss (ml) + HBL (ml). And the percentage of HBL (HBL%) was calculated using the following formula: HBL% = (HBL/TBL)*100%.

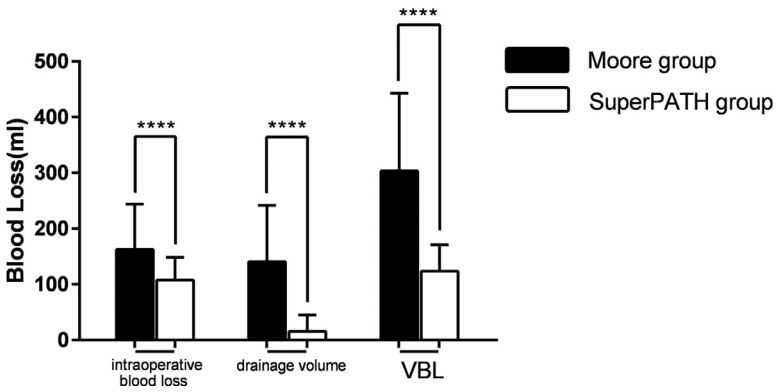

Fig. 1. Comparison of HBL and TBL between two groups.
Comparison of HBL and TBL between Moore and SuperPATH group. *P* values indicate that HBL of SuperPATH group were increased in comparison with those of Moore group ($P = 0.004$). There is no difference was observed between TBL of those two groups ($P = 0.222$). (Mann-Whitney *U* test).
Abbreviation: HBL, hidden blood loss; TBL, total blood loss.

Table 1
Characteristics of the patients.

Characteristics	Moore	SuperPATH	*P* value
Age (years)	80.0 ± 7.7	80.8 ± 4.4	0.457
Male/Female	25/53	19/33	0.596
Weight (kg)	58.4 ± 11.8	59.8 ± 8.58	0.483
Height (cm)	161.7 ± 8.7	162.8 ± 8.2	0.501
BMI (kg/m$^{2)}$	36.0 ± 6.3	36.6 ± 4.4	0.527

Notes: Data are represented as mean ± SD. *P* values indicating no significant difference among two groups.
Abbreviation: BMI, body mass index.

Statistical analysis

Data analysis was performed using SPSS 22.0 for Windows (SPSS Inc., Chicago, IL, USA). Descriptive statistics were shown as mean ± SD or number of cases and percentages when appropriate. Patient baseline characteristics were compared to determine whether the two groups were comparable. For continuous variables, the Kolmogorov-Smirnov test was applied to determine whether they followed a normal distribution. Student's *t*-test for independent samples was used to compare the normally distributed variables and the Mann-Whitney *U* test was used to compare variables not following normal distribution. Gender was compared using the Chi-square test. The level of statistical significance was set at $P < 0.05$ (two-sided).

Results

The baseline characteristics of the patients are shown in Table 1. Briefly, the mean TBL of all patients was 1085.4 ± 691.7 mL and the mean HBL (853.8 ± 699.4 ml) was about 84.5% of TBL. The mean operative time and the perioperative change of PBV, Hb, Hct are presented in Table 2. The observed and calculated values for blood loss in different groups, including EBV, VBL, HBL, TBL and HBL% are shown in Table 3. The postoperative complications of the two groups are shown in Table 4. The intraoperative blood loss (162.6 ± 81.1 ml), drainage volume (140.8 ± 101.0 ml) and VBL (123.7 ± 47.5 ml) of Moore group were increased in comparison with those of the SuperPATH group ($P < 0.0001$). (Fig. 1) The HBL (1084.1 ± 816.8 ml), and HBL% (82.7 ± 16.5%) of SuperPATH group were increased in comparison with those of the Moore group ($P < 0.05$). However, no difference was observed between TBL of those two groups ($P = 0.222$) (Fig. 2).

Discussion

The treatment and postoperative rehabilitation of femoral neck fractures in the elderly has always been a challenge for orthopedic surgeons [19]. At present, hip hemiarthroplasty is still the first choice for Garden type III or IV femoral neck fractures [20]. However, problems remain in the traditional approach for hip hemiarthroplasty, such as longer incisions, massive tissue damage, increased perioperative blood loss, and delayed time of postoperative rehabilitation [21]. More recently, minimally invasive techniques have been introduced to the orthopedic fields and have received widespread attention [22,23]. Although success of these modified mini-approaches has been proven, it is still very difficult to perform surgery using a new approach when the surgeon is not familiar with the anatomical structure [21]. The emergence of SuperPATH has provided a good choice for minimally invasive hip replacement. Since the surgical approach was first proposed by Chow and colleagues in 2011 [7], a number of studies have shown several advantages of the SuperPATH approach, including minimal dissection, lack of hip dislocation, reduced blood loss, decreased postoperative pain, and accelerate early rehabilitation in comparison to the conventional posterior approach [8–10,24,25]. Aside from the benefits to the patient, the use of the SuperPATH technique also provides potential advantages to the surgeon, which is the shorter learning curve [26].

Hip hemiarthroplasty *via* the SuperPATH approach has been carried out in our hospital since 2015, we have observed that although the operation time is short with little VBL during operation, a significant portion of patients still suffer postoperative anemia. It is well known that postoperative anemia after hip fracture is related to an inferior functional recovery and a detrimental effect on mortality, especially in the elderly patients [27]. We believe that the significant difference between the decrease of hematocrit (Hct) or hemoglobin (Hb) and the small amount of VBL can be explained by perioperative hidden blood loss (HBL). Foss and colleagues have found the HBL of hip fracture in connection with surgery was an excess of up to six times more than they observed during the operation and the HBL after hemiarthroplasty was 987 mL, which accounts for 75% of TBL (1301 mL). Therefore, perioperative HBL of hip hemiarthroplasty should not be ignored and patients must be closely monitored after surgery to avoid the potential adverse effects of anemia [28].

In our study, we investigated 130 elderly patients with femoral neck fracture after hip hemiarthroplasty in our hospital from January 2015 to January 2017. Fifty-two of them were treated with

Table 2
Perioperative parameters of the patients.

	Moore	SuperPATH
Mean operative time (min)	81.1 ± 33.4	76.6 ± 21.0
PBV (L)	3.76±0.71	3.84±0.62
Transfusion rate (%)	35.9% (28/78)	26.9% (14/52)
Mean transfusion volume (ml)	478.6 ± 36.14	485.7 ± 45.52
Hb values (g/L)		
preoperative	126.3 ± 17.3	121.7 ± 14.1
postoperative	101.6 ± 18.8	95.0 ± 15.1
ΔHb (Difference from preoperative to postoperative)	24.8 ± 15.1	26.7 ± 17.9
Hct values (%)		
preoperative	37.8 ± 4.8	36.5 ± 3.7
postoperative	30.4 ± 5.1	27.9 ± 4.6
ΔHct (Difference from preoperative to postoperative)	8.6 ± 5.2	7.4 ± 4.3

Notes: Data are represented as mean ± SD. Mean operation time, PBV, Transfusion rate, Mean transfusion volume, Perioperative Hct and Hb values were shown in Table 2.
Abbreviations: PBV, patient's blood volume; Hb, Haemoglobin; Hct, Haematocrit.

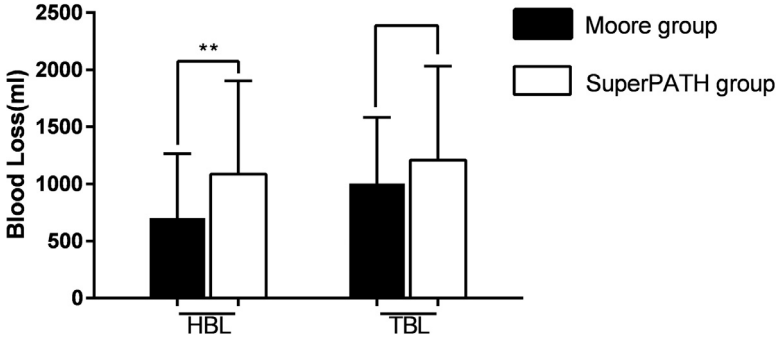

Fig. 2. Comparison of intraoperative blood loss, drainage volume and VBL between two groups.
Comparison of intraoperative blood loss, drainage volume, VBL between Moore and SuperPATH group. *P* values indicate that intraoperative blood loss, drainage volume, VBL of Moore group were increased in comparison with those of SuperPATH group ($P < 0.0001$).
Abbreviation: VBL, visible blood loss.

Table 3
Perioperative parameters regarding hidden blood loss.

	Moore	SuperPATH	*P* value
EBV (ml)	832.0 ± 550.7	1077.0 ± 753.9	0.091
VBL (ml)	303.6 ± 139.6	123.7 ± 47.5	0.001
HBL (ml)	700.2 ± 563.8	1084.1 ± 816.8	0.004
TBL (ml)	1003.8 ± 579.0	1207.8 ± 823.7	0.222
HBL %	61.5 ± 23.8	82.7 ± 16.5	0.001

Notes: Data are represented as mean ± SD. EBV, VBL, HBL, TBL, HBL% were shown in Table 3. *P* values indicate that VBL, HBL, and HBL% of SuperPATH group were increased in comparison with those of Moore group ($P < 0.05$), however, no difference was observed between TBL and EBV of those two groups ($P > 0.05$).
Abbreviations: EBV, estimated blood loss volume; VBL, visible blood loss; HBL, hidden blood loss; TBL, total blood loss; HBL%, the percentage of HBL.

Table 4
Postoperative complications of two groups.

	Moore	SuperPATH
Infection	0% (0/78)	0% (0/52)
Wound complications	2.56% (2/78)	0% (0/52)
Deep venous thrombosis	2.56% (2/78)	1.92% (1/52)
Bedsore	3.85% (3/78)	0% (0/52)
Pneumonia	3.85% (3/78)	1.92% (1/52)
Urine storage	2.56% (2/78)	1.92% (1/52)
Periprosthetic fracture	1.28% (1/78)	0% (0/52)
Dislocation	3.85% (3/78)	0% (0/52)

Notes: The postoperative complications of two groups were shown in Table 4.

the surgery using SuperPATH approach, the rest were operated with the Moore approach. Based on the formulas of Nadler, Gross and Sehat [16–18], which have been widely used to calculate HBL in orthopedic surgery, a relatively reliable method was used to estimate the HBL. According to the changes of hematocrit, the average EBV of all patients was 930.0 ± 648.2 mL, the average HBL was 853.8 ± 699.4 mL, accounting for 70 ± 23.5% of TBL (1085.4 ± 691.7 mL). Our results showed that there was a significant amount of HBL after hip hemiarthroplasty and the results are similar to previous studies [19,28]. There are several possible explanations of HBL. Firstly, part of the injury-related TBL actually occurs before admission, though less than extracapsular fractures, the blood loss caused by initial trauma should not be ignored. Secondly, the anti-coagulant treatment after the operation may increase the hidden blood loss. Thirdly, insufficient hemostasis during the operation may lead to continuous haemorrhage after operation. Finally, hemolysis due to various causes may also lead to the loss of blood.

Our results have shown that HBL of the SuperPATH group is significantly higher than that of the Moore group ($P < 0.01$) (Fig. 2). We believe that this result can be explained by two main reasons. First of all, when we operated using the SuperPATH approach, we used the reamer to open the canal and the reaming procedure could destroy the trabecular structure. Destruction of the bone trabeculae would aggravate the intramedullary bleeding of the femur, and this form of bleeding could last for a long time after the surgery, thus inducing more HBL [29]. Secondly, due to less visualization of the surgical field, the haemostasis in the surgery might be compromised, which might also increase the HBL. We also found that the VBL in the SuperPATH group is less than the VBL in the Moore group ($P < 0.0001$). The minimal dissection,

including shorter incisions, less soft tissue damage, may decrease the VBL in the operative. Meanwhile, we have found that the drainage volume of the SuperPATH group is also less than it in the Moore group ($P < 0.0001$). (Fig. 1) Several studies have shown that the SuperPATH technique could decrease blood loss [5,8,10,26]; however, our study observed no significant difference of TBL between those two groups ($P = 0.125$). We suspected that those studies might record the VBL as the blood loss, while ignored the perioperative HBL. In general, perioperative HBL may be caused by a variety of factors, which should be addressed when the SuperPATH technique is used so as to avoid complications caused by anemia.

Our study has several limitations. First, the study is a retrospective case series, thus a prospective, randomized controlled trial will be needed in order to more appropriately evaluate the HBL of different approaches. Second, the number of patients included in our study was relatively small, so the study could not have enough power to detect a significant difference. Finally, the use of the low-molecular-weight and rivaroxaban can increase bleeding, which might then affect the volume of HBL.

Conclusions

Being a significant component of TBL, HBL should not be ignored in patients after hip hemiarthroplasty for displaced femoral neck fractures. Though no significant difference of TBL was detected between the two groups, the SuperPATH approach can lead to a greater amount of HBL than the conventional Moore approach.

Declaration of Competing Interest

None.

Acknowledgments

This work was supported by the grants from Shanghai Committee of Science and Technology Foundation (No. 13411951500) and The Changhai Hospital Program (CH125510202).

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