Hidden Blood Loss and Factors in Shoulder Arthroscopy Surgery: A Review of 59 Patients

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Research article

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Abstract

Purpose: Subacromial impingement syndrome (SIS) and its related rotator cuff tears are the most important cause of shoulder joint pain, which has recently received greater attention. Arthroscopy is a safe, effective, and minimally invasive procedure for the treatment of stage Ⅱ or Ⅲ SIS. Previous studies have reported that little blood loss usually occurs during this procedure. However, significant perioperative hidden blood loss (HBL) is often overlooked. In this respect, we herein aimed to investigate the amount of HBL and identify its possible risk factors.

Methods: We enrolled 59 patients with SIS who received shoulder arthroscopy between December 2019 and June 2020 in this study. The clinical data recorded included the height of patients, weight pre- and postoperative hematocrit (Hct), which were used to calculate HBL using Gross's formula. We analyzed the risk factors, including sex, age, BMI (body mass index), stage of SIS, diabetes, hypertension, and operative time using multivariate linear regression analysis.

Results: Our results revealed that the mean of HBL was 341.4 ± 214.9 mL, while that of the postoperative Hb loss was 13.3 ± 8.0 g/L. The incidence of postoperative anemia was significantly associated with HBL ($\chi 2 = 14.496$, $P < 0.001$). Furthermore, multivariate linear regression analysis demonstrated that all seven factors, including gender ($P = 0.698$), age ($P = 0.553$), BMI ($P = 0.854$), stage of SIS ($P = 0.906$), diabetes ($P = 0.984$), hypertension ($P = 0.532$), and operative time ($P = 0.645$), were not significantly associated with HBL.

Conclusion: Findings from this study show that postoperative HBL following shoulder arthroscopy was significant, which can aggravate anemia or lead to secondary anemia, thus should not be neglected.

Introduction

Subacromial impingement syndrome (SIS) and its related rotator cuff tears in adult patients are increasing steadily, severely affecting the quality of life of patients. In particular, they are the most significant causes of shoulder joint pain and are likely the outcomes of an age-related, degenerative process [1]. The primary goals of treatment are to relieve pain and restore function. According to Neer *et al.*, SIS and its progression are characterized into three stages [2]. For early-stage impingement, conservative multimodal treatment is the most preferred option. On the other hand, for stage Ⅱ, stage Ⅲ impingement, and rotator cuff tears, shoulder arthroscopic surgery (including arthroscopic acromioplasty or/and rotator cuff repair) is an effective and minimally invasive treatment [3, 4]. Although little visible blood loss in minimally invasive surgeries is well documented, postoperative hemoglobin (Hb) or hematocrit (Hct) of patients undergoing those surgeries are found to be maintained at lower levels than the preoperative [5-7]. Thus, implying that lower postoperative Hb and Hct should be attributed to perioperative hidden blood loss (HBL), which is often overlooked in terms of research.

The concept of HBL was proposed by Sehat *et al.* [8] and has been widely studied. Previous investigations in the realm of orthopedics mostly focused on arthroplasty, posterior spine fusion surgery,

and percutaneous kyphoplasty surgery (PKP), which showed that HBL was remarkable after surgery [5, 9, 10]. Additionally, Wan *et al.* found that the mean of HBL after laparoscopic cholecystectomy (LC) was 259.3 ml [6]. These studies have enumerated that whatever in open or minimal surgery, HBL is a significant part of estimate total blood loss (TBL). Therefore, understanding HBL will help to estimate TBL more accurately during the perioperative period, which possibly can prevent related complications. Unfortunately, there is no published study considering HBL in shoulder arthroscopic surgery for rotator cuff disease. We thus speculated that shoulder arthroscopy can also lead to hidden blood loss. In this regard, we herein performed a retrospective review on patients who had received shoulder arthroscopy in our department to calculate the amount of HBL, as well as to identify the influential factors causing HBL after shoulder arthroscopy surgery. Of note, in this study, we revealed that postoperative Hb in patients who received shoulder arthroscopy was lower in our clinical practice compared with the pre-operative.

Materials And Methods

2.1 Patients

All protocols and procedures used in this study were reviewed and approved by the Ethics Committee of Huzhou Hospital. The patients enrolled in this work provided informed consent. The inclusion criteria for enrollment were as follows: unilateral shoulder arthroscopy, degenerative injury, and complete medical data, while exclusion criteria included: traumatic rotator cuff injury, long-term bleeding disorders, blood transfusion throughout the assessment period, and multiple injuries. We retrospectively reviewed a total of 59 patients (23 males and 36 females) who had undergone shoulder arthroscopy between December 2019 and June 2020. Afterward, we recorded data which comprised of gender, age, weight, height, body mass index (BMI), the level of SIS, preoperative and postoperative hematocrit (Hct) and hemoglobin (Hb), operative time, hypertension, and diabetes mellitus.

2.2 Surgical technique and postoperative therapy

Based on the American Society of Anesthesiologists (ASA) physical score, all individuals received general anesthesia. The operation was performed with the patient lying in a lateral decubitus position by experienced surgeons (SZ). Hypotensive anesthesia, irrigated with epinephrine saline solution, and intra-articular tranexamic acid was applied to reduce bleeding and to provide a clear operative field. After the operation, the patients routinely received short-term postoperative analgesia.

2.3 Management of blood loss

Intraoperative visible blood loss was too little to be assessed. In addition, no patient underwent wound drainage. Therefore, we ignored it, and TBL was approximately considered as HBL. Notably, it is generally believed that fluid shifts have been largely completed and the hemodynamics of patients become stable on the second or third days after surgery [11]. Thus, a complete blood count including Hct and Hb of all patients were recorded before the operation and on the third postoperative day.

2.4 Calculation of the hidden blood loss

We computed the patient's blood volume (PBV) as described by Nadler *et al.* as follows [12]:

PBV (L) = k1 × height (m)3 + k2 × weight (kg) + k3,

where k1 = 0.3669, k2 = 0.03219, and k3 = 0.6041 are for males, whereas k1 = 0.3561, k2 = 0.03308, and k3 = 0.1833 are for females.

In this study, the TBL was estimated using the formula developed by Gross *et al.* as stated below [13]:

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

Where Hct_{pre} is the initial preoperative Hct, Hct_{post} is the Hct on the second or third day postoperatively, and Hct_{ave} is the average of Hct_{pre} and Hct_{post}.

We recorded perioperative Hb so as to calculate Hbloss according to the following formula:

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

2.5 Level of SIS

Here, we classified SIS into three stages as described by Neer *et al.*. In particular, patients with stage impingement underwent arthroscopic surgery after failure of conservative treatment. Subsequently, those patients with stage impingement were also included.

2.6 Additional measurements

A hemoglobin level of < 130 g/L for men and < 120 g/L for women was defined as anemia based on the World Health Organization (WHO) criteria [14].

2.7 Statistical analysis

All data analyses were implemented using SPSS software, version 26.0 (SPSS, Chicago, IL). A level of $P < 0.05$ was considered statistically significant. Mean ± standard deviations were used as descriptive statistics. First, we used the Shapiro-Wilk test to assess the normality of variables, while the paired sample t-test was used to compare the differences between pre- and post-operative Hb levels and Hct values. We then examined the significant differences between the two stages using the independent sample' Student t-test and $\chi2$ test. Additionally, we adopted the $\chi2$ test to compare the pre- and post-operative incidence of anemia. Finally, multivariate linear regression analysis was performed to identify the influencing factors associated with HBL, including three quantitative variables (age, BMI, and operative time) and four qualitative variables (sex, stage of SIS, diabetes, and hypertension). A positive coefficient indicates a positive influence on the dependent variable (HBL), whereas a negative coefficient reflects a negative influence.

Results

Overall, 64 patients underwent shoulder arthroscopy between December 2019 and June 2020 in this work. Five patients were excluded: 1 patient with a traumatic injury, 1 patient (with shoulder joint infection), and 3 patients (with incomplete clinical data). Consequently, a total of 59 patients were enrolled in this study. As shown in Table 1, the average age was 60.6 years (range, 35 - 84 years), while that of BMI was 23.5 (range, 22.6 - 24.3). In addition, the mean of postoperative HBL was 341.4 ± 214.9 mL, whereas that of Hb loss was 13.3 ± 8.0 g/L. The operative time of shoulder arthroscopy was 92.5 ± 37.3 min. Notably, a paired sample t-test revealed a significant difference between the values of pre- and post-operative Hb ($P < 0.001$).

There was no statistical difference in sex ($P = 0.985$), age ($P = 0.118$), height ($P = 0.306$), weight ($P = 0.223$), BMI ($P = 0.354$), hypertension ($P = 0.052$) and diabetes (0.363) between the two stages (Table 2). As shown in Table 3, 23 patients suffered from stage □ impingement. The HBL and operative time of those patients were 347.5 ± 192.1 mL and 71.1 ± 35.2 min, respectively. On the other hand, 12 patients suffered from stage □ impingement. The mean HBL and operative time were 337.5 ± 230.9 mL and 106.5 ± 31.8 min, respectively. The increase in operation time was associated with the stage of SIS ($P < 0.001$). The procedure of rotator cuff repair in patients with stage □ impingement prolonged the duration of surgery for about 35 min. We observed no significant difference in HBL between stage □ and □ impingement ($P = 0.863$). Of note, 12 patients suffered from preoperative anemia, and subsequently, the number of patients with anemia after shoulder arthroscopy increased to 32. We also recorded that HBL can significantly increase the risk of postoperative anemia ($\chi2 = 14.496$, $P < 0.001$).

We further performed multiple linear regression analysis to examine the relationship between HBL and seven different influential factors. As is shown in Table 4, gender ($P = 0.698$), age ($P = 0.553$), BMI ($P = 0.854$), stage of SIS ($P = 0.906$), diabetes ($P = 0.984$), hypertension ($P = 0.532$), and operative time ($P = 0.645$) were not significantly associated with HBL.

Discussion

As a new minimally invasive technique, arthroscopy exhibits the benefit of less visible blood loss during surgery. Unfortunately, HBL is often neglected by doctors in clinical practice. Previously, the perioperative bleeding volume has been demonstrated to be closely associated with postoperative complications, especially in old patients. Specifically, HBL occupies a significant proportion of perioperative bleeding, accounting for more than 50% of TBL [9]. Furthermore, excessive HBL increases early complications as well as affects functional reconstruction, which will lead to poor prognosis and dissatisfaction of patients [15, 16]. Therefore, HBL in shoulder arthroscopy should be taken into consideration.

Herein, we found that the mean of HBL was 341.4 ± 214.9 mL, while that of Hb was 13.3 ± 8.0 g/L in the perioperative period. Besides, 20 patients whose preoperative Hb was normal developed secondary anemia. These results far exceeded the expected visible blood loss and were consistent with reports by

Wu *et al.* and Wan *et al* [5, 6]. For patients with shoulder arthroscopy, initial injury and incomplete intraoperative hemostasis were the major causes of HBL. Elsewhere, it has been noted that anemia due to HBL, particularly in the elderly, may increase postoperative mortality and morbidity.

To counteract these adverse effects, several previous studies focused on the mechanisms of HBL and found that HBL is possibly attributed to blood infiltration in tissue compartments and hemolysis. However, the risk factors which may contribute to the rising levels of HBL remain unclear. In this study, we executed multiple linear regression analysis to detect the association factors. Surprisingly, we uncovered that all seven factors were unrelated to the amount of HBL. Previous studies have established that those factors were associated with a high level of HBL [5-11].

For as is well-known, more serious injuries will result in complex surgery and more blood loss. Herein, patients with stage Ⅲ SIS suffered from degenerative rotator cuff tears. The procedure of rotator cuff repair prolonged the duration of surgery for approximately 35 min. However, there was no statistical difference in HBL between the two stages. Additionally, serious injury and long operative time did not increase the HBL in shoulder arthroscopy. This result contradicted the findings reported by Cao *et al.* and Wan *et al.* [6, 17].

We further speculated whether several factors eliminated the influence of stage on HBL. To begin with, numerous reports have highlighted that the blood flow of cuffs with SIS has significantly decreased [18, 19]. Also, pathologies of SIS, such as sterile inflammation and calcification of the supraspinatus tendon, may impair cuffs tissue and affect its blood supply. Elsewhere, another study elucidated that cuff groups with stage Ⅱ impingement showed significantly lower blood flow than those with stage Ⅲ impingement [19]. Besides, suture anchors were applied for repairing the rotator cuff tears in patients with stage Ⅲ SIS, which resulted in a significant decline in the blood flow of cuffs at the initial time point of fixation [20]. Recently, the perioperative blood supply of cuffs in stage Ⅲ impingement has been well below expectations. Notably, irrigation with epinephrine saline and application of tranexamic acid significantly reduced postoperative intra-articular bleeding [20, 21].

Furthermore, in the present study, we found no association between hypertension and HBL, and this finding was parallel to the results by Wu *et al.* [5]. However, this conclusion is still under discussion. A study by Wan *et al.* demonstrated that hypertension significantly increased HBL [6]. Whether the operative region involves major arteries may disturb the influence that hypertension on the HBL. For example, the procedure of LC involving ligation of the cystic artery, vascular fragility caused by long-term hypertension may increase postoperative bleeding [6]. However, other operations such as PKP and cervical open-door laminoplasty primarily affect blood capillaries and tiny vessels, which may explain why postoperative HBL was no associated with hypertension [7, 17].

Moreover, we herein revealed that HBL was unaffected by gender, age, BMI, and diabetes mellitus. This finding was congruent with studies on LC and PKP, likely because of similarity in the concept of minimally invasive surgery techniques [5, 6].

However, despite these intriguing results, this study exhibits several shortcomings. First, the number of patients included in this retrospective study was insufficient, and the operations were not performed by the same surgeon. Thus, we recommend to future prospective studies to incorporate an adequate number of patients. Second, we used Hct on the third day after surgery to evaluate HBL, because previous research suggested that the fluid shifts of patients would be complete at this time. However, we cannot guarantee that this way was optimum. Finally, visible bleeding was overlooked in this study. The amount of HBL that we calculated was inaccurate, which may have affected our investigation.

In conclusion, this study demonstrates that postoperative HBL following shoulder arthroscopy was significant, which can aggravate anemia or lead to secondary anemia, thus should not be overlooked.

Abbreviations

HBL: Hidden blood loss; TBL: Total blood loss; SIS: Subacromial impingement syndrome; Hct: hematocrit; Hb: hemoglobin; BMI: Body mass index; PKP: percutaneous kyphoplasty surgery; LC: laparoscopic cholecystectomy; SZ: experienced surgeons.

Declarations

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Authors' contributions

JN, MJ, TF, XL, HJ, and JL were all with the conception and design of the study or acquisition of data, or analysis, and interpretation of data, and drafting the article and revising it. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

All protocols and procedures used in this study were reviewed and approved by the Ethics Committee of Huzhou Central Hospital.

Consent for publication

All authors have seen the manuscript and approved to submit to your journal.

Competing interests

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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Tables

Table 1 Patients’ demographic information and clinical results in patients with shoulder arthroscopy

Paraments	Mean±SD
Number of patients	59
Age, years	60.6±9.5
Height, m	1.61±0.09
Weight, kg	61.7±12.2
BMI, kg/m^2	23.5±3.3
Hemoglobin loss, g/L	13.3±8.0
Hematocrit level loss, %	9.0±5.7
Hemoglobin level loss, %	10.3±6.2
Operative time, min	92.5±37.3
Hidden blood loss, mL	341.4±214.9

Data are mean±SD

BMI are body mass index

Table 2 Patients' demographic information of two stages

Parameters	Stage Ⅱ (n=23)	Stage Ⅲ (n=36)	p
Sex, n			0.985
Male	9	14	
Female	14	22	
Age, years	58.2±10.0	62.2±8.9	0.118
Height, m	1.63±0.07	1.61±0.09	0.306
Weight, kg	64.1±11.9	60.1±12.3	0.223
BMI	24.0±3.2	23.1±3.4	0.354
Hypertension, n	3	13	0.052
Diabetes, n	1	4	0.363

Data are mean±SD

BMI are body mass index

Table 3 Number and involved levels

Neer grade	Number of patients	Hidden blood loss, mL	Operation time, min
Stage II	23	347.5±192.1	71.1±35.2
Stage III	36	337.5±230.9	106.5±31.8
P		0.863	0.000

Data are mean±SD

Table 4 Results of multiple linear regression analysis for HBL coefficients

	Unstandardized coefficients		Standardized coefficients		
	β	SE	*β*	*T*	*P*
(constant)	148.32	380.54		0.390	0.698
Sex	76.10	62.82	0.174	1.211	0.231
Age, years	2.22	3.71	0.097	0.597	0.553
BMI, Kg/m^2	-0.57	9.78	-0.009	-0.058	0.954
Stage of SIS	8.51	72.01	0.019	0.118	0.906
Diabetes	2.12	107.47	0.003	0.020	0.984
Hypertension	-47.32	75.26	-0.100	-0.629	0.532
Operative time, min	-0.44	0.94	-0.075	-0.464	0.645

Dependent variable: HBL (mL)

BMI: body mass index