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RESEARCH

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Intraoperative cell salvage reduces postoperative allogeneic blood transfusion and shortens off-bed time in simultaneous bilateral total hip arthroplasty: a single-center retrospective study

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Abstract

Background Simultaneous bilateral total hip arthroplasty (SI-THA) results in more blood loss and a greater need for postoperative allogeneic blood transfusion (ABT). Previous studies have reported that multimodal patient blood management (PBM) strategies were associated with a smaller effect of intraoperative cell salvage (ICS) in unilateral total hip arthroplasty. However, there are few studies on the role of ICS in SI-THA. This study aims to explore the effect of ICS with multimodal PBM strategies on SI-THA and to identify risk factors associated with ABT.

Methods This retrospective matched cohort study included 72 patients in the ICS group and 72 patients in the control group who were matched according to age, sex, and year of hospitalization. Demographic data, hematological indicators, blood loss, and ABT were compared between the two groups. Logistic regression analysis was performed to identify independent risk factors for postoperative ABT. Postoperative outcomes were also recorded.

Results In the cohort of 144 patients, 27 patients (37.5%) in the ICS group while 45 patients (62.5%) in the control group received postoperative ABT after SI-THA. Compared with the control group, the ICS group showed significant differences in terms of blood loss, postoperative hemoglobin and hematocrit. The transfused volume of allogeneic red blood cells per ABT patient was also lower in the ICS group. Multivariate logistic regression analysis indicated that sex, the utilization of ICS, and preoperative hematocrit level were identified as independent factors associated with postoperative ABT. The utilization of ICS significantly shortened off-bed time and length of hospital stay, but had no effect on early pain and functional outcomes.

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Conclusion The utilization of ICS can significantly affect postoperative ABT in SI-THA patients with multimodal PBM strategies. Sex, the utilization of ICS and preoperative hematocrit level were identified as independent factors associated with postoperative ABT. The utilization of ICS promoted weight-bearing functional exercises, but had no effect on early outcomes.

Keywords Intraoperative cell salvage, Simultaneous bilateral total hip arthroplasty, Allogeneic blood transfusion, Patient blood management, Hematocrit, Length of stay

Introduction

Total hip arthroplasty (THA) is associated with a large amount of perioperative blood loss [1], and the rate of postoperative blood transfusion can reach 12.7 to 50% [2–4].Researchers have shown that approximately 15–17% of patients who undergo unilateral total hip arthroplasty also need total hip arthroplasty on the contralateral side [5].With the development of anesthesia technology, the maturity of surgical techniques and the continuous development of operating instruments, simultaneous bilateral total hip arthroplasty (SI-THA) has become increasingly popular since the first SI-THA was reported by Jaffe and Charnley in 1971 [6]. Several studies have shown that compared with staged bilateral total hip arthroplasty (ST-THA), SI-THA has the advantages of shorter total anesthesia time, lower economic cost, and shorter total recovery time [7, 8]. However, it has more blood loss and a greater allogeneic blood transfusion (ABT) rate [9, 10], increasing the risk of related complications [2] and prolonging the length of hospital stay [11]. In addition to transfusion-related risks such as immune response, disease transmission, and allergic reactions, transfusion after THA also shows a dose-dependent relationship with surgical site infection [12], which was disastrous for joint arthroplasty surgery. Therefore, massive blood loss during SI-THA is still a major problem faced by surgeons.

Due to the increasing risks and costs of blood transfusions, patient blood management (PBM), which emphasizes appropriate indications, minimizes blood loss, and optimizes red cell mass, has generated a great deal of interest [13]. Intraoperative cell salvage (ICS) reduces blood loss mainly by collecting blood during surgery. Blood is mixed with anticoagulants and sucked into the blood reservoir through negative pressure suction for filtration, after which high-speed centrifugal washing of the filtered blood is performed. After removing anticoagulants and other substances, the filtered blood is reinfused into the patient [14]. According to the 2018 guidelines from the Association of Anesthetists regarding cell salvage for perioperative blood conservation, when intraoperative blood loss in adult patients may exceed 500 ml, ICS should be considered to rescue potential cells [15]. Studies have been inconclusive regarding its ability to reduce the rate and volume of ABT in unilateral THA. Some studies reported that multimodal PBM strategies were associated with a smaller effect of ICS in unilateral THA [16–18]. However, there are few studies on the role of ICS in SI-THA. We hypothesize that the combination of ICS and multimodal PBM strategies can significantly reduce the need for postoperative ABT in SI-THA.

The purposes of this study were (i) to explore the effect of ICS with multimodal PBM strategies on blood loss and postoperative ABT in SI-THA patients; (ii) to explore the risk factors for ABT, and (iii) to explore the effect on postoperative outcomes.

Materials and methods

Data source and study population

This retrospective matched cohort study collected data on consecutive patients who underwent SI-THA in our hospital between January 2010 and December 2020. All data were sourced from our hospital's electronic medical records database. After excluding patients with intraoperative ABT and incomplete data, we identified 284 patients who underwent SI-THA. To reduce the impact of anesthetic, surgical techniques and perioperative management on blood loss, each ICS patient was individually matched to a control patient on the basis of age (±2 years), sex and year of hospitalization. The final cohort consisted of 144 patients: patients who received ICS in the ICS group (n=72) and patients who did not receive ICS in the control group (n=72). The study was approved by the Institutional Review Board of Qilu Hospital, Shandong University (KYLL-202312-050) and registered at Scientific research registration and filing information system (www.medicalresearch.org.cn, ID:220985) .

Surgery and management

All patients underwent SI-THA through the posterolateral approach by one experienced joint surgeon and received general anesthesia with endotracheal intubation and intravenous anesthesia. The first surgery was performed on the side with the more severe imaging findings, followed by the side with the milder imaging findings. Two sets of negative pressure suction equipment were prepared during the surgery, one connected to the ICS system and the other to the standard operating room system [14]. After the joint capsule was incised, the intraoperative blood flow was collected in the ICS device. Iodophor was used to rinse the joint capsule after the placement of the prosthesis. Therefore, the ICS device was stopped, and the system was switched to a standard operating room system to avoid inhaling iodine [15]. During the process of suturing after the second side and awakening from anesthesia, the blood collected by the ICS system was transfused back into the patient's body.

Recombinant human erythropoietin and iron supplements were routinely administered before surgery [19]. Tranexamic acid (TXA) at a dose of 20 mg/kg was intravenously injected 5 to 10 min before incision, with an additional 1 g of TXA added 6 h post-surgery, respectively. Thromboprophylaxis with low-molecular-weight heparin was universally prescribed for all patients. Additionally, all patients received mechanical thromboprophylaxis *via* a portable intermittent inflatable calf pump. Lower extremity vascular ultrasonography was conducted for all patients the day before discharge. Weight-bearing functional exercises with a walker were encouraged. Patients were encouraged to engage in off-bed activities as soon as possible if they exhibited no symptoms of anemia.

Primary outcome

Perioperative hematology results were documented. Postoperative ABT was defined as any allogeneic red blood cells or plasma (including whole blood) received from the end of surgery to the patient's discharge. A restrictive transfusion threshold was adhered to for all patients. ABT was initiated if the hemoglobin level was <80 g/L or 80 to 100 g/L accompanied by symptoms of anemia, such as altered mental status, palpitations, or shortness of breath not attributable to other causes.

Total blood loss was equal to the preoperative total blood volume multiplied by the preoperative hematocrit level subtracted from the postoperative hematocrit level plus the ABT volume [20]. Preoperative total blood volume was calculated with the Nadler equation [21]: total blood volume = K1 * height (m)^3 + K2 * body mass (kg) + K3. With men: K1 = 0.3669, K2 = 0.03219, K3 = 0.6041; with women: K1 = 0.3561, K2 = 0.03308, K3 = 0.1833.

Secondary outcome

The off-bed time, operative duration, length of hospital stay, and postoperative complications were documented. Postoperative pain outcomes during active motion were assessed using a visual analogue scale (VAS) at 3 days, 1 week, and 6 weeks post-surgery. Functional outcomes were evaluated using a Harris Hip Score (HHS) at 1 week and 6 weeks post-surgery.

Data analyses

Data analyses were performed using SPSS 27.0. Results are reported as mean ± SD. The differences in the variables in each group were compared. Continuous variables were tested by independent *t-test*, and categorical variables were tested by *chi-square* tests. *P*-values < 0.05 were considered to indicate statistical significance. Univariate logistic regression analysis was performed to screen for risk factors with $p < 0.05$, and multivariate logistic regression analysis was subsequently performed *via* the Forward: *LR* method to identify the independent risk factors.

Results

Postoperative allogeneic blood transfusion and blood loss

There were no significant differences in the baseline characteristics observed between the 2 groups (Table 1). In the ICS group, an average volume of 445.14 ± 193.04 ml of red blood cells was returned. In total, 72/144 (50.0%) patients received postoperative ABT after SI-THA: 27/72 (37.5%) in the ICS group and 45/72 (62.5%) in the control group. The rate of postoperative ABT was significantly lower in the ICS group compared to the control

Table 1 Comparison of baseline characteristics between ICS group and control group

	ICS group (*n* = 72)	Control group (*n* = 72)	*p*-value
Age (y)	50.61 ± 9.71	50.50 ± 9.68	0.945
Sex (Men)	44(61.1%)	44(61.1%)	1.000
Weight (kg)	71.21 ± 11.03	73.08 ± 10.16	0.292
Height (cm)	167.61 ± 7.01	166.33 ± 6.68	0.265
Diagnosis			0.553
Osteonecrosis of femoral head	50(69.4%)	54(75.0%)	
Osteoarthritis	6(8.3%)	3(4.2%)	
Developmental dysplasia of hip	16(22.2%)	15(20.8%)	
Smoking history	28(38.9%)	23(31.9%)	0.384
Drinking history	31(43.1%)	27(37.5%)	0.497
History of hypertension	13(18.1%)	10(13.9%)	0.495
History of coronary heart disease	4(5.6%)	1(1.4%)	0.172
History of diabetes	3(4.2%)	3(4.2%)	1.000
Blood volume (L)	4.47 ± 0.64	4.50 ± 0.61	0.802

ICS: intraoperative cell salvage

Table 2 Comparison of preoperative hematology between ICS group and control group

	ICS group($n=72$)	Control group($n=72$)	*p*-value
Preoperative Hematology			
Hemoglobin (g/L)	141.14 ± 13.12	141.32 ± 12.89	0.934
Hematocrit (%)	41.92 ± 3.59	42.27 ± 3.26	0.548
Erythrocyte sedimentation rate (mm/h)	15.23 ± 13.60	13.06 ± 12.36	0.336
C-reactive protein (mg/L)	4.68 ± 3.90	4.80 ± 3.49	0.862
Platelet (*10^9/L)	243.56 ± 52.74	231.24 ± 52.88	0.164
Prothrombin time (s)	10.84 ± 0.70	10.64 ± 0.86	0.138
Activated partial thromboplastin time (s)	30.81 ± 3.27	31.24 ± 2.76	0.334
Fibrinogen (g/L)	3.13 ± 0.60	3.10 ± 0.63	0.785
Postoperative Hematology			
Hemoglobin (g/L)	87.16 ± 18.56	80.79 ± 16.16	**0.030**
Hematocrit (%)	25.86 ± 5.51	23.69 ± 4.58	**0.011**
Erythrocyte sedimentation rate (mm/h)	41.30 ± 30.07	44.48 ± 36.50	0.657
C-reactive protein (mg/L)	85.62 ± 53.14	95.14 ± 51.74	0.415
Platelet (*10^9/L)	179.35 ± 67.42	162.60 ± 65.60	0.133
Prothrombin time (s)	13.19 ± 1.56	13.01 ± 1.73	0.732
Activated partial thromboplastin time (s)	30.21 ± 4.26	29.90 ± 3.45	0.764
Fibrinogen (g/L)	3.86 ± 1.43	4.00 ± 1.29	0.698

ICS: intraoperative cell salvage

group ($p=0.003$). Statistical Comparisons also revealed significant differences in blood loss between the 2 groups (715.98±238.59 ml vs. 830.43±212.58 ml, $p=0.003$). Moreover, there was a statistical difference in the volume of ABT per patient among those who received postoperative ABT between the 2 groups (2.73±0.96 units vs. 3.82±1.96 units, $p=0.010$).

Perioperative hematology

No significant differences were found in preoperative hematology between the 2 groups (Table 2). However, statistical analysis revealed significant differences in postoperative hemoglobin and hematocrit levels between the 2 groups. Additionally, there were no significant differences observed in other postoperative hematology parameters, including clotting and inflammation.

The risk factors for allogeneic blood transfusion

Univariate logistic regression analysis indicated that sex, smoking history, drinking history, blood value, the utilization of ICS, preoperative hemoglobin, and hematocrit levels were associated with postoperative ABT. After adjusting for covariates using the multivariate logistic model, sex (OR=2.570, 95% CI=1.114–5.931, $p=0.027$), the utilization of ICS (OR=0.357, 95% CI=0.171–0.744, $p=0.006$) and preoperative hematocrit level (OR=0.866, 95% CI=0.765–0.980, $p=0.023$) were identified as independent factors associated with postoperative ABT (Table 3).

Table 3 Logistic regression of the risk factors for postoperative ABT in SI-THA patients

Parameter	*p*-value	OR	95%CI
Univariate logistic regression analysis			
Age	0.474		
Sex (women)	**<0.001**	3.786	1.843–7.777
Weight	0.092		
Height	0.088		
Blood volume	**0.007**	0.462	0.263–0.813
Diagnosis	0.268		
Smoking history	**0.023**	0.446	0.222–0.896
Drinking history	**0.036**	0.484	0.246–0.953
History of hypertension	0.642		
History of coronary heart disease	0.707		
History of diabetes	0.465		
Operative duration	0.925		
ICS	**0.013**	0.429	0.220–0.836
Hemoglobin	**<0.001**	0.952	0.925–0.979
Hematocrit	**<0.001**	0.827	0.743–0.921
Erythrocyte sedimentation rate	0.549		
C-reactive protein	0.406		
Platelet	0.478		
Prothrombin time	0.060		
Activated partial thromboplastin time	0.520		
Fibrinogen	0.488		
Multivariate logistic regression analysis			
Sex (Women)	**0.027**	2.570	1.114–5.931
Blood volume	0.823		
Smoking history	0.911		
Drinking history	0.787		
ICS	**0.006**	0.357	0.171–0.744
hemoglobin	0.921		
hematocrit	**0.023**	0.866	0.765–0.980

ICS: intraoperative cell salvage; OR: odd ratio; CI: confidence interval

Off-bed time, operative duration and length of hospital stay

The mean off-bed time was 1.39±0.59 days in the ICS group, which was significantly shorter than the 1.63±0.62 days observed in the control group ($p=0.021$). The mean operative duration of ICS group was 3.35±0.72 h, slightly longer than and the 3.18±0.79 h in the control group, although this difference didn't reach statistical significance ($p=0.170$). Additionally, the mean length of hospital stay was 9.83±2.69 days in the ICS group, which was significantly lower than the 11.10±3.49 days in the control group ($p=0.016$).

Postoperative complications

In the ICS group, 5 cases of intramuscular venous thrombosis occurred post-surgery, accounting for an incidence of 6.94%. Meanwhile, in the control group, there were 4 cases of intramuscular venous thrombosis occurred post-surgery, resulting in an incidence of 5.56%. There was no significant difference in the incidence of intramuscular venous thrombosis between the two groups (p=0.731). All patients diagnosed with intramuscular venous thrombosis were asymptomatic and received both physical and drug therapy. Notably, no infection or deep venous thrombosis were reported in either group during the 6 weeks follow-up period.

Pain and function outcomes

The postoperative pain and functional outcomes up to 6 weeks follow-up are summarized in Table 4. Overall, no significant differences were observed in the postoperative pain and functional outcomes at any of the measured time points between the 2 groups.

Discussion

Our retrospective matched cohort study underscores the crucial role of ICS, alongside multimodal PBM strategies, in SI-THA. Despite the implementation of multimodal PBM strategies, the utilization of ICS still proved to be significantly impactful. Patients received ICS exhibited 25% reduction in the likelihood of requiring postoperative ABT accompanied by a decreased of 1.09 units in the volume of ABT attributed to its efficacy in reducing blood loss. Furthermore, the utilization of ICS didn't influence postoperative coagulation and inflammation hematology parameters, nor did it escalate complication rates.

Multimodal PBM strategies encompassing anesthetic and surgical techniques alongside TXA usage and restrictive transfusion thresholds, have been implemented to diminish the necessity for transfusions in THA [22, 23]. Loftus et al. [24] reported that employing a restrictive transfusion threshold of 70 g/L hemoglobin, alongside optimized preoperative hemoglobin levels, can significantly decrease the incidence of ABT in unilateral total joint arthroplasty without increasing additional complications. However, whether ICS is necessary when multimodal PBM strategies is employed remains controversial. In studies related to unilateral THA, Miller et al. [16] reported that the combination of ICS with TXA for primary unilateral THA failed to enhance outcomes regarding blood loss or transfusion compared with TXA alone. Furthermore, a meta-analysis by van et al. [17] revealed that a more restrictive transfusion threshold (≤8 g/dL) was associated with a smaller effect of ICS in primary unilateral THA. Our findings indicate that even with the adoption of multimodal PBM strategies, the utilization of ICS remains necessary in SI-THA. Despite SI-THA demonstrating superiority over ST-THA in terms of total blood loss [25], SI-THA encompasses a greater blood loss than unilateral THA within a single surgery. This might explain why ICS proves to be more necessary in SI-THA than ST-THA. An intriguing observation was noted in the ICS group, where despite receiving an average of 445.14 ml of red blood cells, the blood loss was only 114.45 ml less than that in the control group. We attribute this disparity primarily to the fact that hidden blood loss in THA significantly surpasses dominant blood loss [26, 27], and red blood cells may be lost again during the process of postoperative hidden blood loss, thereby partially diminishing the efficacy of ICS.

Table 4 Comparison of postoperative pain and functional outcomes between ICS group and control group

	ICS group(n=72)	Control group(n=72)	p-value
VAS			
3 days	4.14±1.23	4.19±1.50	0.808
1 week	2.29±1.16	2.25±1.10	0.825
6 weeks	1.26±0.77	1.19±0.74	0.583
HHS			
1 week	55.24±11.99	58.68±10.81	0.072
6 weeks	81.69±8.44	82.11±8.22	0.765

ICS: intraoperative cell salvage; VAS: visual analogue scale; HHS: harris hip score

Another finding of our study was that sex, the utilization of ICS, and preoperative hematocrit level were identified as independent factors associated with postoperative ABT in SI-THA. Another multicenter study highlighted several risk factors for blood transfusion after SI-THA, including women, lower body mass index, inflammatory arthritis, an American Society of Anesthesiologists (ASA) score 3 or greater, drain use, and increased intraoperative bleeding. They also found that higher preoperative hemoglobin level and the use of TXA can decrease the risk of ABT [28]. Our results are in partial agreement with theirs. Following the PBM concept, for patients who have inflammatory arthritis such as rheumatoid arthritis, preoperative anemia or a preoperative ASA score of 3 or greater, we prefer ST-THA rather than SI-THA to decrease the postoperative ABT. In addition, drainage was not routinely used in THA.

Our study further demonstrated that the utilization of ICS in SI-THA resulted in a reduction in off-bed time and length of hospital stay. While early functional and pain outcomes showed no differences, the utilization of ICS improved postoperative hemoglobin and hematocrit levels, alongside reduced the need for postoperative ABT and fluid replacement. An advantage of ICS-derived blood lies in the immediate availability of functional red blood cells, ensuring prompt oxygen consumption delivery to the patient [29]. In contrast, the red blood cells obtained from blood banks may take require hours to optimize oxygen-carrying capacity because of storage lesions [30]. By utilizing ICS, red blood cells remain capable of providing sufficient oxygen during patients' early weight-bearing activities, which shortened off-bed time.

Furthermore, the reduction in length of hospital stay has facilitated enhanced patient turnover, thereby enabling the treatment of more patients, presenting an additional advantage for the hospital.

The current study has several potential limitations worth acknowledging. Patients' height and weight were not included in the matching criteria for cohort matching, as it's very challenging to match two patients of similar height and weight based on our matching principles. Additionally, we did not consider cost-effectiveness. While the cost of ICS and ABT can be calculated, the need for postoperative fluid rehydration is reduced after the utilization of ICS, thus also lowering the cost of postoperative management. Moreover, the purchase and maintenance costs of ICS systems also need to be taken into account. However, this study was not designed as a cost-effectiveness analysis, so we didn't pay more attention to it.

Conclusions

Our results demonstrated that even with multimodal PBM strategies, the utilization of ICS remained necessary for SI-THA. The utilization of ICS significantly impacted postoperative ABT in SI-THA patients by reducing blood loss and improving hemoglobin and hematocrit. Women and a lower preoperative hematocrit level were identified as independent risk factors associated with postoperative ABT, while the utilization of ICS was identified as an independent protective factor. Additionally, the utilization of ICS promoted weight-bearing functional exercises, but it has no effect on early pain and functional outcomes.

Abbreviations

THA	Total hip arthroplasty
SI-THA	Simultaneous bilateral total hip arthroplasty
ST-THA	Staged bilateral total hip arthroplasty
ABT	Allogeneic blood transfusion
PBM	Patient blood management
ICS	Intraoperative cell salvage
TXA	Tranexamic acid
VAS	Visual analogue scale
HHS	Harris hip score
ASA	American Society of Anesthesiologists

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Author contributions

All authors contributed to either the conception, design or data analysis. Qunshan Lu were responsible for conception and design of the study. Peilai Liu provided case data. Material preparation, data collection and analysis were performed by Dehua Liu, Ziyue Chu, Tong Zheng and Binglong Li. Registration of research was performed by Dehua Liu. The first draft of the manuscript was written by Zhuang Miao and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Data availability

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

Declarations

Ethics approval and consent to participate

This study was approved by the Institutional Review Board of Qilu Hospital, Shandong University (KYLL-202312-050).

Consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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