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Original study

Effectiveness of intraoperative cell salvage in aseptic revision total hip arthroplasty: a single-center retrospective study

N. Piette[1], M. Carella[1], F. Beck[1], G. A. Hans[1], V. Bonhomme[1,2], J.-P.Lecoq[1]

[1]Department of Anesthesia and Intensive Care Medicine, Liege University Hospital, Liege, Belgium; [2]Anesthesia and Intensive Care Laboratory, GIGA-Consciousness Thematic Unit, GIGA-Research, Liege University, Liege, Belgium.

Corresponding author: Dr. Nicolas PIETTE. Department of anesthesia and intensive care medicine, Liege University Hospital, Avenue de l'Hôpital 1, Bat B35, 4000 Liege, Belgium, Tel. +3243667655; E-mail: npiette@chuliege.be

Abstract

Background and study aim: **Revision of total hip arthroplasty (rTHA) is associated with significant blood loss. We have used intraoperative cell savage (ICS) systematically in these patients for the last ten years. We sought to determine how often re-suspended red blood cells could be re-transfused and to identify predictors of re-transfusion.**

Materials and methods: **Patients who underwent aseptic rTHA between January 2011 and December 2020 at our center were enrolled in this retrospective observational study. Exclusion criteria were revision for infection or tumor. The primary outcome was the successful use of ICS defined as the ability to re-transfuse at least 125 mL of ICS blood. Secondary outcome measures included re-transfused ICS blood volume, aspirated blood volume, allogenic blood transfusion, and post-operative hemoglobin level. Uni- and multi-variable logistic regressions were used to identify patients and procedure characteristics associated with successful ICS. Mann-Whitney U tests, Student's t tests and Chi-square tests were used to compare outcomes between patients with and without successful ICS. A P value < 0.05 was considered statistically significant.**

Results: **ICS was successful in 93 (69.9%) out of 133 patients. The extent of revision, categorized as isolated acetabulum, isolated femur, or combined revision was the only predictor of successful ICS. Postoperative hemoglobin levels as well as rate and amount of allogenic red blood cells transfusion did not differ between the groups.**

Conclusions: **ICS is useful in most patients undergoing rTHA. Those requiring a combined revision have the greatest chance of successful re-infusion.**

Keywords: **Arthroplasty, Replacement, Hip, Operative blood salvage, Anemia, Erythrocyte transfusion.**

Introduction

Patients undergoing aseptic revision of total hip arthroplasty often experience significant blood loss and require perioperative red blood cell transfusion[18]. Although blood transfusion is a potentially life-saving therapy, it also carries risks and costs, and should therefore be used cautiously[4,16,17,19,21]. Patient blood management (PBM) is an evidence-based, patient-centered and multidisciplinary approach aiming at preserving patients' own blood mass and promoting rationale use of blood and blood products. PBM measures are classified into three pillars: anemia management, minimization of blood loss, and optimization of tolerance to anemia[5,7]. The exact effectiveness of PBM programs has not been fully characterized yet, but current evidence suggests that they may lead to substantial clinical benefits including reduced need for allogenic blood transfusion and improved clinical outcomes[1,13]. In addition, they not only reduce the cost of blood transfusion, but also the financial burden of the complications they help avoid and, thereby, have a great cost-saving potential[9,12,20].

Intraoperative cell salvage (ICS) is an important measure of the second pillar, but its effectiveness in patients undergoing revision total hip arthroplasty remains unclear[8]. Over the last decade, we have systematically used ICS in this group of patients.

However, insofar as the use of ICS has a cost and requires additional resources, we decided to retrospectively investigate its usefulness in this particular indication[8]. Our primary goal was to determine how often cell-saved blood could be re-transfused. We also sought to identify patients and procedure-related characteristics associated with effective ICS.

Materials and methods

Study design and participants

This manuscript adheres to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement. The study was approved by our local ethics committee (Comité d'éthique hospitalo-facultaire de Liege; Reference 2021/94; Chairperson Pr. V. Seutin) previously and registered with Clinical Trial (NCT 05237830). Given the retrospective nature of the study, a waiver of informed consent was given by the ethics committee.

Eligible patients were adults undergoing elective aseptic revision of hip arthroplasty at the department of orthopedic surgery of the University Hospital of Liege between January 1, 2011 and December 31, 2020. Revision was defined as the exchange of any component of the hip prosthesis. Patients undergoing revision for infection or with local malignancies were excluded from this study.

Clinical management

All patients were seen at the preoperative clinic and routine preoperative laboratory investigations included hemoglobin, platelets and creatinine measurements. These laboratory tests were repeated on the morning following surgery. All procedures were performed under general anesthesia using the postero-lateral surgical approach[14]. An intravenous bolus of 1 gr of tranexamic acid was administered immediately after anesthesia induction and repeated once every 4 hours after surgical incision as per institutional protocol. Prophylactic doses of low molecular weight heparin were started 6 to 8 hours after skin closure.

ICS was used in a "collect only" mode at the beginning of all procedures. Salvage blood was processed when the amount of suction blood was deemed large enough to generate a 125 mL bag of re-suspended red blood cells with a hematocrit of 60 %. ICS was performed by Cobe Baylor Rapid Autotransfusion Device [(BRAT) 2®, COBE Cardiovascular Inc., Denver, CO] for patients from 2011 to 2014, and by Xtra® Cell Saver with bowl kit 125 mL [Sorin Group, Mirandola, Italy], from 2015 to 2021. When available, cell saved blood was always re-transfused regardless of the hemoglobin level. Transfusion threshold for allogenic red blood cells was 7 to 8 g.dL-1 according to patients' co-morbidities.

Outcome measures and variables

Data were collected from our electronic patient records and perfusion database. The primary outcome was the proportion of patients in whom the cell saver was effectively used. The effective use of the cell saver was defined as the ability to re-transfuse at least one bag of 125 mL of re-suspended red blood cells with a hematocrit of 60 %, the minimal amount that our cell salvage devices are able to re-concentrate. Indeed, a volume lower than 125 mL could only be processed with addition of crystalloids, which would lead to a low final hematocrit of the re-infused suspension. As a result, cell salvage blood volume inferior to 125mL are discarded in our institution.

Secondary outcome measures included the total volume of re-infused re-suspended blood, the total volume of blood aspirated into the reservoir, post-operative hemoglobin level and the total amount of fluid infused during the surgical procedure. We also noted the need for allogenic blood transfusion during surgery and the whole length of stay. Demographic data including age, gender and body mass index, and the extent of surgery classified as isolated acetabulum, isolated stem or combined revision were also recorded.

Statistics

The distribution of quantitative data was assessed using histogram and the Shapiro-Wilk test. These variables were expressed as mean (standard deviation) or median [p25-p75 interquartile range] according to their distribution. Categorical data were summarized as count (percent). Quantitative variables were analyzed using Student's t tests or the Mann–Whitney U tests as appropriate. The Chi-square test was used to compare categorical variables. Univariate logistic regression was used to identify crude associations between patients and procedure characteristics, on the one hand, and successful use of intraoperative of cell-salvage on the other hand. Characteristics significantly associated with the primary outcome were then included into a multivariate model. Results were reported as Odds ratio (OR) and 95% confidence intervals (CI). A P value ≤ 0.05 was considered statistically significant. Since our primary objective was to determine how often the cell saver was effectively used in this particular patients' population, no sample size estimation was performed a priori. We arbitrarily chose to review our practice of the last ten years, which still adequately reflects our current practice.

Statistical analyses were performed using Stata (StataCorp. 2019. Stata Statistical Software: Release 16. College Station, TX: StataCorp LLC).

Results

During the study period, 140 patients underwent aseptic revision of hip arthroplasty of whom 133 were retained for final analyses (Figure 1). Demographic and procedure characteristics of these patients, stratified according to whether the cell saver was used effectively or not are presented in Table I.

Re-suspended red blood cells were transfused in 93 (69.9 %) patients. The success rate of ICS was 50% in patients undergoing isolated acetabulum repair, 70% in patients undergoing isolated femoral repair and 81% in those having combined surgery. The median volume of transfused re-suspended red blood cells was 250 mL [183-350]. The type of surgical revision was the only preoperative factor that was significantly associated with the effective use of cell saver (Table II). As a result, no multivariable analysis could be performed. Patients in whom the cell saver was used successfully had greater intraoperative blood loss, as reflected by the higher volume of aspirated blood ($P < 0.001$) and larger intraoperative fluid requirements ($P = 0.04$). The hemoglobin level at post-operative day 1, the proportion of patients who required allogenic red blood cell transfusion during surgery and the whole length of stay, as well as the number of transfused units of allogenic red blood cells did not differ between the groups. (Table III)

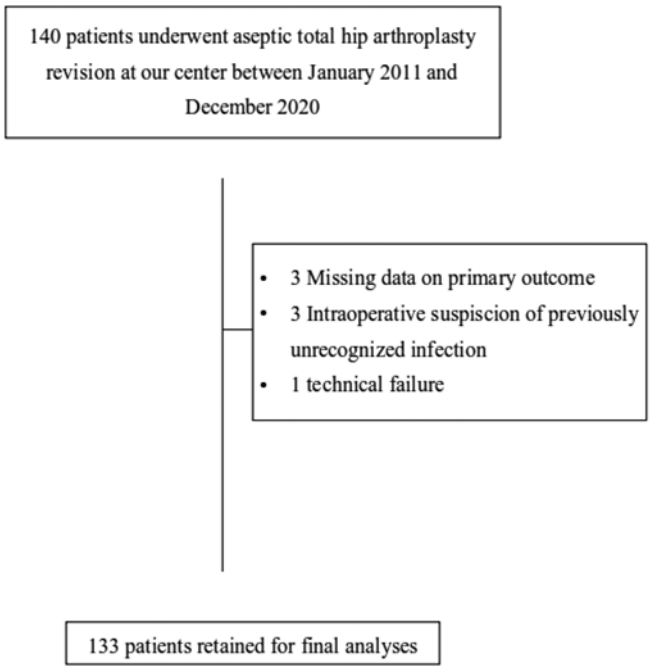

Fig. 1 — Flow diagram of the study.

Table I. — Patients and procedure characteristics.

		All patients n = 133	Successful ICS n = 93	Unsuccessful ICS n = 40
Age, y		69 [59-75]	69 [60-75]	72 [54-81]
Height, cm		168 [160-174]	168 [160-177]	167 [161-173]
Weight, Kg		70 [60-79]	71 [61-85]	69 [60-74]
BMI, $Kg.m^{-2}$		24 [22-28]	25 [22-30]	24 [22-26]
Female gender, n (%)		79 (59)	54 (58)	25 (63)
Preoperative Hb, gr dL^{-1}		12.2 (2.1)	12.4 (2.0)	11.9 (2.4)
Type of surgery, n (%)				
	Isolated acetabulum	28 (21)	14 (15)	14 (35)
	Isolated femur	57 (43)	40 (43)	17 (42)
	Combined	48 (36)	39 (42)	9 (23)

Data are mean (SD) or median [p25-p75] unless otherwise stated. y = years; ICS = intraoperative cell salvage; BMI = body mass index; Hb = hemoglobin.

Table II. — Predictors of successful cell saver use in uni- and multi-variable regression analyses.

		Univariable Analyses	
		OR (95% CI)	P Value
Age, y		1.00 (0.97-1.02)	0.83
Weight, Kg		1.02 (1.00-1.05)	0.07
Female gender		0.83 (0.39-1.78)	0.64
Preoperative Hb, gr dL^{-1}		1.11 (0.93-1.32)	0.27
Type of repair			
	Acetabulum only	Ref	Ref
	Femur only	2.35 (0.93-5.98)	0.072
	Combined	4.34 (1.54-11.22)	0.006

OR = odds ratio; 95% CI = 95% confidence interval; y = year; Kg = kilogram; Ref = reference; Hb = hemoglobin.

Table III. — Secondary outcome measures.

	Successful ICS n = 93	Unsuccessful ICS n = 40	P Value
Hb level at POD 1, $g.dL^{-1}$	10.2 (1.5)	10.1 (1.5)	0.82
RBC transfusion, n (%)	46 (51)	24 (60)	0.32
Amount of transfused allogenic RBC units transfused, median [range]	1 [0-5]	1 [0-5]	0.32
Amount of transfused re-suspended RCB transfused, mL	250 [164-350]	0 [0-0]	<0.001
Aspirated blood, mL	750 [500-1000]	275 [150-400]	<0.001
Amount of intraoperative fluid administered, mL	2500 [2000-3000]	2000 [1500-3000]	0.04

Data are mean (SD) or median [p25-p75] unless otherwise stated. Hb = hemoglobin; POD = postoperative day; RBC = red blood cells; ICS = intraoperative cell salvage.

Discussion

In the present study, the amount of aspirated blood was large enough to re-infuse re-suspended red blood cells in more than two thirds of the patients. The single best preoperative predictor of successful re-infusion was the type of surgical procedure. Unsurprisingly, patients in whom re-suspended red blood cells could be re-infused experienced more intraoperative blood loss. However, several factors influence the cell-saver effectiveness. One of the main ones is the preoperative hematocrit level. The lower the preoperative hematocrit, the higher the collection volume needed to generate a minimal amount of 60% hematocrit re-suspended red blood cells to be re-infused. But, in a non-anemic patient, it is commonly accepted that the collected volume should be around 3 times larger than the expected washed blood volume.

These results are largely consistent with those of a recently published trial[15]. In their study, Palmer et al. indeed reported an effective use of re-suspended red blood cells in 76 % of the cases but the mean intraoperative blood loss was also greater than in our study. This difference may result from the fact that they included revision surgery for infection, whereas we only included patients undergoing aseptic revision. Accordingly, revision for infection was positively associated with successful re-infusion of re-suspended red blood cells in their study. However, another study reported no association between infection and successful re-infusion of cell-salvage blood[3]. Similarly to previous reports, we found that the extent of surgical revision was associated with successful re-infusion, patients undergoing combined revision having the highest rate of re-infusion[6,15]. Other studies also reported an association between age and weight and successful ICS. Although we observed a trend for an association between patients' weight and re-infusion of re-suspended red blood cells, it did not reach statistical significance. The smaller sample size of the present study likely accounts for this discrepancy.

Unfortunately, our data do not allow to determine whether the use of intraoperative cell salvage in this particular context is cost-effective. The

costs of the consumables for the cell-saver in our institution include the suction tank (66.65€) and the bowl (87.73€), for a total of 154.88€. But this does not take account of other indirect costs, such as purchase of the device, maintenance, training of users, washing crystalloids, and heparin. Regarding allogenic transfusion, a standard unit of erythrocyte concentrate is estimated to 128.89€. But a systematic review evaluated the mean cost of a 2-unit blood transfusion in the West European region at approximately 878.00€ including related costs such as laboratory analyses, complications, and nursing[20]. Based on these data, we can roughly estimated that, to be cost-effective, the use of intraoperative cell salvage should avoid the transfusion of one unit of red blood cells in one in three patients. In our opinion, the cost of starting any procedure with a cell saver in collect-only mode has an acceptable cost of 66.65 € of disposable and, according to our result, this can eventually lead to effective ICS in more than two third of the cases. If resources were limited, this study highlight the fact that patients who undergo a combined revision surgery are those who most likely benefit from the use of ICS.

Whether ICS blood should be re-transfused whenever available and regardless of the hemoglobin level is another interesting question. The risk of allogenic blood transfusion remains significant during the first few postoperative days for several reasons including cytokines-mediated iron homeostasis disruption, hemodilution, postoperative blood loss in drains, and hematoma[19]. As a result and in line with the PBM principles which aim at minimizing intraoperative net blood loss during surgery, our practice is to re-transfuse ICS whenever available. Admittedly, the risk-benefit ratio has to be carefully considered before any blood transfusion including re-transfusion of cell saver blood. However, intraoperative re-transfusion of cell saved blood is probably safer than allogenic blood transfusion. Firstly, it does not carry risks specific to allogenic blood transfusion such as alloimmunization, febrile non-hemolytic transfusion reactions, allergic transfusion reactions, acute lung injury, and transfusion-associated circulatory overload[20,21]. Furthermore, intraoperative cell saver blood transfusion is a closed loop process and thereby eliminates the risk of human error leading to blood mismatch, which remains the main cause of complications related to blood transfusion including re-transfusion of washed red blood cells.

Despite the use of ICS, 53 % of patients included in this study received at least one unit of allogenic red blood cells, which is in line with previously reported transfusion rates in this patients population,[6,18] but significantly higher than the transfusion rate reported by Palmer et al.[15] This may be explained by an insufficient adherence to a restrictive transfusion threshold in our study. The fact that the hemoglobin level at post-operative day 1 was, on average, almost 1 gr dL-1 higher in our study than in the study from Palmer et al. further supports this hypothesis. In addition, we recorded allogenic blood transfusion anytime during the hospital stay, whereas Palmer et al. only recorded transfusions administered during the first 72 post-operative hours[15].

Interestingly, the post-operative hemoglobin level and the rate of allogenic blood transfusion we observed did not differ between groups, despite significantly greater blood loss in the group of patients in whom the cell-saver was used successfully. Overall, this suggests that ICS effectively protects patients who bleed most against higher rates of allogenic blood transfusion and/or more severe post-operative anemia.

Our study has several limitations. The retrospective design exposes to the risk of bias and inaccuracy. However, since it is a departmental policy to use the cell saver in all cases of aseptic revision of total hip arthroplasty, the risk of selection bias appears limited. In addition, the data used in this study were encoded prospectively in the electronic patient record and the perfusion database. As mentioned above, the relatively small sample size may have hinder our ability to identify predictors of successful use of ICS. Our main results are nevertheless consistent with those of other published trials, and the high rate of successful re-infusion warrants, in and of itself, the use of cell saver in revision hip arthroplasty, whenever feasible. Admittedly, we only included aseptic revisions despite the fact that infection and cancer cannot be considered as absolute contra-indication to ICS[2,10,11]. Lastly, our recruitment periods extended over 10 years, and we therefore cannot entirely rule out inconspicuous changes in clinical practice over time.

In conclusion, the cell saver was successfully used is 70 % of patients undergoing aseptic revision of total hip arthroplasty and enrolled in the present study. Based on this, we would recommend to consider its systematic use in this patient population and at least to use it in the "collect only" mode. Patients who undergo combined revision of the acetabulum and the femoral component are those who benefit the most from its use.

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