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# Intra-operative blood salvage in total hip and knee arthroplasty

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## ABSTRACT

**Purpose.** To review records of 371 patients who underwent total hip or knee arthroplasty (THA or TKA) with intra-operative blood salvage to determine the allogeneic blood transfusion rate and the predictors for allogeneic blood transfusion.

**Methods.** Records of 155 male and 216 female consecutive patients aged 17 to 95 (mean, 70) years who underwent primary THA or TKA by a single surgeon with the use of intra-operative blood salvage were reviewed.

**Results.** The preoperative haemoglobin level was <120 g/dl in 15% of THA patients and 5% of TKA patients; the allogeneic transfusion rate was 24% in THA patients and 12% in TKA patients. Despite routine use of intra-operative blood salvage, only 59% of THA patients and 63% of TKA patients actually received salvaged blood, as a minimum of 200 ml blood loss was required to activate blood salvage. In multivariable analysis, predictors for allogeneic blood transfusion were female gender (adjusted odds ratio [OR]=2.8, p=0.02), age >75 years (adjusted OR=5.9,

p<0.001), and preoperative haemoglobin level <120 g/l (adjusted OR=30.1, p<0.001), despite the use of intra-operative blood salvage. Patients who received allogeneic blood transfusion had a longer hospital stay and greater complication rate.

**Conclusion.** Intra-operative blood salvage is not effective in preventing allogeneic blood transfusion in patients with a preoperative haemoglobin level <120 g/l. It should be combined with preoperative optimisation of the haemoglobin level or use of tranexamic acid.

**Key words:** arthroplasty, replacement, hip; arthroplasty, replacement, knee; blood transfusion; operative blood salvage

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## INTRODUCTION

Substantial peri-operative blood loss in total hip and knee arthroplasty (THA and TKA) may lead to postoperative anaemia and necessitate allogeneic blood transfusion, with the rate being 57% and 39%, respectively.<sup>1</sup> Total joint arthroplasty and fracture surgery account for most cases of allogeneic

blood transfusion, compared with other surgical specialties.<sup>2,3</sup> Nonetheless, allogeneic blood transfusion is associated with risks of disease transmission, haemolytic reactions, immunomodulation, haemodynamic overload, acute lung injury, and coagulopathy.<sup>4</sup> Patients who receive allogeneic blood have an increased risk of postoperative infection, longer hospital stay, and mortality.<sup>5-7</sup> Various blood conservation strategies have been recommended. Nonetheless, preoperative autologous blood donation is not cost-effective and there is a high rate of unused blood.<sup>8-10</sup> The effectiveness of acute normovolaemic haemodilution is debatable.<sup>11</sup> Postoperative re-transfusion may result in transfusion reactions, as unwashed blood contains fibrin degradation products and other contaminants.<sup>12,13</sup>

Intra-operative blood salvage re-transfuses washed blood that is removed of biochemical, cellular, and non-cellular debris including activated clotting factors, fatty lipids, and bone, and results in minimal disruption to surgical workflow.<sup>14,15</sup> Intra-operative blood salvage has been reported to decrease the allogeneic blood transfusion rate varying from 57%<sup>1</sup> to 6%,<sup>16</sup> 8%,<sup>17</sup> and 15%<sup>18</sup> in THA, and from 39%<sup>1</sup> to 7%,<sup>19</sup> 11%,<sup>20</sup> and 16%<sup>21</sup> in TKA. This study reviewed records of 371 patients who underwent THA or TKA with intra-operative blood salvage to determine the allogeneic blood transfusion rate and the predictors for allogeneic blood transfusion.

## MATERIALS AND METHODS

This study was approved by our hospitals' regional ethics committee. The proportion of patients who would require blood transfusion was assumed to be 20%, and thus 246 patients were required to obtain a 95% confidence interval (CI) with a maximum error of 0.05. Records of 155 male and 216 female consecutive patients aged 17 to 95 (mean, 70) years who underwent primary THA (n=135) or TKA (n=236) by a single surgeon from January 2010 to December 2011 (prior to the introduction of tranexamic acid) with the use of intra-operative blood salvage were reviewed.

THA was performed through an anterolateral approach with the patient in a lateral position. Uncemented acetabular and femoral components were used (Exceed acetabular cup Taperloc femoral stem, Biomet, Warsaw [IN], USA); no drain was used. TKA was performed through a standard medial parapatellar approach without tourniquet use. Computer navigation was used for alignment and preparation. Cemented femoral, tibial, and patellar components were used (Legion Primary, Smith and Nephew,

Memphis [TE], USA). An intra-articular drain on low suction was removed on day 1. All patients received enoxaparin 40 mg daily for venous thromboembolic prophylaxis, commencing 4 hours postoperatively and continued for 14 days for TKA and 28 days for THA. Aspirin was continued throughout the peri-operative period if it was already prescribed.

Using the Haemonetics Cell Saver 5+ machine (Braintree [MA], USA), salvaged blood was washed and concentrated prior to re-transfusion in the recovery room. Haemoglobin level was checked on postoperative day 1. The transfusion trigger was patient-specific, based on the guidelines of the National Blood Authority of Australia. An absolute trigger was a haemoglobin level <80 g/l. Patients with symptomatic anaemia and significant comorbidities may be given transfusion at a haemoglobin level <100 g/l,<sup>22</sup> based on the surgeon's decision.

Binary variables were presented in proportion; normally distributed variables were presented as mean±standard deviation and compared using independent *t*-test; non-normally distributed variables were presented as median and inter-quartile range and compared using Mann-Whitney *U* test; discrete variables were presented as percentages and compared using Pearson Chi-squared test. Univariate and multivariate analyses were used to determine predictors for allogeneic blood transfusion, a *p* value of ≤0.10 and <0.05 was considered significant, respectively.

## RESULTS

The preoperative haemoglobin level was <120 g/dl in 15% of THA patients and 5% of TKA patients; the allogeneic transfusion rate was 24% in THA patients and 12% in TKA patients (Table 1). Despite routine use of intra-operative blood salvage, only 59% of THA patients and 63% of TKA patients actually received salvaged blood, as a minimum of 200 ml blood loss was required to activate blood salvage. Only 9 patients who did not receive salvaged blood had blood loss >200 ml. Intra-operative blood loss was greater in patients who received salvaged blood than in those who did not (362.48 vs. 156.15 ml, *p*<0.001, Table 2).

Compared with patients who did not receive allogeneic blood transfusion, those who did had a lower preoperative haemoglobin level (139.61 vs. 122.76 g/l, *p*<0.001), less blood loss (290 vs. 245 ml, *p*=0.03), lower rate of re-transfusion of salvaged blood (64% vs. 48%, *p*=0.02), lower postoperative haemoglobin level (121.65 vs. 103.46 g/l, *p*<0.001),

**Table 1**  
Patient characteristics and outcome\*

Parameter	Total (n=371)	Total hip arthroplasty (n=135)	Total knee arthroplasty (n=236)
Female	216 (58)	86 (63)	130 (55)
Age >75 years	101 (27)	39 (29)	62 (26)
Age (years)	70 (17–95)	70 (17–91)	70 (47–95)
Body mass index (kg/m <sup>2</sup> )	29.2 (15.7–52.2)	27.4 (15.7–43.8)	30.3 (18.5–52.2)
Body mass index (kg/m <sup>2</sup> ) category			
<20	4 (1)	3 (2)	1 (<1)
20–25	77 (21)	47 (35)	30 (13)
26–30	143 (39)	45 (33)	98 (42)
>30	147 (40)	40 (30)	107 (45)
Diagnosis			
Osteoarthritis	349 (94)	119 (88)	230 (97)
Inflammatory	6 (2)	2 (1)	4 (2)
Other	16 (4)	14 (10)	2 (1)
Preop haemoglobin (g/l)	137 (72–177)	134 (72–170)	138 (103–177)
Preop haemoglobin (g/l) category			
≥150	83 (22)	20 (15)	63 (27)
120–150	257 (69)	95 (70)	162 (69)
<120	31 (8)	20 (15)	11 (5)
Allogeneic blood transfusion	61 (16)	32 (24)	29 (12)
Whole blood loss (ml)	283 (50–1200)	271 (50–1200)	290 (100–950)
Re-transfusion of salvaged blood	228 (61)	79 (59)	149 (63)
Salvaged blood volume (ml) <sup>†</sup>	197 (10–890)	205 (40–890)	193 (10–650)
Haemoglobin drop until day 0 (g/l)	18.3 (-34–47)	17.7 (-34–40)	18.7 (-12–47)
Haemoglobin drop until day 1 (g/l)	28.4 (-29–56)	27.3 (-29–53)	29.1 (6–56)
Knee drain volume (ml)	-	-	209 (0–800)
Any complication	74 (20)	29 (21)	45 (19)
Length of hospital stay (days)	6 (3–30)	6 (3–16)	6 (3–30)

\* Data are presented as no. (%) of patients or median (range)

<sup>†</sup> Only 79 and 149 total hip and knee arthroplasty patients actually received salvage blood, respectively

**Table 2**  
Comparison of patients who did or did not receive intra-operative salvaged blood in terms of preoperative haemoglobin level and intra-operative blood loss

Parameter	Received salvaged blood (n=228)	Not received salvaged blood (n=143)	Mean difference (95% CI)	p Value
Preop haemoglobin (g/l)	137.40±14.03	135.85±12.76	1.6 (-1.4–4.5)	0.30
Intra-operative blood loss (ml)	362.48±136.69 (200–1200)	156.15±52.06 (50–350)	206.3 (182.8–229.8)	<0.001

longer hospital stay (5 vs. 6 days,  $p=0.01$ ), and higher complication rate (15% vs. 48%,  $p<0.001$ ) [Table 3].

In univariate analysis, main predictors for allogeneic blood transfusion were female gender (odds ratio [OR]=3.5,  $p<0.001$ ), age >75 years (OR=5.2,  $p<0.001$ ), THA (OR=2.3,  $p=0.004$ ), and preoperative haemoglobin level <120 g/l (OR=44.4,  $p<0.001$ ) [Table 4]. In multivariate analysis, predictors for allogeneic blood transfusion were female gender (adjusted OR=2.8,  $p=0.02$ ), age >75 years (adjusted OR=5.9,  $p<0.001$ ), and preoperative haemoglobin level <120 g/l (adjusted OR=30.1,  $p<0.001$ ), despite the use of intra-operative blood salvage (Table 4). All 4 patients with a body mass index <20 kg/m<sup>2</sup> required allogeneic blood transfusion. THA was no longer a predictor for allogeneic blood transfusion,

as this group had more percentage of patients with a preoperative haemoglobin level <120 g/dl and female gender.

## DISCUSSION

Intra-operative blood salvage avoids problems with the storage of pre-donated autologous blood and allogeneic blood transfusion, and enables re-transfusion of more efficacious oxygen-carrying red blood cells that have a higher erythrocyte viability<sup>23</sup> and increased preservation of 2-3 diphosphoglycerate.<sup>24</sup> It also removes contaminants and concentrates the re-transfusion volume.

In our study, patients who underwent THA were

**Table 3**  
Comparison of patients who did or did not receive allogeneic blood transfusion\*

Outcome	Total (n=371)	Allogeneic blood transfusion (n=61)	No allogeneic blood transfusion (n=310)	Difference (95% CI)	p Value
Preop haemoglobin (g/l)	136.80±13.56	122.76±14.26	139.61±11.54	-16.9 (-13.5 to -20.2)	<0.001
Whole blood loss (ml)	283±150	245±156	290±148	-45.6 (-4.4 to -86.8)	0.03
Received salvaged blood	228 (61)	29 (48)	199 (64)	-16 (-3 to -30)	0.02
Salvaged blood volume (ml)	150 (135–250)	156 (130–270)	150 (135–250)	6	0.40
Haemoglobin drop until day 0 (g/l)	18.3±9.3	19.3±13.2	18.1±8.2	1.2 (-1.33 to 3.73)	0.38
Haemoglobin drop until day 1 (g/l)	28.4±10.1	28.4±16.2	28.5±8.4	-0.1 (-3.0–2.8)	0.95
Haemoglobin at day 1 (g/l)	118.46±14.14	103.46±11.04	121.65±12.60	-18.19 (-21.59 to -14.78)	<0.001
Knee drain volume (ml) <sup>†</sup>	209±169	205±162	210±170	-4.8 (-73.4–63.7)	0.89
Length of hospital stay (days)	5 (5–7)	6 (5–8)	5 (5–7)	1	0.01
Any complication	74 (20)	29 (48)	45 (15)	33 (20–46)	<0.001

\* Data are presented as mean±SD, no. (%), or median (interquartile range)

<sup>†</sup> In 27 and 197 total knee arthroplasty patients who did and did not receive allogeneic blood transfusion, respectively

**Table 4**  
Univariate and multivariate analyses for predictors for allogeneic blood transfusion

Predictor	OR (95% CI)	p Value
Univariate analysis		
Crude		
Female sex	3.5 (1.8–6.8)	<0.001
Age >75 years	5.2 (2.9–9.2)	<0.001
Total hip arthroplasty (vs. total knee arthroplasty)	2.3 (1.3–4.0)	0.004
Diagnosis of inflammatory condition (vs. osteoarthritis)	1.2 (0.1–10.1)	0.75
Diagnosis of other condition (vs. osteoarthritis)	4.62 (1.74–12.28)	0.002
Haemoglobin <120 g/l (vs. haemoglobin >150 g/l)	44.4 (12.8–154.3)	<0.001
Haemoglobin 120–150 g/l (vs. haemoglobin >150 g/l)	2.5 (0.8–7.3)	0.21
Body mass index (BMI) <20 kg/m <sup>2</sup> (vs. BMI 20–25 kg/m <sup>2</sup> ) <sup>*</sup>	-	-
BMI 25–30 kg/m <sup>2</sup> (vs. BMI 20–25 kg/m <sup>2</sup> )	0.34 (0.17–0.67)	0.002
BMI >30 kg/m <sup>2</sup> (vs. BMI 20–25 kg/m <sup>2</sup> )	0.23 (0.11–0.48)	<0.001
Multivariate analysis		
Adjusted		
Female sex	2.8 (1.2–6.6)	0.02
Age >75 years	5.9 (2.9–12.1)	<0.001
Haemoglobin <120 g/l (vs. haemoglobin >150 g/l)	30.1 (7.5–121.6)	<0.001
Haemoglobin 120–150 g/l (vs. haemoglobin >150 g/l)	1.3 (0.4–4.1)	0.32

\* All 4 patients with a BMI <20 kg/m<sup>2</sup> required allogeneic blood transfusion

more likely to require allogeneic blood transfusion, probably owing to a higher percentage of patients with preoperative haemoglobin level <120 g/l and lower percentage of patients actually received salvaged blood. Patients who received allogeneic blood transfusion had a longer hospital stay and higher complication rate. Those with a preoperative haemoglobin level <120 g/l were 30 times more likely to require allogeneic blood transfusion (despite the use of blood salvage), compared with patients with a preoperative haemoglobin level >150 g/l. Thus, preoperative optimisation of the haemoglobin level to a minimum of 120 g/l is essential.<sup>11,25</sup>

Our study had several limitations. It was retrospective and predisposed to recall and selection bias. A tourniquet was not used in TKA in order to avoid initial decrease in quadriceps strength, swelling, and postoperative pain.<sup>26</sup> Although tourniquet use decreases intra-operative blood loss, total blood loss

is similar owing to decreased postoperative blood loss.<sup>27</sup> Patients did not receive any form of tranexamic acid; this eliminated the effect of tranexamic acid as a confounder of intra-operative blood salvage. Patients were allowed to continue taking aspirin during the peri-operative period, but this increases the risk of major bleeding.<sup>28</sup>

Allogeneic blood transfusion is associated with an increasing cost of blood banking. Intra-operative blood salvage combined with preoperative optimisation of haemoglobin level, use of tranexamic acid, and individualisation of the transfusion trigger is recommended.

## CONCLUSION

Intra-operative blood salvage is not effective in preventing allogeneic blood transfusion in patients

with a preoperative haemoglobin level <120 g/l. It should be combined with preoperative optimisation of the haemoglobin level or use of tranexamic acid.

## DISCLOSURE

No conflicts of interest were declared by the authors.

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