Journal of Orthopaedic Surgery 2005;13(1):19-26

Blood salvage in total hip and knee arthroplasty in a community hospital: A retrospective study

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ABSTRACT

Purposes: To assess the results of postoperative and intra-operative blood salvage in patients undergoing total knee and hip arthroplasty, respectively, and to determine if both methods of blood salvage reduce allogeneic transfusion.

Methods: Of 229 patients who attempted blood salvage, 114 of 152 patients who underwent total knee arthroplasty received the salvaged blood postoperatively, 35 of 77 patients who underwent total hip arthroplasty received the salvaged blood intra-operatively. Various data were collected to assess whether certain factors resulted in autologous and / or allogeneic blood transfusions.

Results: Patients that received postoperative salvaged blood after total knee arthroplasty generally had higher postoperative levels of haemoglobin and haematocrit compared to those who did not. Patients with autologous blood transfusion following cemented knee surgery were less likely to require allogeneic blood transfusion. For hip arthroplasty patients, postoperative levels of haemoglobin and haematocrit were similar in both groups who received and did not receive salvaged blood. Lower preoperative haemoglobin and haematocrit levels correlated with a greater likelihood of autologous and / or allogeneic blood transfusion for both knee and hip arthroplasty patients.

Conclusions: Although total knee arthroplasty patients who received salvaged blood had higher haemoglobin levels on the first postoperative day, the receipt of salvaged blood did not significantly reduce the incidence of allogeneic blood transfusion, because salvaged blood was a kind of blood loss. However, reinfusion of salvaged blood may reduce the number of units of allogeneic blood used. Given the short supply of allogeneic blood and its risks of transmitting disease, intra-operative and postoperative blood salvage carries clear advantages.

Key words: *arthroplasty, replacement; blood; blood transfusion, autologous*

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INTRODUCTION

Total hip and knee arthroplasties usually associate with a considerable amount of blood loss and may necessitate allogeneic blood transfusion, which increases pressure on the blood-bank system and may cause disease transmission, anaphylaxis, and haemolytic reactions. Preoperative autologous blood pooling is commonly used for patients undergoing elective joint arthroplasty to reduce the risks associated with allogeneic blood transfusion.[1–3]

Intra-operative and postoperative blood salvage are 2 other methods that have been used to reduce the need for blood transfusion.[4,5] Intra-operative blood salvage is a technique where blood is collected during the operation through a suction device and then the blood is reinfused either instantly or in the recovery room. Postoperative blood salvage is a technique where the blood is collected by placing drainage tubes in the wound at the end of the operation for several hours, the blood is then reinfused into the patient. Labelling errors may occur in allogeneic and autologous blood transfusions when the blood is delivered from the blood bank to the patient. In contrast, salvaged blood is directly reinfused to the patient through suction tubes at the bedside, eliminating potential clerical error of verifying and matching identification labels between the blood and the patient.

The literature has reported conflicting views regarding the efficacy of the postoperative blood savage procedure.[6–12] Several studies have reported no significant benefit in reducing the need for allogeneic blood transfusion, whereas others have demonstrated that postoperative blood salvage is effective in decreasing allogeneic blood transfusions.[6–12] It is difficult to compare these studies and to conclude whether postoperative blood salvage is useful, because factors such as surgical technique affect the amount of blood salvaged.

The purpose of this study was to examine the results of blood salvage in patients undergoing elective total joint arthroplasty at a community hospital. Factors that may affect the efficacy of blood salvage in total joint arthroplasty were examined.

METHODS

We performed a retrospective chart review on 1406 adult patients undergoing total hip or knee arthroplasty at Scarborough Hospital between January 1997 and May 2000 after obtaining ethics approval from the Institutional Review Board. Patients who had infection or fracture, and cases that were incorrectly coded as total joint replacement were excluded (n=58). Patients undergoing bipolar hip hemiarthroplasty, unipolar hip hemiarthroplasty, or unicompartmental knee hemiarthroplasty and patients with incomplete data (eg no haemoglobin level recorded) were excluded.

Of 229 patients included, 152 undergoing total knee arthroplasty had Hemovac drains (Zimmer, Dover [OH], US) inserted at the end of the procedure, which were connected to a blood salvage system (Dideco Recovery BT 797; Mirandola, Modena, Italy). Blood was collected for up to 6 hours postoperatively and reinfused to the patients if a minimum volume of 175 ml was obtained. The hospital's respiratory therapists and registered nurses were responsible for the processing and transfusion of the salvaged blood. All the operations were performed using tourniquet control.

77 patients undergoing total hip arthroplasty had blood collected intra-operatively using a suction device and then reinfused at the end of the procedure if a minimum volume of 175 ml was obtained. The threshold of 175 ml was selected because it was the minimum volume required for the salvage process to be effective, according to the manufacturer's instructions and the surgeons' expertise. The salvaged blood was discarded if less than 175 ml was collected because it could not be effectively processed in the Dideco device and reinfused to the patient.

The number of drainage tubes used varied among surgeons. In patients using one Hemovac drain, the drain was placed in the joint and connected to the blood salvage system. In patients using 2 drain tubes, both drains were placed in the joint and connected by a Y-shaped connector to a single tube, which was connected to the blood salvage system. In patients using more than 2 drains, only 2 of the drains were placed in the joint, the remaining drains were placed in the subcutaneous layer. All the drains were connected to the blood salvage system.

The details of the patients were obtained from the charts retrospectively including: diagnosis, co-morbidities, surgical details (procedure, operating time, blood loss, and the number of drains and blood salvage system used), preoperative and postoperative haemoglobin and haematocrit levels, volume of blood salvaged, volume and nature of blood transfusion, adverse reaction to transfusion, and the use of anticoagulants.

The volume of blood salvaged, the volume of blood reinfused, the incidence and volume of autologous and allogeneic blood transfusions, levels of haemoglobin and haematocrit at preoperation,

postoperation, and discharge, as well as adverse reaction to blood transfusion were also assessed.

The data were analysed to determine whether certain factors affected the volume of blood salvaged such as: age, sex, cemented versus cementless arthroplasty, operating time, body weight, preoperative haemoglobin and haematocrit levels, preoperative autologous blood pooling, hip versus knee arthroplasties, and the use of anticoagulation. The correlation between the need for autologous and allogeneic blood transfusions and the receipt of salvaged blood were assessed using logistic regression.

RESULTS

Patients undergoing total knee arthroplasty

Of 152 patients undergoing total knee arthroplasty, 114 received a mean volume of 527 ml (standard deviation [SD], 262 ml) of salvaged blood postoperatively, the remaining 38 did not because less than 175 ml of salvaged blood was collected. These patients were divided into 2 groups: patients who received salvaged blood versus patients who did not receive salvaged blood (Table 1). The characteristics of patients in both groups were similar apart from the postoperative haemoglobin level and the preoperative haematocrit level. The mean preoperative haematocrit level was slightly higher in the blood salvaged group than non–blood salvaged group, but the clinical significance was small because the difference in the absolute value was small. The mean preoperative haemoglobin level and the mean postoperative haematocrit level at discharge were similar between the 2 groups, but the mean postoperative haemoglobin level at discharge was higher in the blood salvaged group. No significant difference was found in the rates of allogeneic and / or autologous transfusion between the 2 groups. The blood salvaged group had higher haemoglobin and haematocrit levels at the first postoperative day than the non–blood salvaged group because of the receipt of the salvaged blood.

We stratified the patients undergoing total knee arthroplasty by the use of cement (Table 2). Patients undergoing hybrid (cemented tibial tray and cementless femoral component) and cementless total knee arthroplasties were compared with those undergoing cemented total knee arthroplasty. Most of the characteristics of both groups were similar apart from the type of prosthesis used, operating time, number of drains used, preoperative haemoglobin level, preoperative haematocrit level, and preoperative autologous blood pooling. When autologous and allogeneic transfusions were considered as one entity, the cementless and hybrid group was less likely to require blood transfusions. It was not surprising that the cemented group had longer operating times, because it took time for the cement to set. Although the mean preoperative levels of haemoglobin and haematocrit were higher in the cementless and hybrid group, the mean postoperative levels of them were similar in both groups. The haemoglobin and haematocrit levels at the first postoperative day and the volume of salvaged blood were similar between the 2 groups.

Regression analysis was performed to determine if certain factors affected the rate of blood transfusions (Table 3). Allogeneic blood transfusion was a dependent categorical variable of continuous independent variables (age, operating time, and preoperative haemoglobin level) and dichotomous independent variables (autologous blood transfusion, sex, cemented versus noncemented procedures, and the reinfusion of salvaged blood). The results indicated that increased age, increased operating time, lower preoperative haemoglobin level, and the use of cemented procedure correlated to the increased likelihood of allogeneic blood transfusion. The use of autologous blood transfusion correlated to reduced allogeneic blood transfusion. However, the reinfusion of salvaged blood did not significantly affect the use of allogeneic blood transfusion.

When autologous and allogeneic transfusions were considered as a single entity for regression analysis, lower preoperative haemoglobin levels and the use of salvaged blood correlated to the increased rates of blood transfusions (Table 3). Other factors including age, sex, operating time, and cemented procedure did not significantly affect the use of blood transfusions.

Patients undergoing total hip arthroplasty

Of 77 patients undergoing total hip arthroplasty, 35 received reinfusion of salvaged blood intraoperatively, with a mean volume of 437 ml (SD, 176; range, 200–1000 ml), 42 did not because less than 175 ml of salvaged blood was collected. The majority of patients in each group underwent cementless total hip arthroplasty. Both groups were similar in most characteristics. The blood salvaged group had a higher mean operating time than the non–blood salvaged group ($p=0.0005$). The mean haemoglobin and haematocrit levels at discharge were similar between the 2 groups (Table 4).

Both groups had similar rates of autologous and / or allogeneic blood transfusion. Regression analysis

Table 1
Comparison of total knee arthroplasty patients who received salvaged blood with those who did not

	Salvaged blood not used (n=38)*	Salvaged blood used (n=114)*	p value
Mean age (standard deviation [SD]) [years]	70.1 (7.8)	70.3 (7.9)	NS†
Sex			
Male	12	74	NS
Female	26	40	NS
Diagnosis			
Osteoarthritis	36	108	NS
Rheumatoid arthritis	2	6	NS
Procedure			
Primary	38	113	NS
Revision	0	1	NS
Prosthesis			
Biomet	7	21	NS
Johnson and Johnson	31	93	NS
Treatment			
Cemented	20	41	NS
Hybrid	18	72	NS
Cementless	0	1	NS
Mean operating time (SD) [minutes]	71.0 (14.1)	72.4 (19.2)	NS
No. of drain(s)			
1 drain	21	52	NS
2 drains	3	10	NS
3 drains	13	48	NS
4 drains	1	4	NS
Mean haemoglobin level (SD) [g/l]			
Preoperative	124 (16)	129 (15)	NS
At first postoperative day	103 (14)	109 (16)	0.04
At discharge	98 (18)	105 (13)	0.02
Mean haematocrit level (SD)			
Preoperative	0.37 (0.04)	0.39 (0.04)	0.02
At first postoperative day	0.31 (0.04)	0.33 (0.04)	0.02
At discharge	0.30 (0.03)	0.31 (0.04)	NS
Preoperative autologous blood pooling			
0 unit	24	58	NS
1 unit	1	8	NS
2 units	12	48	NS
3 units	1	0	NS
Mean volume of salvaged blood reinfused (SD) [ml]	0	527 (262)	NS
Autologous blood transfusion			
0 unit	27	70	NS
1 unit	2	8	NS
2 units	8	36	NS
3 units	1	0	NS
Allogeneic blood transfusion			
0 unit	30	93	NS
1 unit	1	4	NS
2 units	6	15	NS
3 units	0	0	NS
4 units	1	2	NS
Both autologous and allogeneic blood transfusion			
0 unit	21	51	NS
1 unit	3	9	NS
2 units	10	51	NS
3 units	1	2	NS
4 units	2	2	NS

* Data are shown in No. of patients unless otherwise stated
† NS Not significant

Table 2
Comparison of total knee arthroplasty patients who underwent cemented procedure with those who underwent cementless/hybrid procedure

	Cemented group (n=61)*	Hybrid or cementless group (n=91)*	p value
Mean age (standard deviation [SD]) [years]	70.8 (7.8)	69.9 (7.9)	NS†
Sex			
Male	20	32	NS
Female	41	59	NS
Diagnosis			
Osteoarthritis	59	85	NS
Rheumatoid arthritis	2	6	NS
Procedure			
Primary	60	91	NS
Revision	2	0	NS
Prosthesis			
Biomet	4	24	0.005
Johnson and Johnson	57	67	0.005
knee			
Right	29	36	NS
Left	32	54	NS
Bilateral	0	1	NS
Mean operating time (SD) [minutes]	80.5 (19.2)	66.4 (14.9)	0.0001
No. of drain(s)			
1 drain	57	16	0.0001
2 drains	3	10	NS
3 drains	1	60	0.0001
4 drains	0	5	NS
Blood salvage system used	61	86	NS
Mean haemoglobin level (SD) [g/l]			
Preoperative	124 (14)	131 (15)	0.006
At first postoperative day	103 (15)	111 (16)	0.002
At discharge	101 (17)	105 (13)	NS
Mean haematocrit level (SD)			
Preoperative	0.37 (0.04)	0.31 (0.04)	0.004
At first postoperative day	0.31 (0.04)	0.33 (0.04)	0.002
At discharge	0.31 (0.0005)	0.33 (0.04)	NS
Preoperative autologous blood pooling			
0 unit	25	57	0.008
1 unit	4	5	NS
2 units	32	28	0.007
3 units	0	1	NS
Salvaged blood obtained	51	84	NS
Volume of blood salvaged (SD) [ml]	464 (295)	513 (266)	NS
Salvaged blood reinfused	41	73	NS
Volume of salvaged blood reinfused (SD) [ml]	488 (298)	543 (245)	NS
Autologous blood transfusion			
0 unit	29	68	NS
1 unit	6	4	NS
2 units	26	18	NS
3 units	0	1	NS
Allogeneic blood transfusion			
0 unit	52	71	NS
1 unit	1	4	NS
2 units	7	14	NS
3 units	0	0	NS
4 units	1	2	NS
Both autologous and allogeneic blood transfusion			
0 unit	21	51	0.05
1 unit	7	5	NS
2 units	31	30	0.03
3 units	0	2	NS
4 units	2	3	NS

* Data are shown in No. of patients unless otherwise stated
† NS Not significant

Table 3
Logistic regression results of blood transfusion in patients undergoing total knee arthroplasty

Logistic regression for independent variable of allogeneic blood transfusion	Coefficient	Standard error	p value
Constant	0.24	3.92	0.95
Age	0.08	0.04	0.03
Operating time	0.03	0.02	0.03
Preoperative haemoglobin level	-0.07	0.02	0.001
Autologous blood transfusion received	-1.12	0.38	0.003
Female	0.40	0.60	0.50
Hybrid or cementless procedure	-1.35	0.63	0.03
Salvaged blood reinfused	-0.21	0.58	0.97
r^2=0.26			
Logistic regression for independent variable of autologous and/or allogeneic transfusions	**Coefficient**	**Standard error**	**p value**
Constant	11.73	3.06	0.0001
Age	0.03	0.03	0.27
Operating time	-0.004	0.01	0.72
Preoperative haemoglobin level	-0.11	0.02	0.0001
Female	0.070	0.46	0.89
Cemented procedure	0.69	0.47	0.14
Salvaged blood reinfused	0.002	0.001	0.03

showed that higher preoperative haemoglobin levels and the use of autologous blood transfusions correlated to lower rates of allogeneic blood transfusion. When allogeneic and autologous transfusions were considered as a single entity, lower preoperative haemoglobin level and male correlated to increased blood transfusions (Table 5). The receipt of salvaged blood did not affect the rate of allogeneic transfusion.

DISCUSSION

114 of 152 patients undergoing total knee arthroplasty were reinfused a mean of more than 500 ml of salvaged blood; however, the use of salvaged blood did not reduce the need for allogeneic and/or autologous transfusions. In fact, patients who received salvaged blood were more likely to require blood transfusions, because of the higher perioperative blood loss. Patients who had a large volume of blood salvaged postoperatively were likely to have greater perioperative blood loss. These patients might have ongoing blood loss that was not counted, because salvaged blood was collected postoperatively for 6 hours only.

In the total hip arthroplasty group, intra-operative blood salvage did not affect the rate of allogeneic blood transfusion although a mean of more than 400 ml salvaged blood was reinfused. Unlike the total knee arthroplasty group, haemoglobin and haematocrit levels at first postoperative day of the total hip arthroplasty group were not significantly affected by the reinfusion of salvaged blood. This was probably because most of the blood loss occurred intra-operatively in total hip arthroplasty, whereas intra-operative blood loss tended to be much less in total knee arthroplasties performed using tourniquet control. Once the tourniquet was released after the surgery, further blood loss may occur.

The results of this study did not indicate the effectiveness of salvaged blood in reducing autologous and/or allogeneic blood transfusions. Given the limited resources of the blood bank, salvaged blood reinfusion may offer an adjunctive method of blood conservation.

Although our study did not show that reinfusion of salvaged blood was effective in reducing allogeneic blood transfusion and increasing haematological values at discharge, we found that reinfusion of salvaged blood to total knee arthroplasty patients increased their haemoglobin and haematocrit levels at the first postoperative day.

Other studies have demonstrated conflicting results on the use of salvaged blood in reducing the need for allogeneic blood transfusion. In a study of 128 patients undergoing hip or knee arthroplasty or spinal fusion, the postoperative blood salvage was reported to reduce the risk of allogeneic blood transfusion by 60%.[13] Another study reported that postoperative blood salvage in total hip arthroplasty patients reduced the rate of allogeneic blood transfusion, regardless of patients with or without preoperative autologous blood pooling.[8]

In a randomised trial of 102 patients undergoing unilateral or bilateral total hip or knee replacements, investigators found that reinfusion of a mean volume of 493 ml of salvaged blood did not reduce the rate of allogeneic blood transfusion among patients undergoing unilateral total joint replacements. However, among patients undergoing bilateral knee replacement, reinfusion of salvaged blood reduced the rate of allogeneic blood transfusion.[14]

There are several limitations in our study. This was not a randomised controlled clinical study. A

Table 4
Comparison of total hip arthroplasty patients who received salvaged blood with those who did not

	Salvaged blood not used (n=42)*	Salvaged blood used (n=35)*	p value
Mean age (standard deviation [SD]) [years]	66.3 (13.3)	68.4 (12.7)	NS†
Sex			
Male	18	13	NS
Female	24	22	NS
Diagnosis			
Osteoarthritis	37	30	NS
Rheumatoid arthritis	0	1	NS
Ankylosing spondylitis	2	0	NS
Avascular necrosis	3	1	NS
Failure of hip fracture fixation	2	0	NS
Previous hip fusion	0	1	NS
Procedure			
Primary	38	32	NS
Revision	4	2	NS
Prosthesis			
Biomet	41	32	NS
Howmedica Protek	1	2	NS
Osteonics	0	1	NS
Procedure			
Cemented	4	7	NS
Hybrid	1	3	NS
Cementless	37	25	NS
Mean operating time (SD; range) [minutes]	65 (30; 41–122)	86 (21; 41–187)	0.0005
No. of drain(s)			
1 drain	24	10	0.01
2 drains	8	11	NS
3 drains	0	0	NS
4 drains	10	14	NS
Mean haemoglobin level (SD) [g/l]			
Preoperative	136 (14)	132 (14)	NS
At first postoperative day	110 (15)	107 (18)	NS
At discharge	104 (14)	106 (18)	NS
Mean haematocrit level (SD)			
Preoperative	0.39 (0.04)	0.39 (0.04)	NS
At first postoperative day	0.33 (0.05)	0.32 (0.06)	NS
At discharge	0.32 (0.04)	0.32 (0.04)	NS
Preoperative autologous blood pooling			
0 unit	21	17	NS
1 unit	0	2	NS
2 units	21	16	NS
Volume of salvaged blood reinfused (SD; range) [ml]	0	437 (176; 200–1000)	NS
Autologous blood transfusion			
0 unit	22	19	NS
1 unit	3	2	NS
2 units	17	14	NS
Allogeneic blood transfusion			
0 unit	31	22	NS
1 unit	2	0	NS
2 units	7	12	NS
3 units	1	1	NS
4 units	1	0	NS
Both autologous and allogeneic blood transfusion			
0 unit	13	10	NS
1 unit	4	1	NS
2 units	21	20	NS
3 units	2	0	NS
4 units	2	4	NS

* Data are shown in No. of patients unless otherwise stated
† NS Not significant

Table 5
Logistic regression results of blood transfusion in patients undergoing total hip arthroplasty

Logistic regression for independent variable of allogeneic blood transfusion	Coefficient	Standard error	p value
Constant	5.88	4.89	0.23
Age	0.02	0.03	0.42
Preoperative haemoglobin level	-0.06	0.03	0.04
Operating time	0.00009	0.01	0.99
Male	0.67	0.72	0.35
Cemented/hybrid procedure	0.85	0.83	0.31
Autologous blood transfusion	-2.14	0.74	0.004
Salvaged blood reinfused	0.38	0.61	0.53
Logistic regression for independent variable of autologous and/or allogeneic blood transfusions	**Coefficient**	**Standard error**	**p value**
Constant	8.83	4.69	0.06
Age	0.02	0.03	0.49
Operating time	0.005	0.01	0.70
Preoperative haemoglobin level	-0.76	0.03	0.007
Salvaged blood reinfused	-0.001	0.001	0.68
Male	1.72	0.76	0.02
Cemented/hybrid procedure	1.61	1.20	0.18

transfusion protocol based on set clinical criteria was not administered. The decision to transfuse a patient depended on the individual surgeon, based on his or her own medical judgement of the patient's condition. Other factors that affected blood loss in patients undergoing orthopaedic surgery such as hypotensive or epidural anaesthesia were not specifically examined in this study because these methods were not frequently used in our series. However, the demographic and clinical characteristics of patients were similar between the blood salvaged group and non–blood salvaged group.

CONCLUSION

Although the reinfusion of salvaged blood did not significantly reduce the rate of allogeneic blood transfusion, it may still be beneficial. If the salvaged blood was not used, an extra one to 2 units of the autologous and allogeneic blood might be required to fulfil the transfusion needs of the patient. Given the short supply of allogeneic blood and its risks of transmitting disease, intra-operative and postoperative blood salvage may become necessary.

REFERENCES

1. Woolson ST, Marsh JS, Tanner JB. Transfusion of previously deposited autologous blood for patients undergoing hip-replacement surgery. J Bone Joint Surg Am 1987;69:325–8.
2. Thomson JD, Callaghan JJ, Savory CG, Stanton RP, Pierce RN. Prior deposition of autologous blood in elective orthopaedic surgery. J Bone Joint Surg Am 1987;69:320–4.
3. Feagan BG, Wong CJ, Lau CY, Wheeler SL, Sue-A-Quan G, Kirkley A. Transfusion practice in elective orthopaedic surgery. Transfus Med 2001;11:87–95.
4. Faris PM, Ritter MA, Keating EM, Valeri CR. Unwashed filtered shed blood collected after knee and hip arthroplasties. A source of autologous red blood cells. J Bone Joint Surg Am 1991;73:1169–78.
5. Borghi B, van Oven H. Reducing the risk of allogeneic blood transfusion. CMAJ 2002;166:332–4.
6. Adalberth G, Bystrom, Kolstad K, Mallmin H, Milbrink J. Postoperative drainage of knee arthroplasty is not necessary: a randomized study of 90 patients. Acta Orthop Scand 1998;69:475–8.
7. Gannon DM, Lombardi AV Jr, Mallory TH, Vaughn BK, Finney CR, Niemcryk S. An evaluation of the efficacy of postoperative blood salvage after total joint arthroplasty. A prospective randomized trial. J Arthroplasty 1991;6:109–14.
8. Grosvenor D, Goyal V, Goodman S. Efficacy of postoperative blood salvage following total hip arthroplasty in patients with and without deposited autologous units. J Bone Joint Surg Am 2000;82:951–4.
9. Han CD, Shin DE. Postoperative blood salvage and reinfusion after total joint arthroplasty. J Arthroplasty 1997;12:511–6.
10. Lux PS, Martin JW, Whiteside LA. Reinfusion of whole blood after revision surgery for infected total hip and knee arthroplasties. J Arthroplasty 1993;8:125–8.
11. Rizzi L, Bertacchi P, Ghezzi LM, Bellavita P, Scudeller G. Postoperative blood salvage in hip and knee arthroplasty. A prospective study on cost effectiveness in 161 patients. Acta Orthop Scand 1998;69:31–4.
12. Southern EP, Huo MH, Mehta JR, Keggi KJ. Unwashed wound drainage blood. What are we giving our patients? Clin Orthop 1995;320:235–46.
13. Healy WL, Pfeifer BA, Kurtz SR, Johnson C, Johnson W, Johnston R, et al. Evaluation of autologous shed blood for autotransfusion after orthopaedic surgery. Clin Orthop 1994;299:53–9.
14. Slagis SV, Benjamin JB, Volz RG, Giordano GF. Postoperative blood salvage in total hip and knee arthroplasty. A randomised controlled trial. J Bone Joint Surg Br 1991;73:591–4.