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Efficacy and economics of postoperative blood salvage in patients undergoing elective total hip replacement

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ABSTRACT

INTRODUCTION Patients undergoing total hip replacement (THR) regularly receive allogenic blood transfusions. The infusion of allogenic blood exposes the recipient to significant risks including the transmission of infection, anaphylactic and haemolytic reactions. The purpose of this study was to determine the effect of introducing a system to retransfuse salvaged drainage blood in patients undergoing primary THR.

PATIENTS AND METHODS We reviewed records of 109 consecutive patients who underwent THR following the introduction of the ABTrans™ autologous retransfusion system at our institution in January 2000. For comparison, we reviewed the medical records of 109 patients who underwent the same procedure immediately before the introduction of the retransfusion system.

RESULTS: Overall, 9% of patients treated with blood salvage and 30% treated without blood salvage required allogenic blood transfusions. Patients treated with the salvage system had significantly smaller haemoglobin drops in the peri-operative period (difference 0.56 g/dl; $P = 0.001$). The overall cost of using the retransfusion system was similar to that of routine vacuum drainage when the savings of reduced allogenic blood transfusion were taken into account.

CONCLUSIONS The retransfusion of postoperative drainage blood is a simple, effective and safe way of providing autologous blood for patients undergoing primary THR.

KEYWORDS
Blood salvage – Transfusion – Hip replacement

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Total hip replacement (THR) is a common orthopaedic procedure that can lead to significant blood loss. Patients undergoing THR often receive allogenic red blood cell transfusion to replace blood lost in the peri-operative period.[1,2] Transfusion of allogenic blood introduces several risks to the patient, including transmission of blood-borne infections, iso-immunisation, haemolytic and anaphylactic reactions. In Britain, the theoretical transmission of variant Creutzfeldt-Jacob disease has become a recent concern.

Increasing awareness of the potential risks of allogenic transfusion has lead to the emergence of autologous blood transfusion. Pre-operative donation, intra-operative and postoperative cell salvage techniques have become widely used in attempts to reduce allogenic blood requirements.[3–7]

Despite initial safety concerns regarding particulate contamination and development of coagulopathy, the retransfusion of unwashed salvaged blood has been shown to be a safe and effective alternative to allogenic transfusion.[8–12]

Previous studies have assessed the use of postoperative re-infusion of drainage blood in patients undergoing THR. These studies included patients who had predonated autologous blood or had had blood salvage carried out intra-operatively.

The benefit of postoperative drainage blood retransfusion in patients who have predonated autologous blood is not clear. Studies carried out by Rollo *et al.*[3] and Ayers *et al.*[13] indicated that the use of a postoperative retransfusion system in patients who had predonated autologous blood did not reduce their allogenic blood requirements. These findings were contradicted by Grosvenor *et al.*,[12] who found that postoperative blood retransfusion significantly reduced the need for allogenic transfusion in patients undergoing THR whether or not they had predonated autologous blood. In the study of Grosvenor *et al.*,[12] a group of 19 patients had not

been able to predonate allogenic blood. All six of the patients in this group without postoperative retransfusion required allogenic blood, compared with six out of the 13 patients treated with retransfusion. In the prospective randomised trial carried out by Gannon *et al.*,[14] 27% of the patients had predonated autologous blood. Patients in this study had undergone primary, revision or bilateral THRs, and results indicated that those treated with postoperative blood retransfusion sustained higher postoperative haemoglobin levels and had reduced requirements for allogenic blood.

Friederichs *et al.*[15] assessed the use of an integrated intra-operative and postoperative blood salvage system in 68 patients undergoing primary THR. These patients had an allogenic blood transfusion requirement of 4.4%. The authors concluded that peri-operative blood salvage is a viable alternative to predonation of autologous blood in patients undergoing primary THR.

The purpose of this study was to evaluate the introduction of a postoperative blood retransfusion system for primary THR, without concomitant use of intra-operative cell salvage or pre-operative blood donation. We aimed to assess the changes this system had on patients' allogenic blood requirement, and to evaluate the cost effect of using the retransfusion system compared with closed vacuum wound drainage.

Patients and Methods

In January 2000, the ABTrans™ autologous retransfusion system (Surgical Innovations Limited) was introduced for use in THR in the Department of Orthopaedics, Weston General Hospital following its successful use in total knee replacement.

The medical records of 109 consecutive patients who underwent primary THR for osteoarthritis from January 2000 to January 2003 were reviewed retrospectively to assess the efficacy of postoperative cell salvage (Group A). For comparison, we reviewed the medical records of 109 consecutive patients undergoing primary THR immediately prior to the introduction of the retransfusion system from March 1998 (Group B).

Patients with incomplete notes were excluded from the study, as were those undergoing THR for fracture treatment, conversion from dynamic hip screw, rheumatoid arthritis and

Table 1 Summary of results

	Average[a]	Spread[a]	Number	Test and test statistic	*P*-value
Age					
Group A	72	65–79	109	Mann-Whitney U-test = 5771	0.716
Group B	70	64–77	109		
Length of postoperative stay (days)					
Group A	7	7–9	109	Mann-Whitney U-test = 3351	< 0.001
Group B	9	8–11	109		
Pre-operative haemoglobin level (g/dl)					
Group A	13.8	12.8–14.4	109	–	–
Group B	13.5	12.7–14.6	109		
Postoperative haemoglobin level (g/dl)					
Group A	10.8	10.0–11.9	108[c]	–	–
Group B	10.2	9.3–11.6	103[d]		
Peri-operative haemoglobin drop[b] (g/dl)					
Group A	2.79	1.13	108	Unpaired *t*-test $t_{209} = 3.521$	0.001
Group B	3.35	1.18	103		

[a]The average and spread represent the median and inter-quartile range unless stated otherwise.
[b]The average and spread shown are the mean and the SD.
[c]One patient in Group A received allogenic transfusion in the recovery room prior to postoperative haemoglobin check – this patient's measurement was not included in postoperative haemoglobin calculation.
[d]Six patients in Group B received allogenic transfusion in the recovery room prior to postoperative haemoglobin check – these patients' measurements were not included in postoperative haemoglobin calculation.

revision procedures. Two senior consultant surgeons using the same anterolateral approach, similar surgical technique and drain placement carried out all the procedures.

Group A patients had the ABTrans™ retransfusion system inserted during wound closure. This system is a closed circuit configuration with a 1200-ml reservoir and self-contained suction. Blood is passed through a 125-µm microaggregate filter before it enters the reservoir. Anticoagulant citrate dextrose (50 ml; Formula A, South Devon Healthcare) was added to the reservoir prior to the release of the drainage valves. Autologous blood was retransfused to the patient through the closed circuit at 4-hourly or 400-ml intervals (whichever came first) for a period of 12 h. Maximum autologous transfusion allowed was 1200 ml. Blood drained after 12 h was discarded. The drains were removed at 2-days' post-surgery. Group B patients had two Medinorm vacuum drains (Summit Medical Limited, Gloucestershire, UK) inserted during closure. These were removed at 2 days' post-surgery.

All patients underwent identical postoperative protocol including two doses of postoperative antibiotics, low molecular weight heparin thromboprophylaxis and early mobilisation. There are wide variations in the indications for transfusion and the transfusion trigger levels between different centres and individual health professionals.[2,16,17] The decision to give allogenic blood transfusion was made based on the condition of the patient and development of symptomatic anaemia (vertigo, dizziness, ischaemic cardiac disease, confusion, dyspnoea) or if the absolute value of haemoglobin fell below 8 g/dl. These were based on the guidelines for red cell transfusion after total hip replacement from the Oxford Blood Centre[18] and have been used in other studies.[17] All patients were monitored during infusion of allogenic and autologous blood in accordance with hospital protocol.

The following parameters were recorded for each patient: age, prosthesis used, type of drain, pre-operative haemoglobin, postoperative day one haemoglobin, autologous blood retransfused (Group A), blood in vacuum drain on removal (Group B), the need for allogenic blood, postoperative in-patient stay and early complications up to 6-week assessment.

The hospital supplies department provided costs of the ABTrans™ retransfusion system, Medinorm vacuum drains and blood giving sets. The cost of preparing autologous blood was provided by the transfusion blood bank.

Results

The medical records of 109 consecutive patients were analysed for each group. Group A patients who underwent postoperative blood salvage and retransfusion had a median age of 72 years (inter quartile range (IQR), 65–79 years). The implants of group A consisted of 49 (45%) cemented and 60 (55%) hybrid prosthesis (cemented femur but not acetabulum). Group B patients who had their THR prior to the introduction of the retransfusion system had a median age of 70 years (IQR, 64–77 years). The implants used in this group consisted of 84 (77%) cemented and 25 (22%) hybrid prostheses. There was no statistical difference in the ages of the two groups ($P = 0.716$). The average pre-operative haemoglobin levels between the two groups did not differ significantly (13.8 g/dl and 13.5 g/dl, respectively). Postoperative blood measurements revealed a significant difference (0.56 g/dl; $P = 0.001$) in haemoglobin drop between group A (2.79 g/dl; SD = 1.13) and group B (3.35 g/dl; SD = 1.18) patients (Table 1). The average length of stay from surgery to discharge was less in group A patients treated with the retransfusion system (7 days; IQR, 7–9 days) compared with patients in group B (9 days; IQR, 8–11 days) who received standard vacuum drainage ($P \leq 0.001$; Table 1).

Patients treated with the retransfusion system received an average of 300 ml (IQR, 200–400 ml) of salvaged blood in the postoperative period. There was no significant difference ($P = 0.085$) in the amount of blood drained and retransfused in

Table 2 Volume of blood retransfused in cemented and hybrid cemented replacements

	Cemented	Hybrid
Median volume retransfused (ml)	270	300
Inter-quartile range	200–300	200–400
Number	47	59

There was no evidence that the amount of drainage blood retransfused differed in the cemented and hybrid prosthesis patients (Mann-Whitney U-test = 1118; $P = 0.085$).

Table 3 Allogenic blood transfusion requirements for both groups

	Group A	Group B
No transfusion given	99 (90.8)*	76 (69.7)
Patients requiring 2 units	9 (8.3)	23 (21.1)
Patients requiring 3 units	1 (0.9)	10 (9.2)
Total number receiving allogenic blood transfusion	10 (9.2)	33 (30.3)

*Percentages in brackets.
There was a significant difference in the number of allogenic blood transfusions between the two groups ($c^2 = 16.511$; $P < 0.001$).

Table 4 Group A length of stay by prosthesis type

	Cemented	Hybrid
Postoperative stay (median days)	8	7
Inter-quartile range	7–10	6–8
Number	49	60

Patients with cemented prostheses in group A stayed on average 1 day longer than those with a hybrid prosthesis (Mann-Whitney U-test = 758; $P < 0.001$).

Table 5 Group B length of stay by prosthesis type

	Cemented	Hybrid
Postoperative stay (median days)	10	8
Inter-quartile range	8–11	7–10
Number	84	25

Patients with cemented prostheses in group B stayed on average 2 days longer than those with a hybrid prosthesis (Mann-Whitney U-test = 565.5; $P < 0.001$).

patients receiving cemented (270 ml; IQR, 200–300 ml) or hybrid (300 ml; IQR 200–400 ml) prostheses (Table 2).

Three of the patients in group A were unable to receive their salvaged blood. In two of these cases, the connector tubing on the ABTrans™ retransfusion system broke and in one case the venous cannula tissued and was not re-sited in time for the retransfusion.

Ten patients (9.17 %) in group A and 33 patients (30.1%) in group B received allogenic transfusions. These data suggest that patients receiving retransfusion of salvaged blood had significantly lower allogenic blood requirements (χ^2, 16.511; $P < 0.001$; Table 3).

In both groups, patients with cemented prosthetic implants stayed longer than those patients receiving hybrid implants (Tables 4 and 5)

No complications associated with allogenic or autologous transfusions were noted in either group. In group A, four wound infections were noted; two of these patients returned to theatre for debridement, three patients developed wound haematomas requiring evacuation in theatre and two patients developed atrial fibrillation postoperatively. In group B, three wound infections were noted; one of these required surgical debridement, one patient developed atrial fibrillation, one patient suffered a non-fatal myocardial infarction and one patient was treated for a deep venous thrombosis.

Table 6 Basic equipment costs per patient

Item	Group A	Group B	Routine 2 unit cross-match
Group and save	£5.57	£5.57	£5.57
ABTrans™ autologous retransfusion system	£49.50	NA	NA
Anticoagulant citrate dextrose	£6.71	NA	NA
Medinorm vacuum drains (x2)	NA	£14.68	£14.68
Basic cost total	£61.78	£20.25	£20.25

Cost analysis

The direct costs to our institution of the retransfusion system and vacuum drainage were calculated (Table 6). The costs of preparing and providing allogenic blood for group A and group B patients was also calculated, as was the cost of 'routinely' cross-matching two units of blood for every patient as this is normal practice in a number of orthopaedic departments (Table 7). The overall costs for drainage equipment and allogenic blood was calculated for both groups (Table 8).

Table 7 Allogenic transfusion costs per patient

Item	Group A	Group B	Routine 2 unit cross-match
Blood cross-match	£5.57	£5.57	£5.57
Blood giving set	£1.26	£1.26	£1.26
Median allogenic transfusion of 2 units	£220.00	£220.00	£220.00
Percentage requiring allogenic transfusion	9.17	30.3	100*
Total transfusion cost per patient	£20.80	£68.73	£226.83

*Unused blood returned following cross-matching and preparation is not refunded at our institution.

Table 8 Overall cost per patient

Item	Group A	Group B	Routine 2 unit cross-match
Basic cost	£61.78	£20.25	£20.25
Allogenic blood transfusion costs	£20.80	£68.73	£226.83
Overall cost per patient	£82.58	£88.98	£247.08

The overall cost effect of introducing the postoperative transfusion is a saving of approximately £6.40 per patient. (If patients had been routinely cross-matched 2 units preoperatively, savings increase to approximately £164.50 per patient).

Discussion

Concerns regarding the safety of allogenic blood transfusion, particularly in the setting of elective surgery, have lead orthopaedic surgeons to look for methods of reducing allogenic blood requirements. Fibrin tissue adhesive sealant,[19] tranexamic acid,[20] aminocaproic acid[21] and recombinant erythropoietin[22] are pharmacological strategies that have been tried for this purpose. The other major development has been the introduction of procedures that enhance the use of the patients' own blood.

Both pre-operative donation and intra-operative salvage of autologous blood have been shown to reduce the demand for allogenic transfusion in the postoperative period.[3,12,14,15] Predonation of autologous blood has drawbacks due to wastage of blood (which can be as high as 45%[23]), patient suitability and the costs associated with administering predonation programmes, which are comparable or greater than the costs of allogenic transfusion. Transfusion of predonated blood retains the risks of bacterial contamination, and reactions due to non-compatible transfusion secondary to administrative error.[1,3,6,8,15,23–25] Acute normovolaemic haemodilution is used for this purpose albeit much less commonly than other methods.[2]

The use of intra-operative cell salvage techniques incur high start-up and running expenses which limit their cost effectiveness. Indeed, the study of Guerra and Cuckler[26] demonstrated that, due to expensive equipment and the need for specially trained personnel, this method was not cost effective in primary hip arthroplasty. This restricts their use mainly to cases where high blood loss is expected, such as revision procedures.[3,7,15,27]

The results of our study suggest that the introduction of a system to retransfuse salvage drainage blood, without concurrent use of predonation or intra-operative salvage techniques, significantly reduced the exposure of our patients to allogenic blood transfusion (30.1% to 9.2%; $P < 0.001$). Patients who received postoperative retransfusion also had a significantly smaller haemoglobin drop (difference 0.56 g/dl; $P = 0.001$) in the peri-operative period. In a study of 186 patients undergoing elective THR and TKR, Wynn Jones *et al.*[25] demonstrated a reduction in the incidence of allogenic transfusion from 46% to 22% and their analysis showed that the patients in whom ordinary closed suction drains were used were three times as likely to receive an allogenic blood transfusion than those in whom postoperative blood salvage and retransfusion were used. Strumper *et al.*[28] demonstrated a similarly significant reduction in allogenic blood requirements from 47% to 34% and Wojan *et al.*[29] reported a 25% reduction allogenic blood requirements in total hip arthroplasty. In a study of 111 patients, Rossner[30] also demonstrated that the use of peri-operative blood collection and retransfusion significantly reduces homologous blood transfusion in prosthetic hip surgery. The type of prosthesis used for the THR (cemented or hybrid) did not alter the volume of blood salvaged and retransfused postoperatively (difference 30 ml; χ^2 $P = 0.085$) or cause a significant difference in peri-operative haemoglobin drop (difference 0.08 g/dl; t-test $P = 0.74$). This is in contrast to the findings of Hays and Mayfield[31] who demonstrated that patients undergoing uncemented prosthetic implants tend to lose more blood than their counterparts undergoing cemented implants.

Although care must be taken in interpreting these results due to the non-randomised nature of the study and use of a historical control group, we believe these findings are significant. It is unlikely that the significantly reduced requirement for allogenic transfusion in the study group is solely due to changes in blood prescribing practices over the investigated time period (1998–2003). The historical nature of the control group is also unlikely to account for the reduced haemoglobin drop in the patients who received retransfusion of salvaged blood.

An interesting finding of our study was that patients in group A, who received postoperative retransfusion had a shorter postoperative in-patient stay (median 7 days compared to 9 days; $P < 0.001$) than the control group B. These data are difficult to interpret because of the use of historical comparisons in our study. The difference in stay may be solely due to improvements in postoperative rehabilitation for group A (studied between the years 2000 to 2003) compared with group B patients (studied from 1998 to 2000), although no other significant changes in postoperative care or rehabilitation were introduced at our institution during the time of this study. Previous studies have shown that allogenic blood transfusion has been associated with delayed hospital discharge and increased incidence of infection[25,32–34]

although a direct cause and effect relationship has not been shown. The OSTHEO study[2] demonstrated a significantly greater hospital stay for patients who received allogenic transfusion after total joint replacement than those who received autologous blood alone. The reduced need for allogenic transfusion and higher postoperative haemoglobin levels in the retransfusion group may have been a factor in their earlier discharge. Wynn Jones *et al.*[25] has also demonstrated a significant reduction in the mean length of stay in those in whom postoperative blood salvage and retransfusion was used after total joint arthroplasty. The use of hybrid cemented implants was associated with shorter in-patient stay in both study groups. This association is likely to be due to the fact that the treating surgeons tended to use hybrid prostheses with healthier and higher demand patients.

Cost analysis of the two study groups has shown that using the ABTrans™ retransfusion system incurred higher initial costs when compared to the use of two standard vacuum drains (£68.73 versus £20.80). When the reduced need for allogenic transfusion between groups A and B were included in the cost analysis, the overall costs were very similar (£82.58 versus £88.98). Wynn Jones *et al.*[25] demonstrated a small, but significant, difference in cost in favour of a retransfusion system for postoperative blood salvage. Many institutions still routinely cross-match two units of blood pre-operatively for patients undergoing THR. Our analysis suggests that if this practice was changed in favour of using pre-operative blood grouping and a postoperative salvage and retransfusion system, significant savings could be made (approximately £160 per patient). The basic calculations we have carried out have not analysed the cost of training nursing and medical staff to use the retransfusion system, neither have we attempted to calculate the savings made by reducing the potentially huge costs incurred in treating the complications associated with allogenic transfusion.

Concerns have been expressed regarding the safety of retransfusing shed, unwashed blood with a few studies concluding that there is not much merit in the use of this method.[35] There have been rare reports of haemolytic,[36,37] allergic and febrile reactions.[8,38] The concentrations of C3a, complement split products ($C_{5b\text{-}9}$), TNF-α, IL-6 and IL-8 have been found in shed blood in previous studies.[39–43] Reduced fibrinogen levels and increase in fibrinolytic activity[44] observed in shed, unwashed blood is thought to be due to activation of coagulation pathways due to exposure to tissue factors, air and the synthetic material of the collection equipment. However, most studies in the literature indicate that retransfusion of salvage blood after total joint replacement is safe.[8,14,25,45–47] In a study of 50 patients undergoing postoperative cell salvage and retransfusion, Sinardi *et al.*[48] found a 40–60% increase in various complement activation factors, an 8-fold increase in TNF-α , a 26-fold increase in IL-1β and a 115% increase in CRP compared to a presurgery control blood. In spite of these levels, the study demonstrated no adverse events related to autotransfusion of salvage blood. These findings are supported by other studies[28,39,43] as well as our own. The occurrence of adverse events may be related to the collection and retransfusion duration of shed blood[49] as well as the volume transfused.[43] It is generally accepted that retransfusion of unwashed shed blood of up to 15% of the patients total blood volume is safe.[45,50,51] Moreover, Dalen *et al.*[47] found a less than 1% erythrocyte haemolysis rate after 24 h of incubation of shed blood, despite complement activation. Red blood cells (RBCs) from shed blood have been shown to have normal morphology, mean corpuscular fragility and life-span as those taken from intravenous blood[48,52,53] indicating its suitability for retransfusion. Indeed, RBCs from shed blood were found to have increased concentrations of 2,3-DPG and ATP, thus causing a favourable shift in the oxygen–haemoglobin dissociation curve and easier delivery of oxygen to tissues.[48]

Immunosuppression with increased risk of infection is thought to be one of the negative effects of allogenic blood transfusion.[33,54,55] The OSTHEO study found wound infection rates in patients undergoing retransfusion of drainage blood to be similar to those in whom allogenic blood was used and greater than those in whom pre-operative donation or intra-operative blood salvage was used.[2] However, in addition to other studies,[8,56] our study did not demonstrate any increased wound infection risk with the use of the retransfusion system compared with allogenic blood transfusion. It is thought that a strict aseptic technique for collection of shed blood and timely retransfusion may reduce the risk of infection when the postoperative salvage system is used.[2]

Conclusions

The salvage and retransfusion of drainage blood is a simple and safe way of providing autologous blood for patients undergoing THR. The technique can be used for the majority of patients and is relatively inexpensive when compared to pre-operative donation or intra-operative cell salvage.[7] The results of the present study suggest that using a postoperative blood retransfusion system in patients undergoing primary THR significantly reduces the requirement for allogenic blood transfusion (30.1% to 9.2%) and reduces the haemoglobin drop (difference 0.56 g/dl) in the peri-operative period. In addition, our calculations show that the higher basic cost incurred when using a postoperative salvage and retransfusion system are compensated for by the reduced costs of allogenic blood transfusion. Considering the significant potential benefits of avoiding the hazards associated with allogenic infusion, we continue to use this system routinely for primary total hip replacement.

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