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The Role of Autologous Blood Transfusion in Joint Replacement Surgery

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SUMMARY

The efficacy of predeposited autologous blood transfusion (PABT) with and without intra/postoperative blood salvage to reduce or eliminate the need for homologous blood transfusion (HBT) in primary total hip or knee replacement surgery was investigated by retrospective and prospective studies. Depending on the type of surgery, one to three units of PABT eliminated the need for HBT in 50 to 78% of patients, but, intra/postoperative blood salvage alone reduced the need only in 11 to 29%. In contrast, blood salvage, when combined with three units of PABT, eliminated the need for HBT in all patients undergoing primary joint replacement surgery. A cost comparison analysis showed that blood salvage was more expensive than PABT, and therefore it should be limited to patients who had predeposited fewer than three units of autologous blood.

Key Words: BLOOD: transfusion, autologous, salvage; SURGERY: joint replacement, autologous blood transfusion

Until recently, most patients undergoing joint replacement surgery received homologous blood transfusion (HBT), but in recent years, due to increasing public awareness of the morbidity associated with HBT, there has been a steep increase in the demand for predeposited autologous blood transfusion (PABT) and intra- or postoperative blood salvage. However, there has been no systematic assessment of the efficacy of these methods, and there are no data to indicate what amount of predeposited autologous blood or salvaged blood is necessary to decrease or eliminate the need for HBT in primary total hip replacement and total knee replacement. The relative efficacy of PABT with or without blood salvage is unknown, and the assumption that the benefit of each technique is additive may not necessarily be valid. In many recently reported studies, retrospective collection of data from different operations and patient groups were included, and the pattern and the volume of blood loss in the peri-operative period were either not examined or were given little attention[1,2]. We present the results of recently conducted retrospective and prospective studies to determine the relative efficacy of PABT and intra/postoperative blood slavage to decrease or eliminate the need for HBT in primary joint replacement surgery.

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METHODS

At the Repatriation General Hospital in South Australia, PABT in joint replacement surgery has been used since 1986. All patients were encouraged to predeposit autologous blood over three to four weeks prior to surgery, and the Red Cross Blood Transfusion Service's guidelines for the collection of blood were followed. Patients who were assessed in the pre-anaesthetic clinic to be fit for surgery were included provided their haemoglobin was >110 g/l, and we aimed to collect a total of three units of blood from each patient. Prior to 1990, all patients were screened for human immunodeficiency and hepatitis B virus infections, and any collected blood from infected patients was discarded. After 1990, patients were also tested for hepatitis C virus infection. All patients were offered oral iron therapy from the day of collection of the first unit of blood for four weeks. Medical records of consecutive patients undergoing primary joint replacement surgery between January 1986 and June 1990 were reviewed, and information such as the type of surgery performed and the proportion of patients receiving HBT, PABT, or salvaged blood was collected.

In the *prospective* study, patients admitted for elective primary joint replacement surgery were chosen, provided they understood the nature of the study and were capable of giving informed consent. This study was approved by the Clinical Investigations Committee at the Repatriation General Hospital. In order to avoid

excessive bleeding, patients were advised not take any anti-inflammatory medications for at least two weeks before surgery. All patients had spinal or epidural anaesthesia, and any patient with major systemic disease or considered unsuitable for regional anaesthesia was excluded. Although deep venous thrombosis prophylaxis with heparin was not used as a routine during the earlier period of the study, in the later part of the study low molecular weight heparin 5,000 units daily during the first five postoperative days was used. The choice of surgical implants and surgical technique was made depending on individual patients' needs by the treating surgeon. In total knee replacement patients, standard surgical technique using a midline incision and a medial parapatellar approach under tourniquet control was followed, and lateral release of the quadriceps expansion was not routinely performed. In the total hip replacement group, standard surgical technique via the lateral or posterior approach was used, but greater trochanteric osteotomy was not performed. Depending on the surgeon's choice, either the cemented or the uncemented prosthesis was used.

In the *prospective* study, patients were randomized, irrespective of whether they had predeposited autologous blood or not, into blood salvage or no-blood salvage groups using a computer-generated randomized table. Two randomized tables were used, one for the total knee replacement group and the other for the total hip replacement group. Blood salvage was performed using a semi-automated autotransfuser (Electromedics, BT-795, Englewood, U.S.A.) according to the manufacturer's instructions. In total hip replacement patients, intra-operative blood salvage was performed by a nurse in conjunction with an anaesthetist. Postoperative blood salvage was a continuation of the intraoperative salvage for a duration not exceeding six hours, and the set-up was identical to that for intraoperative salvage except that regulated low pressure (−5 kPa) suction was applied by a Y-adaptor connected to two Redivac drains inserted into the wound cavity. In total knee replacement patients, postoperative blood salvage alone was performed as described for the total hip replacement patients for six hours after the tourniquet had been released. On completion of salvage, the wound drains were connected to two vacuum-charged Redivac bottles (Biomet-Bridgend, South Glamorgan, U.K.), and the drains were removed at 48 hours post operation. The average volume of blood salvaged in each patient was calculated after adjusting the haematocrit to 40%. Pre- and postoperative investigations were performed to assess changes in blood cell parameters, coagulation status and liver and kidney function.

The total volume of intraoperative blood loss was estimated by adding blood absorbed in sponges, blood collected in suction bottles and the amount of blood on the operative drapes. The latter was an estimate made by the surgeon and the anaesthetist independently, and the higher amount was used in calculation. In patients undergoing blood salvage, the amount salvaged was added to the total blood loss. Postoperative blood loss was calculated by measuring the volume of blood-stained fluid collected in drainage bottles during 48 hours after surgery. The indications for any blood transfusion during or after surgery was based solely on patients' needs and it was given only when plasma expanders were considered to be inadequate to maintain a safe blood volume and the haemoglobin level around 100 g/l.

Based on the current operating cost of the Red Cross Blood Transfusion Service, the estimated cost of provision of a unit of whole blood was approximately AUD$90 (Prof. R. Beal, 1990, Director of Red Cross Blood Transfusion Services, South Australia, personal communication). The cost of crossmatching with the recipient was added to the total cost as it was performed outside the Red Cross Service. In estimating the cost of PABT, we considered that the Commonwealth Medical Benefits Schedule[3] 1992 was a fair estimate as the schedule itself was based on reasonable cost and reward for the provider of a medical service. Most physicians who examined the patients charged the initial consultation fee, irrespective of the number of units of blood collected. The schedule provided a fee for each unit of autologous blood collection. Tests for transmissable infectious diseases, haemoglobin estimation, antibody screen and crossmatch were performed by pathology laboratories outside the Red Cross Service, and therefore the schedule fee for the appropriate tests was included in the estimate. Finally, as patients pre-depositing autologous blood were offered supplementary oral iron, the cost of the latter was also added to the total cost.

Since blood salvage was performed as a single continuous procedure, irrespective of the amount of blood collected, its cost was calculated based on one procedure. The cost was estimated as follows: the *fixed cost* included the cost of using the autotransfuser estimated on a standard accounting practice of full depreciation over five years and an average use of the machine twice a week. Using this approach, the cost of using the autotransfuser was estimated to be $50 per procedure. To the *fixed* cost the cost of disposable software such as the centrifuge bowl, the wound drains, the cost of normal saline for each salvage cycle, and labour cost of half an hour nursing time to set up the

machine were added. The estimated cost per patient for three units of HBT or PABT, and the cost of blood salvage alone or in combination, is shown in Table 1.

TABLE 1
Cost of blood transfusion per patient in joint replacement surgery

Type of blood transfusion	PABT	HBT	ABS	HBT+ ABS	PABT+ ABS
Number of units	3	3	Variable	3	3
RCBTS cost of blood ($)	—	270***	—	270	—
Donor assessment ($)	106*	—	—	—	106
Collection and processing ($)	102*	—	333***	333	435
Hb estimation ($)	33*	—	—	—	33
Blood group & antibody screen ($)	36*	36	—	—	36
Cross match ($)	88*	88	—	88	88
Infectious disease screen ($)	83*	—	—	—	83
Iron therapy ($)	3**	—	—	—	3
Total cost per patient ($)	451	394	333	691	784

* Commonwealth Medical Benefit Schedule fee; ** 4 weeks of therapy; *** See Methods. PABT=Predeposited autologous blood transfusion; HBT=Homologous blood transfusion; ABS=Intra-/postoperative autologous blood salvage; RCBTS=Red Cross Blood Transfusion Service.

RESULTS

Retrospective Study: Medical records of 317 and 301 consecutive patients undergoing primary total knee replacements and total hip replacements, respectively, were reviewed. There were 435 men and 183 women with a median age of 73 years (range 43-96 years). The number of patients reviewed, the percentage of patients who participated in the PABT program, and the percentage of patients receiving HBT are shown in Table 2. Of the 295 patients participating in the PABT program, 36 had predeposited one unit each, 125 patients two units each, and 134 patients three units each of autologous blood. Since 1989, in addition to PABT, 82 patients had blood salvage at the discretion of the anaesthetist. Because of the retrospective nature of the study, the indication for salvage and the amount of salvaged blood were not known.

In this retrospective study, 12% and 10% of patients undergoing total knee and total hip replacement, respectively, did not receive any blood transfusion. In those patients receiving a blood transfusion, the median amount of blood used in both the pre-deposit and the no pre-deposit group was similar, indicating that the amount of blood loss and indications for a blood transfusion were comparable. Table 3 shows the efficacy of PABT, or blood salvage, on their own, or in combination, in reducing the need for HBT. PABT alone was more effective than blood salvage alone in reducing the percentage of patients receiving HBT. A combination of PABT and blood salvage significantly reduced, but did not eliminate the need for HBT. To assess the effect of blood salvage alone on transfusion requirement, 32 patients who had received salvaged blood only were compared with 32 patients (matched for age, sex, and type of surgery) without blood salvage and without PABT. The median amount of HBT in patients with and without blood salvage was one unit respectively, and this reduction in the volume of HBT in the blood salvage group was statistically significant ($P<0.02$).

TABLE 2
Retrospective study of transfusion in joint replacement surgery

Year	1986-88	1989	1990	Total
No. of patients	220	226	172	618
Number (%) PABT	64 (23)	114 (50)	117 (68)	295 (48)
Number (%) HBT	169 (82)	139 (62)	82 (48)	390 (63)
Number (%) ABS	0	48 (21)	34 (34)	82 (13)

See Table 1 for abbreviations.

TABLE 3
Retrospective study of the impact of PABT and ABS on HBT

Transfusion groups	No-PABT	PABT	ABS	PABT+ ABS
Number of patients	303	233	32	50
Homologous blood (units)	681	177	39	18
Autologous blood (units)	—	471	—	76
% of patients needing HBT*	100	41	63	22

* Excluding patients not needing any blood transfusion. Abbreviations as in Table 1.

Prospective Study: The study included 44 and 62 patients in the cemented and the uncemented total hip replacement groups respectively, and 99 patients in the total knee replacement group. The patients were further divided into three subgroups according to the volume of PABT (Table 4). The details of blood loss and the amount of autologous blood salvaged are shown in Table 5.

TABLE 4
Demographic data and patient groups of the prospective study

PABT Groups	Number of patients		Median (range) age	Sex ratio
	No-ABS	ABS		
Total Hip Replacement				
No PABT	20	16	74 (44-90)	17M/19F
1-2 Units PABT	22	15	75 (42-84)	27M/10F
3 Units PABT	17	16	71 (46-80)	27M/6F
Total Knee Replacement				
No PABT	18	18	74 (65-93)	21M/15F
1-2 Units PABT	12	15	74 (65-86)	25M/2F
3 Units PABT	25	11	71 (65-80)	31M/5F

See Table 1 for abbreviations.

TABLE 5

Prospective study of blood loss and salvaged in joint replacement surgery

Patient groups	n	Median (range) blood loss*	ABS returned**
Total knee replacement			
ABS	18	1.5 (0.2-2.8)	0.6
1-2 units PABT	15	1.5 (0.9-3.0)	0.5
3 units PABT	11	1.8 (0.5-3.4)	0.7
Total hip replacement (uncemented)			
ABS	10	1.4 (1.0-3.0)	0.5
1-2 units PABT	7	1.5 (0.8-2.4)	0.4
3 Units PABT	10	1.4 (1.0-2.7)	0.6
Total hip replacement (cemented)			
ABS	6	1.2 (0.7-1.9)	0.4
1-2 units PABT	8	1.2 (0.8-1.7)	0.4
3 units PABT	6	1.4 (0.7-1.6)	0.4

See Table 1 for abbreviations. * Intra- and postoperative loss in litres; ** Median volume in litres.

There were no significant differences in the preoperative or the postoperative haemoglobin levels amongst the various groups indicating that the transfusion management was comparable (data not shown). The overall pattern and the median volume of blood loss was not different in patients grouped on the basis of the volume of PABT. There was no significant difference in the amount of blood loss and blood salvaged between the cemented and the uncemented total hip replacement groups. The haematocrit-adjusted median volume of salvaged blood returned as a proportion of total blood loss in the total knee replacement group (38%) was marginally higher than the volume returned in the total hip replacement group (32%). The efficacy of PABT with and without blood salvage in reducing the percentage of patients receiving HBT during total knee replacement and total hip replacement is summarized in Table 6. In both groups one, two or three units of PABT alone did not eliminate, but significantly reduced the need for HBT. Similarly, blood salvage alone reduced, but did not eliminate the need for HBT. Combined with one, two or three units of PABT, blood salvage eliminated the HBT in all patients. Since a majority of patients undergoing joint replacement surgery require a minimum of three units of blood, the estimated cost of a blood transfusion in a patient, depending on the combination of HBT, PABT and blood salvage, is shown in Table 1. A comparison of pre-salvage haematological and biochemical parameters with post-salvage parameters showed no clinically significant changes.

TABLE 6

Prospective study of the impact of PABT with and without ABS on HBT

	% of patients needing a homologous blood transfusion					
	Cemented-THR		Uncemented-THR		TKR	
PABT Groups	No-ABS	ABS	No-ABS	ABS	No-ABS	ABS
No PABT	100%	89%	83%	70%	79%	50%
1-2 units PABT	50%	29%	58%	57%	50%	0%
3 units PABT	38%	0%	25%	0%	22%	0%
P-value*	<0.005		<0.001		<0.001	

See Table 1 for abbreviations; *Chi-square (2 df).

DISCUSSION

Our retrospective analysis, like the recently published reports[4-6], confirmed that PABT alone was effective in reducing the percentage of patients receiving HBT by 59%, and with the addition of blood salvage, by 78% (Table 3). The review also indicated that 54% of patients did not pre-deposit more than two units of blood, but it was not possible from the retrospective review to assess the reasons for limiting the amount of predonation to one to two units. Several investigators[7,8] have observed that in the elderly, poor response to anaemia following two to three units of blood donations was an important limiting factor. In younger patients (mean age, 56 years), Goodnough et al[6] have reported a reduction of 88% amd 82% in HBT in total knee and total hip replacement respectively, but his report did not elaborate on the nature of the surgical techniques employed. In our prospective study, 17% and 21% of uncemented total hip and total knee replacement patients respectively did not receive any transfusion. Surgical and anaesthetic techniques used in our patients may have played a role in reducing the blood loss, and anaesthetists, conscious of the adverse effects of HBT, were willing to accept a greater degree of anaemia and used non-blood products as volume expanders. In these patients the collection of autologous blood may appear to be a wasted exercise, but there is no simple way to identify, before surgery, patients who will not need a transfusion. Since our prospective studies were conducted during the time in which the PABT and the blood salvage were routinely practised, there were several practical difficulties in designing randomized studies. For example, it was considered "unethical" not to offer PABT to patients. Therefore, patients who received PABT were compared with patients who did not participate in the PABT program due to medical or personal reasons. Since the efficacy of blood salvage was not known, we randomized patients into the blood salvage and the no-blood salvage groups irrespective of their participation in the PABT program. There was no difference in preoperative or postoperative haemoglobin levels

between the various groups of patients, irrespective of autologous or salvaged or homologous blood transfusion, indicating that the blood loss was comparable.

In our total knee replacement study, the median volume of total blood loss (Table 5) was similar to the one reported by Lotke et al[9], but higher than the one reported by Cushner and Friedman[10]. However, in the latter retrospective study, the type of patients and the anaesthesia used were not stated, and the wound drains were removed at variable periods between 24 and 48 hours. As in the recently reported studies of Slagis et al[11] and Semkiw et al[12], blood salvage was performed for six hours only because of the possibility of increased haemolysis and bacterial contamination with prolonged salvage, and because most of the postoperative loss occurred during that time. In total knee replacement patients, 33-40% of total blood loss was salvaged, and it may be argued that the amount salvaged was too small to be of value for routine blood salvage, but some patients had lost as much as 3.4 litres during the procedure (Table 5). Slagis et al[11] also observed that postoperative blood salvage was not efficacious in most cases of unilateral total knee replacement and suggested that blood salvage should be reserved only in patients in whom the first four-hour postoperative drainage exceeded 500 ml.

Although there was no difference in blood salvaging efficiency between the cemented and the uncemented total hip replacement groups, in practice more washing was needed in the former to remove particulate contaminants. Although blood salvage was conducted during the intra- and postoperative periods in total hip replacement, the median volume of blood salvaged was comparable to that in total knee replacement. Comparison with most published reports was difficult as they either did not specify the prostheses used[13,14], or analysed cemented and uncemented total hip replacement patients together[12], or included patients with uncemented acetabular but cemented femoral components[12,15]. Our results were similar to those of Woolson et al[15] and Gargaro and Walls[13] although their studies were retrospective and the volume of blood salvage returned was not standardized for haematocrit. Turner et al[14] had reported a higher blood salvage return (58%) in primary total hip replacement, but they neither specified prostheses used, nor standardized the volume salvaged for haematocrit.

The benefit of PABT for both total hip and total knee replacement increased proportionately with increasing amount of autologous blood availability, and we observed that in patients undergoing joint replacement surgery, in order to reduce HBT significantly, a minimum of three units of PABT were required. Even with three units, 22-38% of patients needed, on average, one additional unit of HBT, suggesting that in order to assure total elimination of HBT a minimum of four units of PABT is required. Our experience at the Repatriation General Hospital and that of others[7,8,15] suggested that it was not often possible to obtain four units of autologous blood, except in a minority of healthy young patients, without inducing symptomatic anaemia. Since it is difficut to predict which patient is going to need more than three units of blood, it may be advisable to have blood salvage procedure in place to compensate for unexpected large volume blood loss.

The cost comparison analysis indicated that HBT, provided the blood was obtained free from voluntary donors, was still the cheapest form of blood transfusion. Assuming that the elimination of HBT was the desirable goal to assess cost-effectiveness, the analysis suggested that in joint replacement surgery three units of PABT was most cost-effective, and blood salvage alone was most expensive and least cost-effective. A combined approach of two to three units of PABT with blood salvage was effective in eliminating the need for HBT, but it also increased the cost substantially. Recently, Healy et al[16] have critically analysed the cost-effectiveness of PABT and concluded that PABT is not a cost-effective therapy if based solely on avoidance of post-transfusion viral infections, but may be cost-effective if the cost of postoperative bacterial infections were to be included in a cost analysis model. Our study suggests that adequate PABT, in comparison with intra/postoperative blood salvage alone, is a more practical and less expensive method to minimize HBT in joint replacement surgery, collection of a minimum of three units autologous blood should be aimed for, and that blood salvage should not be used in isolation.

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