Intraoperative autotransfusion in primary hip arthroplasty

A randomized comparison with homologous blood

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To study the quality and effect of blood produced by the cell saver compared with homologous blood in total hip arthroplasty, 40 patients were randomly divided into two groups. One group received autologous blood using the cell saver, whereas the second group served as a control, and received homologous bank blood. Hematologic and coagulation parameters of the patients were assessed both preoperatively and postoperatively. Samples from the autologous and the homologous blood were obtained before reinfusion, and were assessed as regards hematologic and biochemical parameters. The autologous blood satisfied all the intraoperative transfusion requirements of the autologous group and 75 percent of the total transfusion requirements. The operative and postoperative blood losses—hence, the total blood loss—were less in the autologous than in the control group. The autologous blood had a high hemoglobin, white blood cell, and plasma hemoglobin content and MCV compared with the homologous blood. Postoperatively, there were no differences as regards the hematologic parameters studied. There was no evidence of intravascular hemolysis in the autologous group. Postoperatively, in both groups, AT III, plasminogen, and protein C decreased. Other coagulation parameters were within normal limits in both groups. Intraoperative autotransfusion is safe and effective, and should be considered in hip arthroplasty to reduce the risks associated with homologous blood transfusion.

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Primary hip arthroplasty is associated with substantial operative blood loss, which frequently necessitates transfusion. Homologous blood transfusion carries definite risks. Hemolysis, anaphylaxis, malaria, posttransfusion hepatitis, and acquired immunodeficiency syndrome (AIDS) are well-known complications of homologous transfusion (Schmidt et al. 1969, Alter 1981, Tabor 1982, Curran et al. 1984).

The concept of autotransfusion was first proposed by Blundell in 1818 as a potentially life-saving technique for patients with massive bleeding. In the early 1970s, Klebanoff (1970) modified the Bentley cardiotomy reservoir with systems for aspiration, filtration, and infusion. Since then, improvements and modifications have been made, thus rendering intraoperative autotransfusion (IAT) safe and effective (Solem 1986, Solem et al. 1988). However, controlled studies on the effect and quality of the reinfused blood are needed (Popovsky et al. 1985, McShane et al. 1987), and especially in orthopedic operations.

We present a prospective randomized study on the quality and the effect of IAT on the hematologic and coagulation parameters compared with homologous blood in primary hip arthroplasty.

Patients and methods

Forty patients undergoing primary hip arthroplasty were randomly allocated by sealed envelopes to IAT or homologous blood. One patient in the IAT group was excluded because the cell-saver operator was unavailable on the day of the operation. She received 2 units of homologous blood intraoperatively.

There were 10 women and 9 men in the IAT group, with a mean age of 68 (59–89) years, and 12 women and 8 men in the control group, with a mean age of 74 (48–89) years.

Intraoperative blood salvage was performed using the Electromedic Autotrans, AT–1000 autotransfusion system (Englewood, CO, U.S.A.). Blood was retrieved from the operative field with a double lumen suction catheter. The blood was immediately anticoagulated with sodium citrate (22.4 g anhydrous glucose, 22 g sodium citrate, and 8 g citric acid/L). Larger debris (fat, bone, and cement particles) was removed by a 240-μ filter in the cardiotomy reservoir. The filtered blood was pumped into a bowl centrifuge and washed with 1,500 mL saline. The supernatant was discarded. The erythrocyte concentrate was pumped into a reinfusion bag and then reinfused into the patient. The cell saver was operated by a specially trained anesthetic nurse.

All the patients underwent a total hip arthroplasty in the supine position according to the Charnley procedure with trochanteric osteotomy. Epidural anesthesia, with continuous access, was used for all the patients in both groups. The operations were performed in both groups by the same surgeons, who used the same technique and the same methods as regards hemostasis. Thromboprophylaxis was given to all the patients using dextran 70, 6 percent in saline (Macrodex® Kabi Pharmacia AB, Stockholm, Sweden): 500 mL during the operation, another 500 mL during the remainder of the operation day, and 500 mL on postoperative Days 1, 3, and 5. An additional 500 mL was given on the second postoperative day if the blood loss had exceeded 2,000 mL.

Intraoperative blood loss was assessed in the IAT group by measuring the blood collected in the cell saver, as well as the estimated amounts in the sponges, if any: viz., almost all the blood lost during the operation was retrieved through the suction catheter to the cell saver.

In the control group, the blood loss was assessed by measuring the amount of blood collected in the suction container, as well as the estimated amount of blood in the sponges. Postoperatively, the blood loss was assessed in both groups by measuring the amount of blood collected in the drainage system during the first 48 hours postoperatively. The indications for blood transfusion were the same in both groups. Intraoperatively, blood was given according to the anesthetist's decision. Postoperatively, a transfusion was given if the hemoglobin was less than 85g/L or if there were symptoms of anemia (Grindon et al. 1985).

Hematology methods

Venous blood and urine samples were obtained from all the patients preoperatively, at the end of the operation, and 24 h, 72 h, and 1 week postoperatively. Using an automated flow cytometry blood cell analyzer (H*l, Technicon Instr., Tarrytown, NY, U.S.A.), the hemoglobin concentration, hematocrit, mean corpuscular volume, and red blood cell, white blood cell, and platelet counts were determined. In EDTA-anticoagulated blood, the fraction of carbon monoxide hemoglobin was determined with a spectrophotometric method (OSM 3 hemoximeter, Radiometer, Copenhagen, Denmark). The concentration of haptoglobin and of free hemoglobin was determined in EDTA plasma with respectively an immunoephelometric method and a spectrophotometric method. In addition, the concentration of serum creatinine and potassium, and urinary hemoglobin and urobilinogen were determined with the standard methods used in our clinical chemistry laboratory.

Blood samples were also obtained from the bank blood bag and the autologous reinfusion bag and anticoagulated with EDTA. Hemoglobin concentration, hematocrit, mean corpuscular volume, and red blood cell, white blood cell, and platelet counts were determined using the same methods and instruments as described above. In addition, the finding of white blood cells and platelets in the washed blood from the cell saver was confirmed by counting the cells manually in the microscope whenever there was a morphologic indication from the instrument. Damaged leukocytes were observed occasionally, but the fraction of these cells was not determined. We also measured the concentration of free hemoglobin in the bank blood, as well as in the blood from the cell saver, using the method described above.

Coagulation methods

Venous blood samples from all the patients were obtained preoperatively, at the end of the operation, and 24 hours postoperatively. The following tests were performed: fibrinogen, P & P (factors II, VII, X), and factor V were determined as previously described by Nilsson (1974). Factor VIII coagulant activity was determined by a chromogenic substrate method (Coatest Factor VIII, Kabi Pharmacia, Stockholm, Sweden). Plasminogen was determined amidolytically (Friberger 1983); protein C by immunoradiometric assay (Malm et al. 1988); AT III and antiplasmin by amidolytic assay using S–2238 and S–2251 (Kabi Pharmacia, Stockholm, Sweden), respectively; tissue plasminogen activator by an ELISA (Imulyse, Biopool, Umeå, Sweden); and plasminogen activator inhibitor (PAI) by using the Streptolyse TM/pL kit (Biopool, Umeå, Sweden). Fibrin/fibrinogen degradation products (FDP) were assayed with a latex agglutination inhibition test (Nilsson 1974).

Table 1. Blood loss and transfusion (mL) in the autologous (cell saver) and the homologous (control) group. Mean *SD*

Blood loss and transfusion	Autologous group (cell saver; n 19)		Homologous group (control group; n 20)		
Blood loss					
peroperative	860	*260*	1,240	*580**	
postoperative	608	*261*	960	*407**	
total	1,464	*386*	2,200	*608****	
Transfusion					
peroperative					
autologous	350	*232*	0		
homologous	0		500	*313*	NS
Postoperative					
autologous	0		0		
homologous	206	*261*	320	*265*	NS
total	591	*387*	820	*265**	

*$P < 0.05$, ***$P < 0.001$.

Table 2. Hematologic parameters in the washed and the bank blood. Mean *SD*

Parameter	Autologous group (cell saver; n 19)		Homologous group (control; n 20)		*P*-value
Hemoglobin (g/L)	204	*11*	179	*21*	0.001
Hematocrit (percent)	69	*4*	57	*8*	0.001
Thrombocytes (10^9/L)	2.5	*1.8*	3	*2.2*	NS
White blood cells (10^9/L)	1.6	*1*	0.5	*0.5*	0.001
Free hemoglobin (g/L) (plasma)	4	*2.7*	0.4	*0.4*	0.0001
MCV (fL)	107	*8*	97	*3*	0.001

Analysis of data was done using analysis of variance (ANOVA) and the Student's *t*-test for repeated measures (hematologic and coagulation parameters). The Mann-Whitney *U*-test was used for blood transfusion and blood loss measurements.

Results

No patient in the IAT group received homologous blood intraoperatively, and 2 patients did not have any blood transfused. In the control group, 2 patients did not require transfusion intraoperatively, whereas the remaining patients received an average of 500 mL. Six patients in the IAT group required a homologous blood transfusion after the third postoperative day (average 200 mL) due to low Hb values (Hb < 85g/L; Grindon et al. 1985) or symptoms related to anemia, compared with 10 patients in the control group (average 320 mL). The intraoperative and postoperative blood losses—and hence the total blood loss—were less in the IAT group than in the homologous group (Table 1).

The average Hb and hematocrit of the reinfused blood in the IAT group were respectively 204 g/L and 0.69, and for the bank homologous blood 179 g/L and 0.57. The autologous blood had a higher plasma concentration of hemoglobin compared with the bank homologous blood (Table 2). Also, there were more white blood cells in the autologous blood compared with the homologous blood.

There were no differences as regards the hematologic parameters between the two groups of patients (Table 3). Serum creatinine and potassium, and urinary hemoglobin and urobilinogen were within normal limits in both groups preoperatively and postoperatively, and no differences were observed between the two groups.

Antithrombin III, protein C, and plasminogen decreased postoperatively in both groups (Table 4). No differences were observed between the groups in any of the coagulation parameters tested, and all of them were within normal limits.

No peroperative complications were encountered in either group. Postoperatively, 2 patients in the control group and 3 in the autologous group had deep vein thrombosis, which was diagnosed clinically and verified radiologically.

Discussion

Earlier generations of intraoperative autotransfusion devices were associated with some complications: namely, coagulopathies and pulmonary embolism. The improved devices now deliver blood almost free of these problems (Flynn et al. 1982, Bovil et al. 1986).

The use of IAT in hip arthroplasty was studied by Law and Wiedel (1989) and McMurray et al. (1990). Both demonstrated a substantial reduction in homologous blood transfusion. We performed all of our operations in the IAT group without needing homologous blood. We attribute this to the high rate of salvage (> 50 percent), which produced sufficient blood for transfusion during the operation.

The overall reduction of homologous blood transfusion in the present study was 75 percent. This is comparable to the previously reported figures (McMurray et al. 1990).

The lower intraoperative blood loss in the IAT group may be due to the more thorough use of suction in that group and also to the more extensive use of

Table 3. Hematologic parameters in the autologous (A) and control (H) patients. Mean *SD*

Parameters	Group	Preoperative		Postoperative							
				End of operation		Day 1		Day 4		Day 7	
Hemoglobin g/L	A	133	*13*	102	*12*	95	*7*	94	*11*	103	*12*
	H	134	*10*	102	*13*	96	*9*	98	*9*	102	*11*
Thrombocytes 10^9/L	A	233	*47*	182	*52*	163	*31*	198	*41*	294	*59*
	H	254	*51*	184	*51*	178	*35*	204	*50*	287	*75*
MCV	A	94	*4*	94	*4*	93	*3*	94	*4*	95	*4*
	H	93	*3*	93	*3*	92	*2*	93	*3*	94	*3*
CO Hb percentage	A	1.0	*1*	1.1	*0.6*	1.5	*0.4*	1.0	*0.2*	0.9	*0.6*
	H	1.1	*1.8*	1.3	*0.9*	1.7	*0.6*	1.4	*1.3*	1.2	*1.4*
Haptoglobin g/L	A	2	0.5	1.3	*0.5*	1.1	*0.4*	2.3	*0.5*	2.6	*0.6*
	H	1.8	*0.5*	1.0	*0.5*	1.2	*0.5*	2.0	*0.6*	2.4	*0.7*
Plasma hemoglobin g/L	A	0.02	*0.01*	0.2	*0.2*	0.04	*0.08*	0.01	*0.01*	0.01	*0.01*
	H	0.06	*0.01*	0.2	*0.4*	0.04	*0.04*	0.02	*0.03*	0.01	*0.02*

Table 4. Coagulation parameters for the autologous group (A) and the control group (H). Mean *SD*

Parameter (ref value)	Group	Preoperative		Postoperative			
				End of operation		24 h	
AT III	A	0.9	*0.1*	0.6	*0.09*	0.7	*0.1*
(0.8–1.3 IE/mL)	H	0.9	*0.1*	0.6	*0.06*	0.7	*0.06*
FDP	A	<10		<10		<10	
(<10 mg/L)	H	<10		<10		<10	
PAI	A	12.7	*9*	11.5	*7*	21	*9*
(0–21 IE/mL)	H	7.7	*6*	14.3	*8*	19	*8*
Plasminogen	A	89	*13*	64	*10*	62	*10*
(70–150 percent)	H	91	*14*	61	*9*	62	*10*
Fibrinogen	A	3.6	*1.1*	2.3	*0.3*	3.4	*0.8*
(2–4.5 g/L)	H	3.9	*0.6*	2.2	*0.5*	3.5	*0.5*
Protein C	A	99	*17*	64	*9*	68	*11*
(70–130 percent)	H	98	*19*	56	*11*	62	*11*

sponges in the homologous group. Because the surgical and hemostatic techniques were the same, as were the surgeons who operated on all the patients, we do not think that the blood-loss difference could be attributed to a subconscious difference in the surgical technique. However, the significant difference in postoperative blood loss may be considered more real, as the type of drainage system and the elapsed time period were equivalent in the two groups. The difference in favor of IAT may be due to an influence of the autologous blood on the patients' hemostasis. However, the coagulation parameters studied did not demonstrate any difference. The results as regards the postoperative hematologic parameters of the patients did not differ between the control and the IAT groups. This emphasizes that IAT produces blood of at least the same quality as bank blood. When considering the high hemoglobin concentration in the IAT blood, which had also been previously reported (Ottesen and Froysaker 1982, Keeling et al. 1983), and that the red blood cells are fresh and have more 2.3 diphosphoglycerate (2.3 DPG), and hence more oxygen delivering capacity (McShane et al. 1987), the autologous blood seems to be even better than homologous bank blood. Also, the reduction of the need for homologous blood transfusion in the IAT group is an evident advantage of IAT when considering the associated risks of homologous blood transfusion, such as anaphylaxis, PTH, HIV, and other infections.

The presence of free plasma hemoglobin in the IAT blood was higher compared with the homologous blood. The possibility cannot be excluded that this hemolysis of the red blood cells is an in vitro event, which is due to the treatment of the cells, the composition of the final buffer system, and the time delay before analysis. To investigate whether a substantial amount of free hemoglobin was actually reinfused into the patients and to determine the level of an eventual intravascular hemolysis, we have also measured the concentration of haptoglobin and carbon monoxide

hemoglobin. The concentration of haptoglobin was lowered on the first postoperative day to the same extent, and by approximately 1 g/L in both groups. This finding could be the result of an infusion of free hemoglobin into the patients in the IAT group, but the fact that there were no differences between the two groups makes this assumption unlikely. A slight overhydration of all the patients during the operation and postoperatively is the more likely explanation. An increase in the formation of hemoglobin-haptoglobin complexes followed by a significant decrease in the haptoglobin concentration could not be detected in either of the two groups. The rise in haptoglobin on the two latter sampling occasions reflects the normal postoperative inflammatory response. Thus, no evidence of infusion of significant amounts of free hemoglobin and no signs of ongoing intravascular hemolysis could be observed during the first postoperative week in either of the two groups. The white blood cell count in the IAT blood was high compared with the homologous blood, which did not correlate with the previous reports, where a low (Orr 1978) and a very high (McShane et al. 1987) count were found. The platelet count in the autologous blood in this study was very low, and was similar to the results of Orr (1978). However, it was lower than the number reported by Ottesen and Froysaker (1982) and McShane et al. (1987).

The coagulation study, as mentioned above, did not demonstrate any differences between the groups. In both groups, there was a decrease in the postoperative levels of AT III, protein C, and plasminogen. The decrease in AT III has also been reported earlier following hip arthroplasty (Fredin et al. 1983, Bredbacka et al. 1987). Because the decrease was similar in both groups, we can say that it was probably not due to the use of IAT, which may also strengthen the fact that blood produced by the cell saver is of a quality similar to that of homologous bank blood or even better when considering the other factors mentioned above. However, this decrease in AT III, protein C, and plasminogen may influence the formation of deep vein thrombosis.

We have previously reported that preoperative blood donation (PBD) in primary hip arthroplasty is safe and effective (Elawad et al. 1991). However, IAT continues to be an alternative in cases where PBD is impractical, as in cases of cardiac disease, operation within a short period, religious reasons, or in cases where there are transportation problems. The only contraindications for the use of IAT are known infection or malignancy.

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