Cell quality of salvaged blood after total knee arthroplasty

Drain blood compared to venous blood in 32 patients

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We used the ConstaVac® drainage retransfusion system in 32 patients operated on with cemented tricompartmental knee arthroplasty. The mean total postoperative bleeding was 1.1 L of which 0.7 L was retransfused within 8 hours postoperatively. Samples were taken from the venous blood and drain blood at 2 hours and 6–8 hours postoperatively. The drain blood had low counts for leukocytes and thrombocytes as compared to venous blood, and fibrinogen was almost absent. Incubation at room temperature slightly lowered glucose and pH which made the erythrocytes swell. There was a slight hemolysis in the drain blood at 2 hours. At 6–8 hours the shed blood was closer to normal, especially with regard to hemolysis, but there was a further decrease in glucose. Within this time, there was no change in acidity and no further swelling of the erythrocytes. No clinical adverse reactions were observed and we consider the observed cellular and chemical changes to be of little importance. The quality of filtered drain blood within the analyzed time limit is considered acceptable for clinical use.

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Autotransfusion of blood has become common in orthopedic operations (Toy 1990, Rosenberg 1992). Primary arthroplasty of either hip or knee has an estimated total bleeding of 1.5 L (Lotke et al. 1991). In hip arthroplasty approximately half of the bleeding occurs during the operation and the other half after the operation. However, in knee arthroplasty, performed with the use of a tourniquet, almost all bleeding occurs postoperatively (Lotke et al. 1991). Therefore it is suitable to use postoperative drain blood collection systems in knee arthroplasties. Shed blood from orthopedic wounds, in contrast to wounds in vascular and cardiac surgery, may be contaminated with bone fragments, fat particles and methyl methacrylate monomers (Healy et al. 1993). A washing procedure is advisible before retransfusion (Clements et al. 1992).

We analyzed and compared the cellular quality of drain blood with that of circulating blood during the recommended extracorporeal incubation time of 6–8 hours at room temperature.

Material and methods

Patients

32 patients, 19 women, with a mean age of 70 (56–80) years were operated with a tricompartmental knee prosthesis. The diagnosis was arthrosis in 25 patients, rheumatoid arthritis in 6 and gout arthritis in 1 patient. The patients with arthrosis participated in parallel studies on prosthesis fixation, with different prostheses designs. All femoral and tibial components were fixed with bone cement. All patients received low molecular heparin subcutaneously once daily from the evening before operation. A tourniquet was routinely used and was released after wound closure, except in 10 cases where the tourniquet was released just before closure of the wound (tourniquet time 111 ± 5 min, mean ± sem). The leg was exsanguinated with a rubber roller before the tourniquet was inflated. Spinal or epidural anesthesia was used. Postoperative analgesia was maintained by continuous epidural infusion of bupivacain, supplemented with i.v. injections of morphine on the first postoperative day.

Autotransfusion

All patients received a ConstaVac® (Stryker, Kalamazoo, MI 49001, U.S.A.) autotransfusion drain postoperatively. This system consisted of a plastic container of 800 mL. The blood first passed a 240 µm filter before entering the container. No anticoagulant

Table 1. Blood parameters of 32 patients before knee arthroplasty

	Mean	SEM	Reference values
Hb (g/L)	139	2.6	115–150
EC (10^{12}/L)	4.7	0.1	3.7–4.8
EVF (%)	40	1.4	35–44
MCV (fl.)	88	0.8	80–100
LC (10^9/L)	7.4	0.4	3.5–9.0
PC (10^9/L)	297	19	150–350

Hb hemoglobin, EC erythrocyte count, EVF erythrocyte volume fraction, MCV mean cell volume, LC leukocyte count, PC platelet count.

was used. The container had a constant suction pressure which was held below 70 mm Hg. When emptying the container, the last 100 mL always remained at the bottom of the container and was not reinfused. During reinfusion, the blood passed through another filter of 40 µm pore size. All patients were observed at a postoperative care unit the first 24 hours, with continuous recording of pulse, ECG, oxygen saturation and frequent recordings of blood pressure, body temperature and pain. After the first day, the patients were observed on a regular orthopedic ward, with documentation of possible adverse reactions, such as temperature reactions, episodes of hypotension, clinical signs of thrombosis, embolism or infection.

Additional homologous blood transfusions were avoided during the first 8 postoperative hours. After that time, patients were transfused with homologous blood when needed, according to our standard routines—i.e., if the hemoglobin fell below 90 g/L or if the patient had obvious clinical signs of anemia. All units of blood were recorded. Shed blood was reinfused within the first 8 postoperative hours, provided the collected blood volume exceeded 200 mL.

Blood sampling and analysis

Samples were taken from the shed blood in the container at 2 hours and 6–8 hours postoperatively. The timing of blood reinfusions was done independently of the blood sampling. We measured the erythrocyte count (EC), leukocyte count (LC), platelet count (PC), hemoglobin (Hb), erythrocyte volume fraction (EVF) and mean cell volume (MCV) by a standard Coulter counter technique. Glucose, acidity (pH), plasma hemoglobin (p-Hb), fibrin degradation products (FDP, D-dimer) and fibrinogen were analyzed by the standard techniques in our hospital. The FDP data were measured in classes and grouped; 1, 2, 3, 4, 5 and 6, denoting FDP <0.5, 0.5–1, 1–2, 2–4, 4–8, >8 mg/L, respectively.

Statistics

Mean values ± SEM are given. For statistical analysis, the paired t-test was used.

Results

Pre- and peroperative data

The patients had a preoperative blood status that was within normal range (Table 1). The patients had a mean peroperative bleeding of 296 ± 91 mL which blood was discarded.

Postoperative data

The mean total postoperative bleeding was 1144 ± 95 mL of which 668 ± 91 mL was retransfused. No patient received an additional homologous transfusion during the first 8 postoperative hours—i.e., the time during which the ConstaVac® system was used for retransfusion. After that time, the patients were given an average of 1.8 ± 0.3 units of homologous

Table 2. Blood parameters of venous and drain blood 2 and 6–8 hours postoperatively

	Venous blood, 2 h			Drain blood, 2 h			Venous blood, 6–8 h			Drain blood, 6–8 h		
	Mean	SEM	n	Mean	SEM	n	Mean	SEM	n	Mean	SEM	n
Hb (g/L)	115	3	32	109	3	30	114	3	25	116	5	27
EC (10^{12}/L)	3.8	0.1	32	3.7	0.1	29	3.8	0.1	25	3.9	0.2	26
EVF (%)	34	0.9	32	32	1.0	28	33	0.9	25	34	1.6	26
MCV (fl.)	88	0.9	32	88	1.0	28	89	0.9	25	89	0.9	23
LC (10^9/L)	10.4	0.8	32	3.2	0.2	30	12.4	0.7	25	6.5	0.7	27
PC (10^9/L)	220	19	32	42	2.3	30	213	23	25	87	12	27
Glucose (mmol/L)	6.6	0.5	28	5.6	0.4	27	7.5	0.6	22	4.4	0.4	22
pH	7.34	0.01	30	7.22	0.02	30	7.34	0.01	26	7.11	0.06	26
p-Hb (g/L)	31	5.7	30	564	53	30	28	3.5	23	417	48	25
FDP (mg/L)	3.6	0.4	27	6.1	0.1	28	5.5	0.2	23	6.1	0.1	22
Fibrinogen (g/L)	2.8	0.1	28	0.1	0.1	25	2.6	0.2	23	0.0	0.0	22

Hb hemoglobin, EC erythrocyte count, EVF erythrocyte volume fraction, MCV mean cell volume, LC leukocyte count, PC platelet count, p-Hb plasma hemoglobin, FDP fibrin degradation products.

Table 3. Differences between drain (D) and venous blood (B) at 2 hours and 6–8 hours postoperatively

	D2–B2			D7–B7		
	Mean	SEM	p-value	Mean	SEM	p-value
Hb (g/L)	–6.9	3.3	0.045	5.5	4.5	0.229
EC (10^{12}/L)	–0.2	0.1	0.048	0.2	0.2	0.208
EVF (%)	–2.0	1.0	0.066	2.1	1.4	0.145
MCV (fl.)	0.5	0.2	0.051	0.7	0.2	0.002
LC (10^9/L)	–7.5	0.8	0.000	–5.7	0.7	0.000
PC (10^9/L)	–180	19	0.000	–124	14	0.000
Glucose (mmol/L)	–0.9	0.3	0.009	–3.3	0.7	0.000
pH	–0.12	0.03	0.000	–0.23	0.06	0.001
p-Hb (g/L)	533	53	0.000	362	53	0.000
FDP (mg/L)	2.4	0.4	0.000	0.7	0.3	0.027
Fibrinogen (g/L)	–2.7	0.1	0.000	–2.6	0.2	0.000

Hb hemoglobin, EC erythrocyte count, EVF erythrocyte volume fraction, MCV mean cell volume, LC leukocyte count, PC platelet count. p-Hb plasma hemoglobin, FDP fibrin degradation products.

Table 4. Differences between 6–8 hours and 2 hours in venous (B) and drain blood (D), respectively

	B7–B2			D7–D2		
	Mean	SEM	p-value	Mean	SEM	p-value
Hb (g/L)	–3.0	1.7	0.089	7.4	6.3	0.249
EC(10^{12}/L)	–0.1	0.1	0.075	0.2	0.2	0.314
EVF (%)	–0.9	0.5	0.084	2.0	2.0	0.339
MCV (fl.)	0.2	0.3	0.435	0.3	0.3	0.191
LC (10^9/L)	1.9	0.8	0.028	3.5	0.7	0.000
PC (10^9/L)	–16	7	0.027	49	12	0.000
Glucose (mmol/L)	1.3	0.8	0.131	–1.0	0.4	0.023
pH	0.00	0.01	0.734	–0.10	0.07	0.172
p-Hb (g/L)	–1.4	4.4	0.746	–142	46	0.005
FDP (mg/L)	1.8	0.5	0.001	0	0	
Fibrinogen (g/L)	–0.2	0.1	0.085	–0.1	0.1	0.329

Hb hemoglobin, EC erythrocyte count, EVF erythrocyte volume fraction, MCV mean cell volume, LC leukocyte count, PC platelet count,. p-Hb plasma hemoglobin, FDP fibrin degradation products.

erythrocyte concentrate during the first postoperative days. 9 patients received no homologous blood and 9 patients received only 1 unit of blood during the postoperative stay.

The blood status of venous and drain blood were analyzed at 2 hours and at 6–8 hours after the operation (Table 2). There was a decrease in hemoglobin and increase in the leukocyte count in venous blood at 2 hours compared to preoperative values. There was also a slight increase in FDP values compared to normal. Drain blood at 2 hours showed a hemoglobin decrease and a marked decrease in leukocytes and platelets. Plasma hemoglobin was increased and fibrinogen was not detectable, except in 1 patient.

There were differences between drain and venous blood at 2 hours (D2-B2) and 6–8 hours (D7-B7) in all blood parameters, except for EVF and MCV (Table 3). At 7 hours there were differences except in the case of Hb, EC and EVF. There was an increase in FDP in venous blood with time. In drain blood, leukocytes, platelets and plasma hemoglobin gradually tended to normalize (closer to venous blood), whereas glucose continued to fall (Table 4). Glucose was reduced significantly after drain incubation, pH was lowered and MCV indicated further, but no significant, swelling. No clinical adverse reactions were noted in our 32 patients.

Discussion

We have compared the quality of shed blood to that of venous blood, in order to characterize the drain blood as a product. One third of the patients received no

additional homologous blood, whereas the remaining patients received one or more units during the postoperative period. In a critical analysis, homologous blood transfusions were not necessarily indicated in another third of the patients, but they were given blood according to previous routines. Recently, we showed that the need for homologous blood was reduced to one third of the patients by using only drain retransfusion (Dalén et al. 1992).

2 hours postoperatively, drain blood had a 5 percent lower hemoglobin content than the circulating blood. This may reflect various parallel phenomena; first one must consider that the drain container accumulates blood over time and thus represents an average composition that is not exactly comparable to the circulating pool of blood cells at a given time. However, by comparing the venous blood at 2 and 6–8 hours, it is evident that the circulating blood remains fairly constant with time and does not interfere with the analysis of drain blood. It is tempting to assume that the reduction in drain blood hemoglobin results from hemolysis in the wound but, although the plasma hemoglobin is markedly increased in the drain blood, 564 g/L versus 31 g/L in the venous blood, this represents only about 0.5 percent of the total amount of erythrocytes. A more plausible explanation is that saline solutions used during operation for cleansing the wound and for tissue exudation, dilute the hemoglobin of the initial drain blood volumes. This is further supported by the absence of differences in erythrocyte concentration between venous and drain blood 6–8 hours postoperatively. Interestingly, leukocytes and platelets were reduced by 70 and 81 percent, respectively, in the drain at 2 hours, probably because of consumption in the wound. This decrease in leukocytes could be one explanation why—although we have an activation of the complement system, which has been reported (Bengtson et al. 1990)—clinical reactions are rare. Fibrinogen was totally consumed in drain blood by all patients except one, and thus no clotting was seen, not even in the patient with detectable fibrinogen. This observation confirms the view that no anticoagulant is needed in the container (Faris et al. 1991, Healy et al. 1994). In the drain blood there was also seen a rise in FDP that relates to the consumption of fibrinogen. At room temperature, incubated blood glucose is consumed, primarily via anerobic oxidation, to lactate by the erythrocytes. Thus plasmaglucose in the drain was 16 percent lower than in the blood and, due to lactate production, pH decreased from 7.34 to 7.22. Acid pH is known to interfere with the ion channels in the red cell membrane and causes cell swelling (Engström and Meiselman 1991).

Results at 6–8 hours postoperatively were similar to those at 2 hours. However, the blood parameters in the drain were, in fact, closer to those in the circulating blood. Hemoglobin was about the same and the leukocyte and platelet counts remained reduced, but less pronounced. MCV continued to increase as pH was lowered, although these changes did not become significant compared to the 2-hour measurements. With time, as additional blood filled the drain container, the amount of plasma hemoglobin declined, suggesting that this newer drain blood was less traumatized in terms of hemolysis.

The absence of adverse reactions accords with the findings of others (Bengtson et al. 1990, Kristensen et al. 1992, Blevins et al. 1993, Healy et al. 1994), although some authors have reported clinical complications between 2 and 25 percent of their patients within 6 hours after reinfusion (Faris et al. 1991, Clements et al. 1992, Martin et al. 1992). Because of reported complications, some authors have recommended that the drain blood be washed prior to retransfusion. The washing procedure partly removes activated leukocytes, cytokines and free hemoglobin, but also important plasma proteins—for example, coagulation factors and immunologically active proteins. In addition, a substantial portion of the erythrocytes is lost during washing (McMurray et al. 1990 and our unpublished observations) and, further, the washing procedure may damage the erythrocytes. Isotonic sodium chloride is used to wash and suspend the erythrocytes; this medium is not balanced in terms of ionic content or pH, and it has no buffering capacity. Since no glucose is present, the cell metabolism becomes static and there is no erythrocyte membrane protection, such as that given by albumin. In experimental blood research, sodium chloride is not acceptable (Bull et al. 1986) and even small variations in sodium chloride concentration may cause dramatic changes in erythrocyte function and may affect the ionic balance across the membrane (Engström and Täljedal 1986, Engström and Täljedal 1989). This study deals with the cellular and chemical changes observed in salvaged drain blood. Results of the present study do not indicate the need for washing procedures of the drain blood.

We conclude that postoperative drain blood after knee replacement surgery differs from circulating blood, especially with regard to leukocyte and platelet counts, and that incubation at room temperature causes additional changes in the blood. However, the general quality of drain blood appears acceptable and, in fact, improves with time after surgery with respect to hemolysis.

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