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Quality of the Blood Sampled From Surgical Drainage after Total Hip Arthroplasty

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A B S T R A C T

Several methods have been found to be successful in reducing the need for allogeneic transfusion among the patients undergoing total hip replacement. The purpose of this prospective study was to analyse the quality and evaluate the effect of postoperative autotransfusion on the need for allogeneic transfusion following total hip replacement. The prospective study was performed in two groups of patients undergoing total hip replacement. Before the operative procedure all patients in both groups predonated two doses of autologous blood. In GROUP 1. the system for postoperative collection and transfusion of shed blood was used. In GROUP 2. the patients underwent total hip replacement without blood salvage system. Standard suction collection sets were used postoperatively. In this group shed blood was not transfused to the patients. The samples of preoperative donated autologus blood, allogeneic blood and postoperative collected autologous blood were analysed for number of red cells, hemoglobin, hematocrit, platelets, white blood cells, values of potassium, sodium, free hemoglobin and acid base status. The postoperatively blood salvage significantly reduced the use of allogeneic transfusion among patients managed with total hip replacement (allogeneic transfusion received 12 % patients in Group 1 and 80% patients in Group 2; $p<0.001$). The values of red blood cells are significantly lower in postoperative collected autotransfusion blood compared with preoperative collected autologous blood and allogeneic blood ($p<0.001$). The values of potassium and acid base status were in normal range in postoperatively collected autotransfusion blood. These values in preoperatively collected autologous blood and allogeneic blood were out of normal range; ($p<0.001$). In addition to reducing the risk of complications that are associated with allogeneic transfusion, postoperative blood salvage may offer benefits including reducing the need for allogeneic blood. Our study confirmed that postoperative collection and transfusion of drainaged blood is simple and safe method that significantly reduce the need for allogeneic transfusion in patients underwent total hip replacement. The blood collected and transfused postoperatively has lower values of red blood cells and normal values of potassium and acid base balance. The transfusion of this blood caused no complications in our patients.

***Key words**: postoperative autotransfusion, quality of blood*

Introduction

During the preoperative, intraoperative and postoperative periods autologous blood may be considered as an alternative to allogeneic blood. Postoperative blood salvage is a simple method employing autologous blood that would normally be discarded. During the process of postoperative autotransfusion a wound drainaged blood is collected with autotransfusion system and transfused to patient using microfilters. This method has become popular in major orthopaedic procedures like total hip and total knee replacement. Postoperative blood loss after total hip replacement is in the range of 700–1500 mL[1,2] and after total knee replacement from 1000–2000 mL[3,4].

Although reinfusion of salvaged shed blood is commonly used, this blood saving technique is still controversial. Questions have been raised, however about the quality of this blood and the related risks for the pa-

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tients. Postoperatively collected drainage blood contains wound debris, bone and fat particles and the presence of bone cement is confirmed. Drainage blood is deficient with coagulation factors and platelets, but cytokines, degradation products, fibrin split products and complement activation factors are increased[5–8].

The quality of postoperatively collected shed blood is widely investigated. There are many studies analysing levels of red blood cells and hemoglobin, but there is no study where number of white blood cells, platelets, potassium, sodium, free hemoglobin and acid base balance is investigated.

The purpose of this study is to analyse the effect of postoperative autotransfusion on need for allogeneic transfusion and to determine the quality of postoperatively collected drainaged blood and to compare it with other blood sources. The values of red blood cells (RBC), platelets (PLT), white blood cells (WBC), sodium (Na), potassium (K), acid-base balance and free hemogobin in postoperative autotransfused blood are compared with values in preoperative autologous donated blood (PAD) and in allogeneic blood.

Material and Methods

We performed a prospective and controlled study involving two groups of patients scheduled for primary total hip replacement. After a full explanation of the aims and risks of the study, whose experimental protocol was approved by the local ethics committee, written informed consent was obtained from all patients. The patients were randomly allocated into a reinfusion Group 1 or in a control Group 2. In Group 1. consisting of 30 patients who underwent uncemented total hip arthroplasty the system for postoperative autotransfusion was used. In Group 2 including also 30 patients who underwent uncemented total hip arthroplasty the system for postoperative autotransfusion was not used. All patients underwent spinal anaesthesia with 0.5% bupivacain. Low molecular weight heparin (Fraxiparin^R) started evening before sugery was used as thromboprophylaxis. Prophylactic antibiotics (first generation of cephalosporines) were administered to all patients before the induction of anesthesia and was continued for 24 hours postoperatively. Volume deficits were substituted with crystalloid and colloid solutions given during and day after surgery. The patients were monitored (ECG, non-invasive blood pressure and oxygen saturation of peripheral blood) for 24 hours after the surgical procedure. Both surgical drains were removed 48 hours postoperatively.

The autotransfusion system

The BIODREN system, BE.R.CO. s.p.a. (Modena, Italy) is a closed, autologous blood recovery system designed for postoperative collection, filtering and reinfusion of shed blood. The vacuum pump provides an adjustable constant vacuum, kept below 100 mm Hg to avoid excessive haemolysis, according to recommendations of the American Association of Blood Banks (AABB 1990). The system is connected to two CH 14 drains during the final stage of the operation and active suction is initiated after closure of the skin. When collection of shed blood in the reservoir is completed (600 mL of blood is collected or after maximum of 360 minutes of collection is passed) the blood flows through a 260 micron filter to the blood bag, from which autotransfusion through a 40 micron filter (PALL blood transfusion set) is done.

Before the reinfusion the blood samples were drawn to analyse the values of red blood cells (RBC), white blood cells (WBC), platelets (PLT), potassium (K), sodium (Na), acid-base balance and free hemoglobin. The acid-base balance was evaluated by measuring pH, base excess index (BE), the partial pressures of oxygen (pO_2) and carbon dioxid (pCO_2), and the oxygen saturation of Hb (SaO_2). The blood samples also were drawn from bag with preoperatively collected autologous and allogeneic blood. The blood samples from allogeneic blood were drawn immediately before transfusion after dilution (350 mL concentrated red blood cells were diluted with 100 mL normal saline).

The values of red blood cells, white blood cells and platelets were determined with method of impendantion; the values of hemoglobin (Hb) level with hemoglobin cyanhemoglobin metfod; hematocrit (Hct) level with method of numeric integration. The values of sodium, potassium and acid base status are measured using potentiometric method.

Patients in both group received blood products to maintain a hemoblogin level of 100 g/L or hematocrit level of 30%.

Results are presented using descriptive statistic. A comparison between the groups were performed by Student t test. and Mann Whitney test. The results were reported as mean ± standard deviations. $P<0.05$ was considered statistically significant.

Results

A total of 60 patients were enrolled in the study, 30 in each group. There were no significant differences be-

TABLE 1
PATIENTS CHARACTERISTICS DATA, DURATION OF OPERATION, BLEEDING AND TRANSFUSION ARE PRESENTED

	Group 1	Group 2	p
N	30	30	
Age	68±12	71±11	
Ratio (M/F)	14/16	12/18	
Duration of operation (min)	92±18	96±24	>0.05
Intraoperative bleeding (mL)	407±211	473±189	>0.05
Postoperative bleeding (mL)	1027±364	899±297	>0.05
Total bleeding (mL)	1434±374	1372±345	>0.05
Tranasfusion of PDA (mL)	733±365	950±153	<0.05
Allogeneic transfusion (mL)	67±293	522±346	<0.001

tween both groups regarding age, body mass index, type of surgery, type of anesthesia and transfusion trigger (Table 1). All patients in both groups predonated two units of autologous blood.

TABLE 2
VALUES OF RED BLOOD CELLS, PLATELETS, FREE HEMOGLOBIN, WHITE BLOOD CELLS, DIFERENTIAL WHITE BLOOD CELLS, K AND Na, ACID BASE BALANCE IN POSTOPERATIVE COLLECTED SHED BLOOD

	X	SD	C	Min	Maks	N
RBC ($\times 10^6/cm^3$)	3.11	0.74	3.01	1.89	4.06	30
Hb	81	21	78	51	119	30
Htc	0.25	0.07	0.24	0.17	0.37	30
PLT ($\times 10^3/mm^3$)	52	28	51	7	123	30
Free Hb (mg %)	348	223	368	150	900	30
WBC ($10^3/L$)	3.4	1.7	3.2	0.9	6.3	30
Segm. (%)	54	17	56	23	78	30
Nonsegm. (%)	5	5	3	0	20	30
Lymphocytes (%)	34	19	29	12	77	30
K (mmol/L)	4.21	0.57	4.15	3.1	5.5	30
Na (mmol/L)	145	3	145	138	149	30
pH	7.38	0.6	7.39	7.21	7.41	30
SaO_2 (%)	92.9	4.0	93.4	83.1	98	30
pO_2 (mm Hg)	14.76	2.94	14.20	11.1	20.4	30
pCO_2 (mm Hg)	6.61	1.05	6.56	4.49	8.22	30
HCO_3 (mmol/L)	16.5	4.0	16.9	10.3	24.4	30
BE (mEq/L)	–12.1	4.5	–12.7	–19.9	–4.7	30

RBC – red blood cells, Hb – hemoglobin, PLT – platelets, Htc – hematocrit, Free Hb – free hemoglobin, SaO_2 – oxigen saturation, pO_2 – partial pressure of oxigen, pCO_2 – partial pressure of CO_2, BE – base excess index

TABLE 3
VALUES OF RED BLOOD CELLS, PLATELETS, FREE HEMOGLOBIN, WHITE BLOOD CELLS, DIFERENTIAL WHITE BLOOD CELLS, K AND Na, ACID BASE BALANCE IN PREOPERATIVE COLLECTED AUTOTRANSFUSED BLOOD

	X	SD	C	Min	Maks	N
RBC ($\times 10^6/cm^3$)	4.51	2.01	3.71	2.65	6.2	30
Hb	131	62	108	97	258	30
Htc	0.40	0.19	0.33	0.25	0.78	30
PLT ($\times 10^3/mm^3$)	138	89	143	0	404	30
Free Hb (mg %)	178	224	104	33	920	30
WBC ($10^3/L$)	5.2	2.6	4.7	1.7	11.1	30
Segm. (%)	48	18	51	5	86	30
Nonsegm (%)	4	2	5	0	8	30
Lymphocytes (%)	43	17	40	9	90	30
K (mmol/L)	11.4	4.2	11.3	4.1	18.6	30
Na (mmol/L)	149	4	150	142	157	30
pH	6.8	1.2	6.9	5.8	7.2	30
SaO_2 (%)	27.3	12.7	24.4	7.4	52.2	30
pO_2 (mm Hg)	5.71	1.07	5.58	3.96	7.63	30
pCO_2 (mm Hg)	14.62	4.14	15.10	3.96	21.46	30
HCO_3 (mmol/L)	13.4	3.2	13.5	6.8	18.9	30
BE (mEq/L)	–21.8	5.0	–22.5	–29.7	–6.8	30

RBC – red blood cells, Hb – hemoglobin, PLT – platelets, Htc – hematocrit, Free Hb – free hemoglobin, SaO_2 – oxigen saturation, pO_2 – partial pressure of oxigen, pCO_2 – partial pressure of CO_2, BE – base excess index

TABLE 4
VALUES OF RED BLOOD CELLS, PLATELETS, FREE HEMOGLOBIN, WHITE BLOOD CELLS, DIFERENTIAL WHITE BLOOD CELLS, K AND Na, ACID BASE BALANCE IN ALLOGENEIC BLOOD

	X	SD	C	Min	Maks	N
RBC ($\times 10^6/cm^3$)	5.32	1.03	5.02	3.44	7.46	30
Hb	156	30	151	103	230	30
Htc	0.49	0.10	0.49	0.30	0.72	30
PLT ($\times 10^3/mm^3$)	57	53	42	0	177	30
Free Hb (mg %)	317	379	218	25	1583	30
WBC ($10^3/L$)	3.6	2.2	3.0	1.0	7.0	30
Segm. (%)	37	17	36	14	65	30
Nonsegm (%)	3	3	2	0	8	30
Lymphocytes (%)	57	17	51	30	80	30
K (mmol/L)	17.5	6.8	17.7	6.1	32.5	30
Na (mmol/L)	140	9	144	125	153	30
pH	6.42	0.6	6.71	6.2	6.9	30
SaO_2 (%)	21.5	6.3	20.0	11.9	35.7	30
pO_2 (mm Hg)	5.70	1.14	5.34	4.47	8.50	30
pCO_2 (mm Hg)	13.15	4.62	12.45	5.45	24.00	30
HCO_3 (mmol/L)	8.1	2.8	7.5	4.1	15.1	30
BE (mEq/L)	–24.9	3.6	–25.5	–29.8	–14.3	30

RBC – red blood cells, Hb – hemoglobin, PLT – platelets, Htc – hematocrit, Free Hb – free hemoglobin, SaO_2 – oxigen saturation, pO_2 – partial pressure of oxigen, pCO_2 – partial pressure of CO_2, BE – base excess index

In Group 1. a mean of 686 mL (250–1200) of whole blood was collected and returned postoperatively with a mean time of collection of 90 min (30–360).

Preoperatively donated autologous blood (PAD) was transfused according blood loss and level of hemoglobin. The average amount of PAD transfused to patients was 733 mL (0–1000 mL; SD 365) in Group 1 and 950 mL (500–100 mL, SD 153) in Group 2. All patients in Group 2 and 24 patients in Group 1 needed transfusion of PAD.

Allogeneic blood was transfused if the value of hemoglobin was under 100 after transfusion of autologous blood. 4 patients in Group 1 (12%) and 24 patients in Group 2 (80%) needed allogeneic blood perioperatively. The average volume of transfused allogeneic blood was 67 mL in Group 1 and 522 mL in Group 2. (Figure 1).

The samples of PAD, allogeneic blood and postoperative autologous shed blood were analysed for the values of red blood cells (RBD), hemoglobin (Hb), hematocrit (Htc), platelets (PLT), free hemoglobin, sodium (Na), potassium (K) and acid-base balance. These values are presented in Table 2, 3, 4 and in Figure 1, 2, 3 i 4 and 5.

The mean level of RBC in preoperatively collected autologous blood was $4.51 \times 10^{12}/L$ (2.65–6.20;SD 2.01); the level of Hb was 131 g/L (97–258; SD 62); the level of Htc was 0.40 (0.25–0.78; SD 0.19). The level of PLT was 138×10^3 /mm^3 (0–404; SD 89).

In samples taken from allogeneic blood these values were: RBC $5.32 \times 10^{12}/L$ (3.44–7.46; SD 1.03) Hb 156 g/L (103–230; SD 30) Htc 0.49 (0.30–0.72; SD 0.10). The level of PLT was 57×10^3 /mm^3 (0–177; SD 53).

In samples taken from postoperatively collected autologous blood these levels were: RBC $3.11 \times 10^{12}/L$ (1.89–4.06; SD 0.74); Hb 81 g/L (51–119; SD 21) and Htc 0.25 (0.17–0.37). The level of PLT was $52 \times 10^3/mm^3$ (7–123; SD 28).

There are statistically significant differences between value of red blood cells, hemoglobin and hematocrit between sources of blood ($p<0.001$; Table 5 and 6).

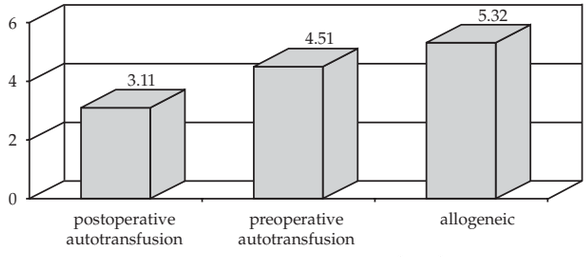

Fig. 1. Red blood cells ($\times 10^6/cm^3$).

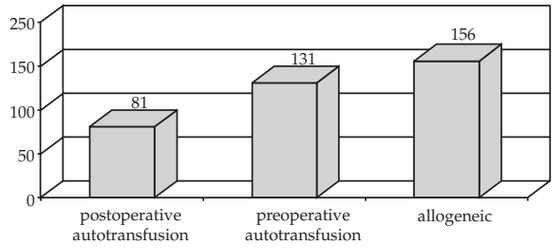

Fig. 2. Hemoglobin.

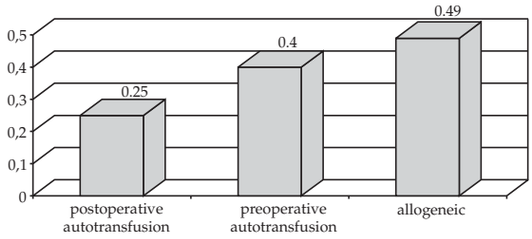

Fig. 3. Hematocrit.

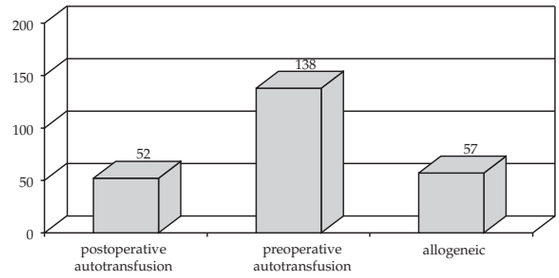

Fig. 4. Platelets (× 10^3/mm^3).

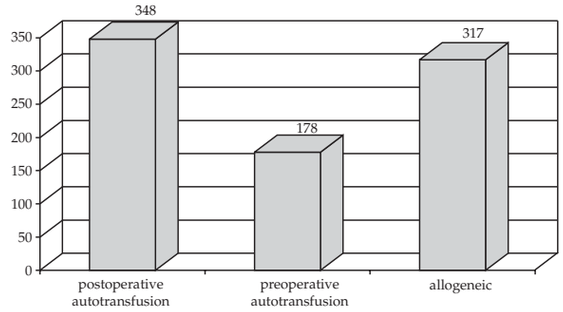

Fig. 5. Free hemoglobin (mg%).

The mean level of free hemoglobin was 348 mg % (150–900) in postoperative autologous blood; the mean level in allogeneic blood was 317 mg % (25–1583!); the lowest level was in preoperative autologous blood 178 mg % (33–920). There is statistically significant difference among preoperative and postoperative autologous blood ($p<0.05$); there is no statistically significant difference among preoperative autologous and allogeneic blood. ($p>0.05$); (Table 5 and 6).

The value of white blood cells (WBC) in postoperative autologous blood was 3.4 ± 1.7 × 10^9/L (0.9–6.3); this value in preoperative donated autologous blood was 5.2 ± 2.6 × 10^9/L (1.7–11.1) and in allogeneic blood 3.6 ± 2.2 × 10^9 /L (1.0–7.0).

The differential white blood cell count showed changes in values of lymphocytes. The mean value of lymphocite in postoperative autologous blood was 34 ± 19 % (12–77); in preoperative autologous blood mean level was 43 ± 17 % (9–90); in allogeneic blood 57 ± 17 % (30–80). The percent of lymphocytes is increased and consenquently the percent of polymorphonuclear leukcytes is decreased.

Comparative analysis of these values is presented in table 5 and 6. The mean level of lymphocytes in postoperative autologous blood is significant lower compared with level in preoperative autologous and allogeneic blood.

The concentration of potassium (K) in postoperatively collected shed autologous blood was 4.21 ± 0.57 mmol/L (3.1–5.5); The concentration in preoperatively collected autologous blood was 11.4 ± 4.2 mmol (4.1–18.6); and in allogenic blood 17.5 ± 6.8 mmol/L (6.1–32.5). There is statistically significant difference between values of potassium in postoperatively collected shed blood with preoperatively autologous blood and allogeneic blood. These results are presented in Tables 2–6.

The concentation of sodium (Na) in postoperatively collected shed autologous blood was 145 ± 3 mmol/L (138–149); The concentration in preoperatively collected autologous blood was 149 ± 4 mmol/L (142–157), and in allogeneic blood 140 ± 9 mmol/L (125–153).

TABLE 5
A COMPARISON BETWEEN POSTOPERATIVE AND PREOPERATIVE COLLECTED AUTOLOGOUS BLOOD

	t	df	p
RBC (× 10^6/cm^3)	–3.24	58	<0.001
Hb	–3.87	58	<0.001
Htc	–4.14	58	<0.001
PLT (× 10^3/cm^3)	–4.08	58	<0.001
Free hemoglobin (mg %)	3.39	58	<0.05
Leukocytes (%)	–2.45	58	<0.05
Potassium (mmol/L)	–6.04	58	<0.001
Sodium (mmol/L)	–4.14	58	<0.001
pH	19.7	58	<0.05

Statistically significant diferences are between all parameters ($p<0.05$); RBC – red blood cells, Hb – hemoglobin, PLT – platelets, Htc – hematocrit.

TABLE 6
A COMPARISON BETWEEN POSTOPERATIVE AUTOLOGOUS AND ALLOGENEIC BLOOD

	T	df	p
RBC (× 10^6/cm^3)	–8.11	58	<0.001
Hb	–9.95	58	<0.001
Htc	– 9.84	58	<0.001
PLT (× 10^3/cm^3)	–0.31	58	>0.005
Free hemoglobin (mg %)	1.03	58	>0.05
Leucocytes (%)	0.96	58	>0.05
Potassium (mmol/L)	–9.21	58	<0.001
Sodium (mmol/L)	2.23	58	<0.05
pH	32.1	58	<0.05

Statistically significant differences are among values of red blood cells, potassium, sodium and pH ($p<0.05$). RBC – red blood cells, Hb – hemoglobin, PLT – platelets, Htc – hematocrit.

Acid base balance is presented in table 2, 3, and 4. The average pH in postoperatively collected autologous blood was 7.38 ± 0.6; pH in preoperatively collected autologous blood was 6.8 ± 1.2 and 6.42 ± 0.6 in allogeneic blood.

The oxygen saturation was 92.9 ± 4.0 % (83.1–98) in postoperatively collected autologous blood; this value is only 27.3 ± 12.7 % (7.4–52.2) in preoperatively collected autologous blood and 21.5 ± 6.3 % (11.9–35.7. in allogeneic blood. The partial pressure of oxygen of l4. 76 ± 2.94 kPa (11.1–20.4) was highest in postoperatively collected blood. There is statistically significant difference between postoperatively collected autologous blood and other sources of blood.

Discussion

Postoperative drainage and return of shed unwashed blood within 6 hours postoperatively is becoming an alternative to allogeneic blood transfusion**.** Autotransfusion of shed unwashed blood has been reported to reduce the need for allogeneic blood transfusion[6–8].

Collection, filtering and transfusion of shed, unwashed blood after total hip replacement surgery is an advantageous procedure, but complications are possible. Several cases of immunologic reactions, febrile nonhemolytic reactions and immune and nonimmune hemolysis have been reported[9,10]. These complications are caused by cellular and humoral activation products and bioactive substances. Some authors found reasons against the retransfusion of unwashed blood, and postulated that washing of shed blood is obligatory[2].

During the transfusion of shed blood patients febrile reactions are posssible. Several studies reported febrile reactions after transfusion of shed blood. Wixson et al.[9] reported febrile reactions in 12 % of patients. Faris et al.[5] reported febrile reactions in 16 of 154 patients after transfusion of shed blood if the blood is collected 12 hours postoperatively, and in only 2 of 99 patients when the blood is collected under 6 hours. The possible cause of febrile reactions after transfusion of shed blood are high levels of cytokines. The cytokines Interleukin–6 and tumor necrosis factor (TNF) are released in association with trauma, surgical trauma, sepsis and haemorhage. During retransfusion the patients were exposed to high levels of Interleukin – 6 wich is potent pyrogen. (10) In our study in Group 1 short shiverring episodes were noticed in two patients during the transfusion of shed blood. It seems possible that immediate postoperative hypothermia caused by infusion of non warmed solutions perioperatively caused a shiverring. These episodes were short and were accompanied with no rise in temperature.

In Group1 the need for allogeneic transfusion was reduced. Only 4 patients in group 1 (12%) needed allogeneic transfusion, but 24 patients in group 2 (80%) The need for transfusion of predonated autologous blood was also reduced in Group 1. The average amount of preoperatively collected autologous blood transfused to patients was 733 mL in Group 1 and 950 mL in Group 2. All patients in group 2 and 24 patients in group 1 needed transfusion of predonated autologous blood. The differeces between groups are significant ($p<0.05$).

There are many studies confirming reduction in use of allogeneic blood if postoperative autotransfusion sets were used. Kristensen and all. with these systems reduced allogeneic transfusion for 72 % in patients underwent total hip replacement and 91 % in patients underwent total knee replacement[11].

In study of Simpson only 3 of 12 patients needed allogeneic transfusion with use of Solcotrans systems for postoperative autotransfusion; without these systems allogeneic transfusion was indicated in 10 of 12 patients[12]. Many other studies of postoperative autotansfusion have been reported to reduce allogeneic transfuision after orthopaedic procedures as much as 30 and up to 74 percent[13,14].

Our result also confirmed reduction in use of allogenic transfusion with systems for postoperative autotransfusion. There is statistically significant difference between two groups regarding allogeneic transfusion ($p<0.001$).

The samples of postoperative autologus shed blood, preoperatively collected autologous blood and allogeneic blood were analysed for the values of red blood cells, hemoglobin, hematocrit, platelets, free hemoglobin, sodium, potassium and acid base balance. (Table. 2–4; Figures 2–5).

The hematological factors of postoperative salvaged blood have been examined in clinical studies. Faris et al. estimated mean value red blood cells of $3.6 \pm 0.86 \times 10^{12}$ /L (1.00–5.21!); hemoglobin 119 ± 25 g/L (54–171); hematocrit 0.34 ± 0.08 (0.16–0.48) (4). Blevins et al. reported lower values: hemoglobin 71 ± 16 g/L (40–92), hematocrit 0.20 ± 0.05 (0.13–0.28)[15]. In Solcotrans system analysed by Simpson hematocrit level was 32.7% (25–32) (10) Clements and al. estimated hematocrit level of 24% in unwashed blood; whereas level increased to 45% after washing of shed blood[8]. Semkiw et al. estimated Htc level of 55% in samples of shed blood after washing and concentration[16].

Our results are comparable with literature data. The level of red blood cells is always decreased in shed blood collected postoperatively. This is caused by several reasons: the patients blood is diluted with perioperative infusion of cristalloids and colloids and there is always collection of interstial fluid around the wound wich is also collected causing further dilution of shed blood.

In order to analyse red blood cells damage the level of free hemoglobin was measured in all sources of blood. (Tables 3–5 and Figure 5). The mean level of free hemoglobin was 348 mg % in postoperative autologous blood; the mean level in allogeneic blood was 317 mg %; the lowest level was in preoperative autologous blood 178 mg %. There is statistically significant difference among preoperative and postoperative autologous blood ($p<0.05$); there is no statistically significant difference among preoperative autologous and allogeneic blood. ($p>0.05$). During the collection of drainage blood a lysis of red blood

cells is possible. The value of free hemoglobin is sign of red blood cells damage and is increased if the membrane of red blood cells is destroyed and hemoglobin is free in plasma. If the values of free hemoglobin are high the hemoglobinuria and renal damage can occur. There are many studies of free hemoglobin in intraoperatively and postoperatively collected blood in orthopaedic patients during total hip and knee replacement surgery. These values are increased and can reach very high values in intraoperatively collected blood. In postoperatively collected shed blood the reported values are 236 mg/dL in total hip replacement (range 97–422) and 152 (31–298) mg/dL in others orthopaedic procedures[15,17,18]. The value of free hemoglobin in collected shed blood presented in our patients is in this range. In the present study the free hemoglobin values due to haemolysis did not exceed 350 mg %. Such levels do not produce hemoglobinuria in patients who have a normal level of haptoglobin. There was no case of hemoglobinuria or renal damage among patients.

The concentration of potassium in postoperatively collected shed autologous blood was 4.21 mmol; in preoperatively collected autologous blood was 11.4 mmol; and in allogeneic blood 17.5. There is statistically significant difference between values of potassium in postoperatively collected shed blood and preoperativey autologous blood and allogeneic blood. These results are presented in Tables 3–6.

The blood is stored under temperature of +4 °C and damage of red blood cells membrane occurred as a result of paralysis of Na/K pump. During the storage of blood the concentration of potassium is increasing, and concentration of sodium is decreasing. The concentration of potassium is increased 1 mmol/L per day, so the concentration of potassium is 25–30 mmol/L in allogeneic blood after 35 days of storage. The concentration of potassium in postoperatively collected blood in our patients was in normal range confirming low level of red blood cells damage. The blood is fresh because storage time is six hours postoperatively.

The highest concentration was in allogeneic blood. This is result of storage of blood. The allogeneic blood is storaged for 20 to 30 days. Preoperatively collected autologus blood is storaged only 7 to 14 days (the patients donated their own blood 7 or 14 days preoperatively). There are many reports of electrolytes in postoperatively collected autologous blood. Our results confirmed that the concentration of potassium is in normal range in postoperatively collected blood. This blood is fresh and collection time is under six hours, so there is no damage of red blood cells as a result of storage of blood. The concentration in preoperatively collected autologous blood and in allogeneic blood is increased as a result of blood storage. This difference is statistically significant.

The value of white blood cells in postoperative autologous blood was $3.4 \pm 1.7 \times 10^9$ /L; this value in preoperative donated autologous blood was 5.2 and in allogeneic blood 3.6.

The differential white blood cell count showed changes in values of lymphocytes. The mean value of lymphocite in postoperative autologous blood was 34 %; in preoperative autologous blood mean level was 43 % and in allogeneic blood 57 %. The percent of lymphocytes is increased and consenquently the percent of polymorphonuclear leukocytes is decreased. Comparative analysis of these values is presented in table 6 and 7. The mean level of lymphocytes in postoperative autologous blood is significantly lower comparing with level in preoperative autologous and allogeneic blood.

There are only several studies about white blood cells in postoperative autologous blood. Faris and al. reported mean value of white blood cells to be $4.8 \pm 1.9 \times 10^9$ /L. (4). Blevins at al. reported increased values of 11.4 (7.1–15.5)[14]. Sinardi et al. estimated level of 4.74 ± 0.97[20]. The number of leucocytes in red blood cells concentrates is 5.5×10^9 /L (4.5–6.6) in first day of conservation. The number is reduced to 1.5×10^9 /L (0.9–2.4) after 42 days of conservation[21].

Acute inflammatory response is triggered in response to a major injury such as total hip replacement. The acute inflammatory response is the first line of defence against infection and is also the primary event in the healing of injured tissue. During this response dilatation of capyllares with collection of fluids and transmigration of leucocytes from bloodstream to the site of injury is occurred. The number of leucocytes is increased in peripheral blood postoperatively. Their number in postoperatively shed blood is not increased. The possible cause is dilution of blood because not only blood from blood vessels is collected but also interstitial fluid.

Local anesthetics have inhibitory effect on leucocytes migration. All our patients underwent spinal anesthesia using local anesthetic bupivacain. The possible effect of local anesthetics on leucocytes migration postoperatively is unknown. There is no study comparing the number of leucocytes in postoperatively collected shed autologous blood in patients underwent spinal or general anesthesia.

Acid base balance is presented in table 3, 4 and 5. The average pH postoperatively collected autologous blood was 7.38 ± 0.6; pH preoperatviely collected autologous blood was 6.8 ± 1.2 and 6.42 ± 0.6 in allogeneic blood.

The acid base analysis showed normal values of oxygen saturation, partial pressure of oxygen and bicarbonate in postoperatively collected autologous blood. The normal pH range is 7.36–7.44 and pH of anticoagulant (CPD, CPDA 1) is 5.6. So the pH of concentrated allogeneic blood is decreased. Although during the storage the glicolysis is occured and lactic acid and other metabolites decrease pH. These changes caused decreased pH in allogeneic and preoperatively collected autologous blood. Prolongation of blood storage causes anaerobic metabolism to develop. Anaerobic metabolism of preoperativlely collected blood was suggested by the reduced values of pH, SaO_2 and pO_2. The storage of postoperatively collected blood is not over 6 hours, so this blood is fresh and the anaerobic metabolism is not started.

Conclusion

In the present study, reinfusion of postoperative drained blood significantly reduced the requirement for allogeneic blood transfusion in patients underwent total hip replacement. The analysis of postoperatively collected autologous blood showed decreased number of red blood cells. The number of leucocytes is in normal range but the percentage of lymphocytes is decreased. The values of sodium, potassium and acid base balance are in normal range. During the transfusion of shed blood there were no complications in our patients when the collection time was under 6 hours. This method is safe, simple and efficacious. The need for allogeneic transfusion is reduced if sets for postoperative autotransfusion are used after total hip replacement. Our results confirmed that washing of this blood is not necessary if small amounts of salvaged blood are returned, whereas larger volumes might be dangerous owing release of proinflammatory cytokines. Further investigations are needed for recommendations regarding the maximum volume of postoperative collected blood that can be safely transfused to the patients.

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KVALITETA KRVI SAKUPLJENE DRENOM NAKON TOTALNE ARTROPLASTIKE KUKA

SAŽETAK

Uvod: Poznato je nekoliko metoda uspješnih u smanjivanju potrebe za alogenom transfuzijom kod bolesnika podvrgnutih totalnoj artroplastiki kuka. Cilj ove prospektivne studije bio je analizirati kvalitetu i procijeniti učinak postoperativne autotransfuzije na temelju potrebe za alogenom transfuzijom nakon totalne artroplastike kuka. Provedeno je prospektivno istraživanje na dvije skupine bolesnika podvrgnutih totalnoj artroplastiki kuka. Prije kirurškog zahvata svim je bolesnicima uzeta krv od čega su pripremljene dvije doze autologne krvi. U skupini 1 korišten je sustav za postoperativno sakupljanje i transfuziju izgubljene krvi, dok u skupini 2 ovaj sustav nije bio korišten, već su bili korišteni standardni setovi ta sukciju i sakupljanje, a sakupljena krv nije bili transfundirana pacijentima. Uzorci preoperativno donirane autologne krvi, alogene krvi i postoperativno sakupljene autologne krvi su bili analizirani te je određivan broj eritrocita, hemoglobin, hematokrit, broj trombocita i leukocita, vrijednosti kalija i natrija, slobodni hemoglobin i acidobazni status. Postoperativno sakupljanje krvi je značajno smanjilo upotrebu alogene transfuzije kod bolesnika podvrgnutih totalnoj artroplastiki kuka (alogenu transfuziju primilo je 12% bolesnika iz skupine 1 i 80% bolesnika u skupini 2; $p<0,001$). Broj eritrocita je značajno manji u postoperativno sakupljenoj krvi za autotransfuziju u usporedbi s preoperativno prikupljenom autolognom i alogenom krvlju ($p<0,001$). Vrijednosti kalija i acidobazni status u postoperativno prikupljenoj autolognoj krvi bili su u granicama normale, dok su vrijednosti kalija i acidobazni status bili poremećeni u preoperativno prikupljenoj autolognoj i alogenoj krvi, $p<0,001$. Kako bi se smanjio rizik komplikacija koje su u svezi s alogenom transfuzijom, postoperativno sakupljanje krvi pokazuje prednost i smanjuje potrebu za transfuzijama alogene krvi. Ovo istraživanje potvrdilo je da postoperativno sakupljanje i transfuzija drenirane krvi je jednostavna i sigurna metoda koja značajno smanjuje potrebu za transfuzijama alogene krvi kod bolesnika podvrgnutih totalnoj artroplastiki kuka. Postoperativno prikupljena i transfudirana krv ima manji broj eritrocita te normalne vrijednosti kalija i uredni acidobazni status. Transfuzija ovakve krvni nije uzrokovale komplikacije kod bolesnika.