Original Article

Comparison of early period results of blood use in open heart surgery

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Background: Various adverse effects of homologous blood transfusion detected particularly in open heart surgery, in which it is frequently used, lead researchers to study on autologous blood use and to evaluate the patient's blood better. Due to the complications of homologous blood transfusion, development of techniques that utilize less transfusion has become inevitable. We aimed to evaluate the effects of acute normovolemic hemodilution (ANH) in patients undergoing open heart surgery. **Materials and Methods:** In this study, 120 patients who underwent open heart surgery were included. Patients were grouped into three: Autologous transfusion group (Group 1), homologous transfusion group (Group 2), and those received autologous blood and homologous blood products (Group 3). Patient data regarding preoperative characteristics, biochemical parameters, drainage, extubation time, duration of stay at intensive care, atrial fibrillation (AF) development, and hospital stay were recorded. **Results:** A statistically significant difference ($P < 0.005$) was found in favor of autologous group (Group 1) with respect to gender, body surface area, European System for Cardiac Operative Risk Evaluation, smoking, hematocrit levels, platelet counts, urea, C-reactive protein levels, protamine use, postoperative drainage, frequency of AF development, intubation period, stay at intensive care and hospital stay, and amount of used blood products. **Conclusion:** The use of autologous blood rather than homologous transfusion is not only attenuates side effects and complications of transfusion but also positively affects postoperative recovery process. Therefore, ANH can be considered as an easy, effective, and cheap technique during open heart surgery.

Key words: Autologous blood transfusion, cardiac surgery, normovolemic hemodilution

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INTRODUCTION

Despite numerous methods performed in the recent years to decrease the rate of homologous blood use, blood transfusion and related problems remain critical. Due to immunosuppression and transfusion-related acute lung injury syndrome in addition to hemolytic, allergic and infectious effects, avoiding blood transfusion become an important target in patients who would undergo surgical procedure.[1]

Various adverse effects of homologous blood transfusion detected particularly in open heart surgery, in which it is frequently used, lead researchers to study on autologous blood use and to evaluate the patient's blood better. Acute normovolemic hemodilution (ANH) is one of the numerous strategies developed to avoid or, at least, to lower the need for allogeneic blood transfusion (ABT). The known advantages of this method include absence of risk for incompatibility, alloimmunization, immunosuppression, and infection. Moreover, this method provides keeping donor blood for the patients requiring blood transfusion, and also the method is more economic.[2,3]

The present study aimed to compare the clinical outcomes of the three approach of blood transfusion. Also, it evaluates the effects of ANH on hemodynamics, tissue oxygenation, need for homologous, and renal and hepatic functions, as well as postoperative complications

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and amount of drainage in patients undergoing heart surgery in whom ANH was performed or not. In addition, we are in the opinion that the present study will illuminate the question whether the morbidity, mortality and cost can be lowered in open heart surgery by demonstrating which of the blood transfusion methods, homologous or autologous, is associated with less organ damage.

MATERIALS AND METHODS

One-hundred twenty patients, who underwent elective isolated open heart surgery in cardiovascular unit of our hospital, were included in the study. This is a prospective randomized controlled clinical study. These patients were divided into the following three groups: (1) Group 1 (n = 40), autologous transfusion group, (2) Group 2 (n = 40), homologous transfusion group, and (3) Group 3 (n = 40), patients who received autologous blood at the beginning but then had to receive homologous blood and blood products due to various reasons (tachycardia, anemia, decreased urine output, etc.). Exclusion criteria before surgery from the autologous group included renal function impairment (creatinine >1.5 mg/dL), anemia (hematocrit [Hct] <35%), an ejection fraction (EF) lower than 30%, infection, hepatic function impairment, decreased coagulation factors, thrombocytopenia, impairment of platelet (PLT) function, coagulation defect or bleeding diathesis, additional cardiac procedures except for valve replacement, redo coronary bypass surgery, and urgent surgical procedure. The study was approved by an appropriate Ethical Committee and signed informed consent was obtained from the patients and/or their relatives.

Antiaggregant and anticoagulant therapies of the patients were discontinued at least 7 days before the surgery. Patients with left coronary artery stenosis, unstable angina or preoperative atrial fibrillation (AF) underwent surgery under the effect of low-molecular-weight heparin or standard heparin, which were used in the preoperative period.

Surgical procedure

Vital signs and measurable hemodynamic parameters of the patients were monitored. The patients underwent standard open heart surgery anesthesia. In patients who were planned to receive autologous blood transfusion, by weighing continuously, at least, 300 and at most 450 mL autologous blood was drawn from the arterial cannula into standard blood bags, which contains CPD, after anesthesia induction before systemic heparinization, and 1–2 units of autologous blood were collected within 20–40 min until the Hct level reached up to 30–35% before cardiopulmonary bypass (CPB). Simultaneously, hemodynamics was maintained by infusing a balanced amount of (1:1) colloid and/or (1:0.5–1) crystalloid solution with the blood taken from the peripheral or central veins. No change was made in the standard surgical techniques.

Study protocol

In addition to the preoperative characteristics of the patients such as age, gender, and body surface area (BSA), patients' data regarding preoperative urea, creatinine, K^+, alanine aminotransferase (ALT), aspartate aminotransferase (AST), and bilirubin levels, as well as complete blood count, arterial blood gases, systolic and diastolic arterial pressures, and pulse rates were also recorded. The European System for Cardiac Operative Risk Evaluation (EuroSCORE) value was calculated for each patient. Moreover, preoperative echocardiographic findings, chronic diseases (diabetes mellitus, hypertension, peripheral artery disease, chronic obstructive disease, and renal disease), history of cerebrovascular disease, smoking and alcohol habits, and previous extra-cardiac surgical procedures of the patients were recorded. In addition, it was also evaluated whether the patients were on heparin or not, as well as a recent history of new myocardial infarction (MI), and angiographically detected left main coronary artery (LMCA) lesions was recorded.

Systolic and diastolic blood pressures (BPs), pulse rate, and central venous pressure (CVP) of the patients were recorded during preoperative induction of anesthesia. Total heparin, protamine, and tranexamic acid use and amount of the collected blood were recorded during surgery. During CPB, systolic BP, arterial blood gas, Hct, body temperature, amount of urine output, and amount of fluid intake were obtained whereas systolic and diastolic BPs, pulse rate, Hct, amount of urine output, and arterial blood gas values were recorded after CPB. CPB time, cross-clamp time, and defibrillation applications were recorded as intraoperative parameters.

At the postoperative 6^{th} and 24^{th} h and 5^{th} day, systolic and diastolic BPs, pulse rate, CVP, arterial blood gas values, complete blood count, urea, creatinine, K^+, ALT, AST, lactate dehydrogenase, bilirubin, C-reactive protein (CRP), and lactic acid levels, activated clotting time, and the amounts of urine output, fluid intake, and drainage were recorded. In addition, total amount of blood and blood products given in the postoperative period, total amount of drainage, AF and rhythm problems, postperfusion status, transient ischemic attack (TIA), extubation duration, and length of Intensive Care Unit (ICU) and hospital stay were also recorded. Biochemical analyses were performed in the Central Laboratory of University Hospital.

Statistical analysis

Data analyses were performed using the STATISTICA AXA 7.1 (StatSoft Inc., USA; Serial number: AXA507C775506FAN3) statistical program. Normality of the measurable variables was analyzed using the single-sample Kolmogorov–Smirnov test. Intergroup comparisons of normally distributed data were performed by one-way variance analysis, followed by a Bonferroni *t*-test for the paired comparison of data that were found to be significant on variance analysis. Intergroup comparisons of nonnormally distributed variables were performed using the Kruskal–Wallis variance analysis, and those that showed significant difference were analyzed by the Mann–Whitney U-test. Descriptive statistics were presented as arithmetic mean ± standard deviation. Qualitative data were expressed as numbers and percentages and were analyzed using the Pearson's Chi-square test and Kolmogorov–Smirnov test for those with an expected value <5. A $P < 0.05$ was considered statistically significant. The Mann–Whitney U-test with Bonferroni correction was performed at an alpha significance level of 0.017 (p/n [α] =0.05/3 = 0.017).

RESULTS

There were statistically significant differences among the three groups in terms of gender, BSA and EuroSCORE values [Table 1]. The number of female patients was higher, the EuroSCORE value was greater, the rate of smokers and the BSA value was smaller in Group 2 ($P < 0.05$).

No significant differences were determined among the groups with respect to intraoperative CPB ($P > 0.05$), [Table 2].

Statistically significant differences were determined among the groups in terms of the mean hemoglobin (Hb) and Hct values preoperatively and at the postoperative 5th day [Table 3]. In Group 1, the mean Hb and Hct values were higher in the preoperative period and lower at the postoperative 5th day ($P < 0.05$).

A significant difference was found among the groups in terms of the mean PLT values at the postoperative 6th and 24th h [Table 3]; the mean PLT value of the patients in Group 3 was lower at the postoperative 6th and 24th h ($P < 0.05$).

There were significant differences among the groups in terms of the postoperative 6th h, 24th h and 5th day urea levels [Table 3]; the patients in Group 2 had higher urea levels at these time periods ($P < 0.05$).

A statistically significant difference was found between the groups in terms of protamine use [Table 4]; protamine use was higher among the patients in Group 3 ($P < 0.05$).

The groups exhibited significant differences in terms of postoperative 6th h and 24th h drainage volumes as well as total amount of drainage [Table 4]; the patients in Group 1 had lower amount of drainage ($P < 0.05$).

Table 1: Preoperative characteristics of the groups

	n=40			*P*
	Group 1	Group 2	Group 3	
Age (years)	54.9±8.2	58.8±11.6	57.4±8.4	>0.05
Male/female	34/6	23/17	34/6	<0.05
BSA (m^2)	1.81±0.17	1.74±0.17	1.86±0.15	<0.05
EuroSCORE	2.5±1.2	4.1±2.8	3.4±2.1	<0.05
DM	9 (22.5)	10 (25)	14 (35)	>0.05
Smoking	23 (57.5)	16 (40)	27 (67.5)	<0.05
Renal disease	0 (0)	2 (5)	0 (0)	>0.05
Heparin use	14 (35)	16 (40)	15 (37.5)	>0.05

Data are presented as mean±SD, *n*/*n*, and *n* (%), where appropriate. BSA=Body surface area; DM=Diabetes mellitus; SD=Standard deviation

Table 2: Intraoperative cardiopulmonary bypass characteristics of the study groups

	n=40			*P*
	Group 1	Group 2	Group 3	
CCT (min)	63.6±21.4	64.8±27.1	62.7±20.3	>0.05
CPBT (min)	102.3±32.0	110.8±38.5	116.3±25.2	>0.05
Body temperature (°C)	34.2±1.5	34.5±1.4	34.1±1.3	>0.05
Urine output during CPB (mL)	1061.8±648.6	1265.8±686.4	1274.9±636.3	>0.05
Urine output after CPB (mL)	947.6±394.6	737.9±470.9	876.3±360.4	>0.05

Data are presented as mean±SD. CCT=Cross clamp time; CPBT=Cardiopulmonary bypass time; CPB=Cardiopulmonary bypass; SD=Standard deviation

Statistically significant differences were found among the groups with respect to fluid intake volumes at the postoperative 6th and 24th h; the amount of fluid intake was lower in Group 1 ($P < 0.05$).

There were also significant differences among the groups in terms of postoperative AF development [Table 5]; the rate of AF development was lower in the patients in Group 1 ($P < 0.05$). The groups showed significant differences in terms of postoperative extubation time [Table 5]; extubation time was shorter in Group 1 ($P < 0.05$).

There were significant differences among the groups regarding the ICU and hospital length of stay [Table 5]; the ICU and hospital length of stay were shorter in Group 1 ($P < 0.05$).

There was significant difference among the groups in terms of intraoperative and postoperative total blood transfusion [Table 5]; it was lower among the patients in Group 1 ($P < 0.05$).

DISCUSSION

Nowadays, transfusion is a complex therapeutic discipline requiring a trained clinician to exhibit all his/her competency.

Table 3: Pre-, intra- and post-operative laboratory results of the study groups

	n=40			*P*
	Group 1	Group 2	Group 3	
Preoperative				
Hb	14.1±1.3	12.6±1.5	13.9±1.0	<0.05
Hct	41.4±3.1	34.9±7.9	41.2±3.2	<0.05
PLT	251.9±48.0	279.5±80.4	246.8±74.6	>0.05
Urea	36.3±10.0	41.8±19.8	37.0±9.0	>0.05
Creatinine	1.0±0.2	0.9±0.2	1.0±0.2	>0.05
CRP	0.7±1.3	0.9±1.1	0.8±0.9	>0.05
Lactate	11.5±1.6	13.9±2.3	15.6±3.5	>0.05
During CPB				
Hct	21.0±2.6	21.2±4.2	21.2±2.5	>0.05
After CPB				
Hct	27.2±3.1	25.6±3.4	26.4±3.9	>0.05
Postoperative 6th h				
Hb	13.8±18.3	10.7±1.5	10.6±1.2	>0.05
Hct	32.3±3.5	31.7±4.6	31.0±3.5	>0.05
PLT	216.3±52.8	217.0±68.2	170.6±60.6	<0.05
Urea	40.3±9.4	45.6±12.3	40.9±7.8	<0.05
Creatinine	1.3±0.3	1.3±0.3	1.3±0.2	>0.05
CRP	2.7±2.3	2.6±1.6	2.8±1.7	>0.05
Lactate	48.5±17.6	53.9±24.3	57.6±30.5	>0.05
Postoperative 24th h				
Hb	9.9±0.8	9.9±0.7	9.7±1.0	>0.05
Hct	29.1±2.9	29.2±2.4	28.2±2.8	>0.05
PLT	202.6±59.6	189.2±62.6	158.3±58.7	<0.05
Urea	54.2±16.0	65.8±19.1	56.4±14.0	<0.05
Creatinine	1.4±0.4	1.5±0.5	1.4±0.5	>0.05
CRP	14.7±4.6	14.3±5.1	15.2±6.3	>0.05
Lactate	38.8±14.5	38.0±18.4	36.0±16.2	>0.05
Postoperative 5th day				
Hb	9.8±0.9	10.9±1.2	10.8±1.0	<0.05
Hct	29.2±2.5	31.8±4.4	31.8±3.1	<0.05
PLT	245.3±96.1	228.0±82.7	211.1±69.4	>0.05
Urea	41.2±12.7	54.1±25.8	45.5±23.5	<0.05
Creatinine	1.0±0.2	1.0±0.3	1.0±0.2	>0.05
CRP	5.9±6.3	20.2±10.0	6.3±3.8	<0.05
Lactate	21.0±8.2	22.6±5.9	21.8±9.5	>0.05

Data are presented as mean±SD. Hb=Hemoglobin; Hct=Hematocrit; PLT=Platelet; CRP=C-reactive protein; CPB=Cardiopulmonary bypass; SD=Standard deviation

Unnecessary blood transfusion must be avoided; only deficient component should be replaced.

As a transfusion product, autologous blood has many advantages over homologous blood; a patient's own blood is the unique blood fully appropriate for the patient. Moreover, the risks of isoimmunization, contamination with hepatitis virus and other infectious agents, and graft versus host disease reaction are eliminated with autologous blood use, and febrile, allergic and hemolytic reactions are decreased.[4] Although there are various methods developed to reduce the use of blood and blood products in elective or emergency cardiac surgery, the use of homologous blood is more common as compared to the other surgical procedures.[5] Transfusions lead to many complications in the cardiac surgery, in which homologous blood use is highly required.

Table 4: Intraoperative heparin and protamine values and postoperative activated clotting time and drainage volumes of the groups

	n=40			*P*
	Group 1	Group 2	Group 3	
Intraoperative heparin (mg)	243.1±50.9	236.6±45.9	249.7±34.9	>0.05
Intraoperative protamine (mg)	408.7±79.1	397.5±67.8	427.5±45.2	<0.05
Postoperative 6th h ACT (s)	103.4±8.7	109.5±13.8	105.2±11.5	>0.05
Postoperative 6th h drainage volume (mL)	209.4±95.5	223.8±131.0	303.8±167.0	<0.05
Postoperative 24th h drainage volume (mL)	410.6±130.2	479.6±251.6	606.3±310.6	<0.05
Total amount of drainage (mL)	500.0±147.6	638.2±336.9	754.6±354.9	<0.05

Data are presented as mean±SD. ACT=Activated clotting time; SD=Standard deviation

Table 5: Total blood and blood product volumes and other postoperative characteristics of the groups

	n=40			*P*
	Group 1	Group 2	Group 3	
Postoperative 6th h				
Fluid intake (mL)	1019.3±372.6	1106.2±374.9	1396.8±499.5	<0.05
Urine output (mL)	1608.0±562.9	1588.7±675.5	1558.7±699.6	>0.05
Postoperative 24th h				
Fluid intake (mL)	3424.3±867.6	3531.5±593.7	4150.5±980.2	<0.05
Urine output (mL)	3178.2±684.0	3175.0±797.7	3172.7±775.8	>0.05
Others				
AF	3 (7.5)	13 (32.5)	8 (20)	<0.05
Postperfusion	0 (0)	3 (7.5)	2 (5)	>0.05
TIA	1 (2.5)	0 (0)	0 (0)	>0.05
Extubation time (h)	10.4±3.5	13.5±4.0	12.0±3.7	<0.05
Length of ICU stay (h)	43.2±12.2	50.6±12.4	46.2±8.4	<0.05
Length of hospital stay (days)	6.8±0.8	7.7±1.8	8.0±2.3	<0.05
Blood (U)	1.6±0.5	3.4±1.3	4.1±1.7	<0.05
FFP (U)	0	3.4±2.0	3.2±1.7	>0.05

Data are presented as mean±SD and *n* (%), where appropriate. AF=Atrial fibrillation; TIA=Transient ischemic attack; ICU=Intensive Care Unit; FFP=Fresh frozen plasma; SD=Standard deviation

The increment in the coronary artery surgery procedures in the recent years has led to a great burden on blood banks.[5] Nevertheless, blood and blood product use should be minimized in open heart surgery both to eliminate the risks and to provide safer surgical procedure.

The risks associated with homologous blood transfusion, have led the researchers to develop cheap and reliable methods salvaging the patients' own blood. It is difficult to use these techniques in all circumstances since some of them are time-consuming, and some of them have high cost. For instance, interventions performed to increase erythrocytes before surgery require time; however, this time is generally limited for patients that would undergo open heart surgery.

One of the disadvantages of the cell saver method is that it is quite expensive to be used routinely.[5] In addition, it is theoretically considered to pose a risk for postoperative bleeding and infection by causing plasma proteins, thrombocytes, and leukocytes to be washed together and removed from the blood.[6]

Pharmacological blood-saving methods include aprotinin, epsilon aminocaproic acid, tranexamic acid, and desmopressin. Aprotinin has been proposed to have negative effect on renal functions due to its metabolic characteristics.[7] Clinical studies showed transient increment in serum creatinine levels with aprotinin; irreversible renal failure has been rarely reported with high doses.[8] Due to the high cost and adverse effects spectrum of aprotinin, its usage in low doses has become popular recently.

Allowing limited anemia in the postoperative period is a kind of blood salvage method. Although this method as well decreases the rate of homologous blood transfusion, studies, which have defined the limits of anemia to be 8 g/100 mL over the age of 70 years and 7 g/100 mL under the age of 70 years, have suggested that a number of problems are likely to be experienced under these limits.[9] In the present study, the mean postoperative Hct levels of the patients, both in the operating room and in the ICU, were kept at or over 25%. Patients, who were unable to tolerate such an anemia and had tachycardia, hypotension and decreased urine output, primarily received their readily available autologous blood. Those failing to achieve hemodynamic stability despite transfusion received additional homologous blood products.

There are also studies that demonstrate decreased need for homologous blood with the availability of autologous blood. Many studies have also shown that transfusion of autologous blood, which is collected before the surgery, to the patient after CPB decreases the need for homologous blood by 20–58%.[4,10] In the present study, we did not approve the use of above-mentioned autologous blood collection methods during our surgical procedures since some of them are costly, some of them require appropriate time and patient group for blood collection, and some of them are associated with disadvantages and complications.

ANH, which is one of the blood salvage techniques, decreasing the rate of ABT and is the most frequently used method in open heart surgery, is an easily applicable method since it is quite reliable and low-cost, does not require additional staff or high-cost technological equipment, and has no serious adverse effects for patients. ANH has been shown to regulate microcirculation by reducing blood viscosity and reduce damage and preserve the functions in many organs by lowering inflammatory response.[11,12] We preferred ANH technique, which has recently become available in many centers, in the present patients due to above-mentioned advantages, its being reliable.

Many studies have suggested that the rate of ABT is significantly reduced by ANH in cardiac surgery.[13] The present study demonstrated that the need for ABT was significantly reduced in the autologous transfusion group that underwent ANH.

Experimental studies have classically shown that ANH application is contraindicated in patients with coronary artery disease. However, animal experiments and clinical studies have not supported the negative effects of ANH on patients with coronary artery disease. Preoperative autologous blood collection can be performed in patients with chronic stable angina to reduce the need for homologous blood;[14] it should be avoided in unstable patients and in patients with LMCA lesions since they might require emergency intervention after catheterization and they usually have low Hct. In the present study, we observed no statistically significant differences among the groups in terms of LMCA lesions and recent MI.

Colloids have the advantage of intravascular retention, which indicates less volume replacement. Studies have suggested that a colloidal solution, which remains in the intravascular space, is biologically degradable and has short life, is an ideal volume expander even in patients with capillary leak.[15] In hemodynamic studies comparing dextran, albumin and hydroxyethyl starch (HES), no difference was reported in terms of hemodynamics.[16] Boldt *et al*.[17] reported 6% HES solution to be the most appropriate colloid solution for volume replacement in cardiac surgery due to its enhancing effect on capillary blood flow. We as well, tried to maintain hemodynamics by infusing balanced amount of colloid (Voluven-sterile 6%, Fresenius Kabi, Istanbul, Turkey) and/or crystalloid (isotonic 0.9% NaCl) solution as diluent. Since high amounts of HES infusion (>1000 mL/day), might impair clotting by depressing Factor VIII activity, none of our patients was infused with a HES solution over this level, and the required fluid was compensated with crystalloids.

In a previous study, no significant difference was reported between the patients receiving and not receiving blood in terms of age and concomitant diseases, which were among preoperative characteristics.[18] In the present study, we also observed no significant differences among the groups in terms of age and concomitant diseases. However, we found that the number of female patients was significantly higher, the BSA value was significantly smaller, and the EuroSCORE value was significantly greater in the patients who received homologous blood transfusion. On the other hand, we found no data in the literature verifying these results. This data suggested that the need for ABT was higher in the patients with higher EuroSCORE values. Corroboration of this hypothesis by the patients in Group 3 strengthens our consideration; because, it is a known fact that patients with high EuroSCORE values have higher morbidity and mortality, thus higher complication rates.

Studies have revealed that ANH is well tolerated and that compensatory mechanisms during ANH are largely independent from the left ventricular EF.[19] However, we found no significant difference among the study groups in terms of echocardiographic parameters.

Many human studies have demonstrated that heart rate and hemodynamics remain constant with ANH.[20] A study investigating ANH in children revealed that systemic pressure remained constant while heart rate was decreased.[21] Furthermore, it should be kept in mind that there are many factors influencing heart rate during surgery. Deepness of anesthesia and intensity of surgical stimulation are particularly important factors that determine heart rate.[19] In the present study, we found no statistically significant difference in hemodynamic parameters among the study groups.

Various compensatory mechanisms act to compensate the decrease in arterial oxygen during ANH. Increase in CO is the mechanism most frequently focused on and activated by ANH.[19] The oxygen carrying capacity is well preserved with a Hct level of 25–45% unless there is a cardiac problem; however, subendocardial ischemia and MI are likely to occur when Hct level is decreased under 15%. In their study, Erol and Erdogan[20] showed that ANH caused no alteration in the arterial blood gases. In our study, we kept the mean Hct values at about 18–23% during CPB and about 22–26% after CPB. Thus, we observed no significant differences among the groups in terms of the intraoperative and postoperative arterial blood gas values.

Different Hct levels, which were targeted during ANH applications for the patients with coronary artery disease, have been reported. The Hct level is recommended to be 20–24% in cases without myocardial dysfunction, whereas a hemodilution was recommended up to a Hct level of 28–30% at the most in those having myocardial dysfunction at a degree that would obscure hemodilution-related CO increment.[22] The American Association of Blood Banks Standards recommends a Hb level not lower than 11 g/dL and a Hct level not lower than 33–34% in patients who would undergo ANH. We as well used this recommendation as the basis while determining the lower limits of preoperative Hb and Hct levels of the patients and paid attention for mean Hct levels to be at or higher than 35%.

Although it has been reported that healthy children can tolerate ANH, which is performed by decreasing Hb level to 3 g/dL[23], accepted Hct limits are as follows: Normal limit 32%, optimal limit 30%, tolerable limit 20%, and critical limit 10%.[24] Studies have shown that a Hct level that is decreased to 16–18% with ANH during CPB supplies adequate oxygen to the tissues.[25] In the present study, we electrocardiographically and hemodynamically observed that the patients in the autologous blood transfusion group were able to tolerate the Hct levels together with warm hypothermia during and after CPB, and in the postoperative period without ischemic signs.

Many studies have also reported that cases undergoing ANH have lower Hb levels than those undergoing ABT at the end of the operation and at hospital discharge.[26] Nonetheless, it has been reported that younger patients are likely to tolerate this unserious condition better. In the present study, there were no significant differences among the study groups in terms of Hct values at the postoperative 6^{th} and 24^{th} h; however, Hct values at the postoperative 5^{th} day was lower in the autologous blood transfusion group.

Many studies have demonstrated that CPB decreases PLT count by 60–70% as compared to the preoperative period, this decrement continues for approximately 1 h, and approximate PLT count reaches to 80–90% of the preoperative values[27] while some researchers have reported that PLT functions are impaired.[4] It is known that the quality of blood drawn after heparinization might be poor due to unfavorable effects of heparin on PLT functions. In the present study, we collected blood after anesthesia induction before systemic heparinization to prevent unfavorable effects of heparin on PLT functions. However, there are also some authors recommending heparinized blood collection from the patients with LMCA lesions, unstable angina and critical aortic stenosis. In their study, Ovrum *et al*.[5] found that rate of reoperation due to drainage and bleeding was significantly lower among patients who received heparinized autologous blood and attributed this finding to better PLT functions and higher PLT count in these patients as compared to those who received homologous blood. Moreover, it has been reported that hemodilution may facilitate hemostasis as it provides fresh PLT at the end of surgery. In the present study, we found a significant difference among the study groups in terms of PLT counts at the postoperative 6^{th} and 24^{th} h; the PLT count was lower in Group 3 as compared to Groups 1 and 2, and it was lower in Group 1 than in Group 2. This finding indicated that autologous blood, which is collected by ANH, preserved the PLT count and functions.

In a previous study, not CRP but erythrocyte sedimentation rate was found to be elevated with homologous blood use.[18] However, another study demonstrated increase in both CRP and erythrocyte sedimentation rate.[28] In the present study, we found a significant difference among the groups in terms of their mean CR*P* values at the postoperative 5th day; the mean CR*P* value of Group 2, was higher than that of Group 1 and Group 3. This finding indicated that systemic inflammation was even more stimulated in patients receiving homologous blood transfusion as compared to those who did not receive homologous blood or did receive less homologous blood and that CR*P* values were increased with homologous blood transfusion. In addition, inflammatory response rarely developed due to ANH effect in patients receiving autologous blood transfusion.

A study, in which open heart surgery was performed only by re-infusing the blood left in the pump and administering tranexamic acid without using blood or blood products, compared urea and creatinine levels of the patients pre- and post-operatively, and before hospital discharge, and no statistically significant difference was reported.[29] In the present study, we found a statistically significant difference among the groups in terms of postoperative 6th h, 24th h and 5th day urea values; the urea level was higher in Group 2, as compared to Group 1 and Group 3. In addition, urea level was slightly higher in Group 3 as compared to the group that received only homologous blood transfusion. However, we found no statistically significant difference in terms of creatinine values. We are of the opinion that these findings might indicate that blood and blood products, which are used during homologous blood transfusion, may increase urea levels and form a basis for renal problems.

Lactate production, which is the indicator of anaerobic metabolism, is increased in animals undergoing hemodilution performed at Hct levels of <10%.[19] In our study, although no significant difference was observed among the study groups in terms of lactate values, lactate values were found to be increased at the postoperative 6th h, 24th h and 5th day as compared to the preoperative values.

Cerebral hypoperfusion, which occurs due to hemodynamic impairment during surgery, is an important factor for the development of neurological complications.[30] The source of microemboli in the cardiac surgery is the gasses rather than the particles.[31] In their study, Weiskopf *et al.*[32] reported that acute decrease in Hb levels to 7 g/dL did not influence cognitive functions, whereas a decrease in Hb levels down to 6–5 g/dL resulted in reversible weakness in perception and impaired delayed memory, which could be improved by blood transfusion. In the present study, no significant differences were determined among the study groups in terms of postoperative neurocognitive functions (TIA and postperfusion syndrome). None of the patients in the autologous blood perfusion group (Group 1) developed postperfusion syndrome; only one patient developed TIA, which was not statistically significant. Three patients in the homologous blood transfusion group (Group 2) and two patients in Group 3 developed postperfusion syndrome; TIA was observed in neither of these groups. These results as well were not statistically significant. This indicates that impairment in neurocognitive functions can be prevented in patients as long as cerebral perfusions of the patients are preserved via adequate Hb levels, even the patients undergo ANH (7 g/dL and higher).

Autologous fresh whole blood transfusion has been reported to have potential advantages, such as reducing postoperative bleeding.[19] However, in the study by Helm *et al.*[33] on 90 cases undergoing open heart surgery (coronary bypass and valve), no change was reported in the amount of postoperative bleeding in patients, in whom ANH was performed by collecting 1540 ± 320 mL blood before heparinization. In the present study, it was determined that drainage volumes at the postoperative 6th and 24th h and total amount of drainage were significantly lower in Group 1, autologous blood transfusion group as compared to Groups 2 and 3. This finding indicated favorable effect of autologous blood transfusion on reducing postoperative drainage.

In their study, Paker *et al.*[29] reported no difference in terms of extubation time and length of hospital stay in patients undergoing open heart surgery who did not receive blood and blood products. In the present study, we found significant differences among the groups in terms of extubation time, the ICU and hospital length of stay. We observed that extubation time, the ICU hospital length of stay were shorter in Group 1, which received autologous blood transfusion, as compared to Groups 2 and 3.

Goksin *et al.*[34] demonstrated that ANH reduced lung damage, which occurred after ischemia-reperfusion injury. From this point of view, we think that ANH plays an important role in early recovery of pulmonary functions by reducing ischemia-reperfusion injury in the lungs, and thereby leads to shorter extubation time and shorter ICU stay. In addition, we are also in the opinion that absence of early complications of ABT is affective in shorter ICU stay and earlier hospital discharge.

Koch *et al.*[35] demonstrated that homologous blood transfusion increases the rate of postoperative development of new AF in patients undergoing open heart surgery. In the present study, we found a significant difference among the study groups in terms of the rate AF development; the rate of AF was found to be lower in Group 1, which received autologous blood transfusion as compared to Groups 2 and 3.

Many studies reported that the need for homologous blood use is decreased with ANH application. This rate ranges from 18% to 90%.[26,36] Most of the studies have reported that ANH reduces the need for ABT whereas some other studies have reported that ANH has no effect on the need for transfusion. In a study conducted in 24 cardiac surgery centers by Russell *et al.*,[37] the mean amount of blood use in a surgical procedure was found to be 5.07 U. In our study, the mean amounts of autologous blood were 1.60 U, 3.4 U, and 4.1 U in Groups 1, 2 and 3, respectively. This showed that the need for ABT was lower even in the group that underwent ANH but required homologous blood and blood product transfusion (Group 3) as compared to the group that received homologous blood transfusion alone (Group 2). Based on this finding, it can be suggested that we can reduce ABT, thus ABT-related complications as well as the cost for the patient and/or health care institute.

Autologous blood that is not affected by CPB has been reported by many researchers as the best volume to transfuse since it contains its own thrombocyte and factors.[4,38] On the other hand, FFP has gained a wide application in cardiac surgery for factor replacement. In the present study, we found no significant between Group 2 and Group 3 in terms of intraoperative and postoperative total FFP infusion.

Emmiler *et al.*[18] reported a low cost was low in patients in whom blood was not used. In another study by Dalgic *et al.*,[39] the cost of autologous blood transfusion was reported to be lower than that of the homologous blood transfusion. Based on cost analysis in the present study, we observe how much the cost could rise in our clinic, in which a mean of 300 open heart surgeries are performed annually, and to what extent this cost rises when the ABT-associated complications are also considered. Comparing the costs of the groups that received and did not receive blood, we observed that autologous blood use was economic and had low cost.

Utley *et al.*[40] demonstrated that one of the reasons for high CABG mortality in female patients was high amount of homologous blood transfusion performed both before and after CPB due to low preoperative Hct values. A recent study found that long-term mortality is substantially lower in patients who did not receive ABT during open heart surgery as compared to those who received ABT.[41] Since the present study did not investigate the long-term outcomes, we had no comment on this subject.

CONCLUSIONS

We observed that autologous blood transfusion not only reduces side effects and complications of transfusion without leading to additional impairment in many intraoperative and postoperative parameters but also favorably affects many postoperative parameters, morbidity and mortality in patients who were clinically suitable and had adequate Hct levels to undergo open heart surgery. If you do not have an option to do autologous blood transfusion, you can choice other transfusion methods with cautiously. Therefore, we are in the opinion that ANH is a simple, effective and cheap technique and can be applied in open heart surgery, which we routinely perform in our clinic.

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Conflicts of interest
The authors have no conflicts of interest.

AUTHOR'S CONTRIBUTION

- SH and OG contributed in the conception of the work, conducting the study, revising the draft, approval of the final version of the manuscript, and agreed for all aspects of the work.
- VY contributed in the acquisition, analysis, or interpretation of data for the work, revising the draft, approval of the final version of the manuscript, and agreed for all aspects of the work.
- FNT contributed in the analysis, or interpretation of data for the work, and agreed for all aspects of the work.
- SC and TE contributed in revising the draft, approval of the final version of the manuscript, and agreed for all aspects of the work.
- HS contributed in approval of the final version of the manuscript, and agreed for all aspects of the work.

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