# Retrospective Comparison of the Effects of Centrifugal and Roller Pump Heads on the Hemostatic System During Open Heart Surgery

## Açık Kalp Cerrahisinde Sentrifugal ve Roller Pompa Başlıklarının Hemostatik Sistem Üzerine Etkilerinin Retrospektif Olarak Karşılaştırılması

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**ABSTRACT**

**Background and Aim:** Technological developments and enhancement of knowledge level enable heart surgery with low mortality and morbidity rates in most centers. On the other hand, hemostasis management during cardiopulmonary bypass (CPB) plays a critical role in development of postoperative complications.
We aimed to compare the effects of centrifugal pump and roller pump techniques on hemostatic system during CPB.
**Material and Methods**: One hundred patients, who underwent coronary artery bypass surgery by the same surgical team with CPB pump using either roller or centrifugal pump, at Department of Cardiovascular Surgery of Gazi University between June 2012 and June 2013 were enrolled. Patients over 40 years old and without any known immunologic, infectious or inflammatory diseases and hematological problems for the last 6 months were included. Two study groups (Group R: Roller pump group and Group C: Centrifugal pump group) were created. Platelet counts, albumin levels were measured before and after CPB (pump); the amount of blood used during CPB, total blood amount used, percentage of patients using five or more units of blood during CPB, percentage of patients who didn't receive f*resh frozen plasma (FFP)*or apheresis platelet concentrates were recorded.
**Results:**The amount of blood transfused during CPB was significantly lower in Group C than in Group R (0.28 ± 0.08 U; 0.68 ± 0.13) (p=0.010), while the total amount of blood transfused was significantly higher in Group R compared to Group C (p<0.0001). Preoperative and postoperative platelet levels were similar between groups, but platelet levels were significantly lower in both groups compared to their preoperative levels (Group C, p<0.0001, Group R, p<0.0001). When the preoperative albumin levels were compared, the patients in Group R had higher albumin levels than in Group C, whereas postoperative albumin levels were significantly higher in Group C than Group R (p<0.0001). The percentage of patients who didn't receive blood transfusion during CPB was significantly higher in Group C (p=0.011). While the percentage of patients who didn't receive FFP transfusion was significantly higher in Group C (p=0.002), the percentage of patients who didn't receive apheresis platelet transfusion was similar.
**Conclusion:** Our findings indicate that usage of centrifugal pump has clear superiority in terms of effects on hemostatic system during CPB when compared to roller pump. Nevertheless, we believe that our results should be supported by advanced clinical and experimental studies.

**Key Words:** Cardiopulmonary bypass (CPB), Centrifugal pump, Roller pump, Hemostatic system

**ÖZET**

**Amaç:** Teknolojik gelişmeler ve bilgi seviyesinin yükselmesi, çoğu merkezde düşük mortalite ve morbidite oranları ile kalp cerrahisine olanak sağlamaktadır. Diğer yandan kardiyopulmoner baypas (KPB) sırasında hemostaz yönetimi, postoperatif komplikasyonların gelişmesinde kritik bir rol oynar.
Sentrifugal pompa ve roller pompa tekniklerinin KPB sırasında hemostatik sistem üzerindeki etkilerini karşılaştırmayı amaçladık.
**Yöntem:** Gazi Üniversitesi Kalp ve Damar Cerrahisi Anabilim Dalı'nda Haziran 2012 - Haziran 2013 tarihleri arasında aynı cerrahi ekip tarafından roller veya sentrifugal pompa ile koroner arter baypas ameliyatı geçiren yüz hasta kayıt altına alındı. Çalışmaya 40 yaş üstü ve bilinen herhangi bir immünolojik, bulaşıcı veya inflamatuar hastalığı olmayan ve son 6 aydır hematolojik problemi olmayan hastalar dahil edildi. İki çalışma grubu (Grup R: Roller pompa grubu ve Grup C: Sentrifugal pompa grubu) oluşturuldu. Trombosit sayıları, albümin seviyeleri KPB'den önce ve sonra ölçüldü. KPB sırasında kullanılan kan miktarı, kullanılan toplam kan miktarı, KPB sırasında beş veya daha fazla ünite kan kullanan hastaların yüzdesi, taze donmuş plazma (TDP) veya aferez trombosit konsantreleri almayan hastaların yüzdesi kaydedildi.
**Bulgular:** KPB sırasında transfüze edilen kan miktarı Grup C'de Grup R'ye göre anlamlı olarak daha düşükken (0.28±0.08 U; 0.68±0.13) (p=0.010) transfüze edilen toplam kan miktarı Grup R'de, Grup C'ye göre anlamlı olarak daha yüksekti (p<0.0001). Preoperatif ve postoperatif trombosit düzeyleri gruplar arasında benzerdi, ancak trombosit düzeyleri preoperatif düzeylerine göre her iki grupta anlamlı olarak daha düşüktü (Grup C, p<0.0001, Grup R, p<0.0001). Preoperatif albümin düzeyleri karşılaştırıldığında, Grup R'deki hastaların albümin düzeyleri Grup C'ye göre daha yüksek iken, postoperatif albümin düzeyleri Grup C'de Grup R'ye göre anlamlı yüksekti (p<0.0001). KPB sırasında kan transfüzyonu almayan hasta oranı Grup C'de anlamlı olarak daha yüksekti (p=0.011). Grup C'de TDP transfüzyonu almayan hasta oranı anlamlı olarak yüksekken (p=0.002), aferez trombosit transfüzyonu almayan hasta oranı benzerdi.
**Sonuç:** Bulgularımız, sentrifugal pompa kullanımının KPB sırasında hemostatik sistem üzerindeki etkileri açısından roller pompaya göre açık bir üstünlüğe sahip olduğunu göstermektedir. Yine de, sonuçlarımızın gelişmiş klinik ve deneysel çalışmalarla desteklenmesi gerektiğine inanıyoruz.

**Anahtar Sözcükler:** Kardiyopulmoner baypas (KPB), Sentrifugal pompa, Roller pompa, Hemostatik sistem

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## INTRODUCTION

Cardiacsurgery is beingperformedwithlowmortalityrates in manysurgicalcenters. However, hemostasis management during cardiopulmonary bypass plays a critical role in development of postoperative complications. There are multiple factors in the etiology of coagulopathy, inflammatory response and hemostatic system disorders during cardiopulmonary bypass (CPB) (1-4). A roller pumpcontributes to these adverse effects more common as the centrifugal pumps are known to damage red blood cells (RBC), platelets, and plasma proteins less than the conventional roller pumps (5-8).

Cardiopulmonary bypass (CPB) provides a bloodless field for cardiac surgery. CPB pumps send gravitational blood pooling in vena cava to a reservoir, oxygenate and send back to the body and maintain a certain pressure and flow velocity during this process. There are two types of pumps; 1–centrifugaland 2–roller pumps (9). Centrifuga lpumps may improve platelet preservation, renal function and neurological outcomes in longer cases (10).

We aimed to compare the effects of centrifugal pump -where it is claimed that blood of patients is exposed to minimal trauma- and roller pump techniques on hemostatic system during CPB.

## MATERIAL and METHODS

After obtaining ethical committee approval from Clinical Investigations Ethical Committee of Gazi University and written consent from all patients, we included 100 patients undergoing coronary artery bypass surgery by same surgeon team with CPB pump between June 2012 and June 2013. Patients aged over 40 years, without any immunological, infectious or inflammatory diseases history in last 6 months and without any known hematological disorders were enrolled into the study.

Premedication was made with Diazepam 10 mg orally one night before surgery and 5 mg morphine subcutaneously in the operation morning. Following routine monitorization (EKG, $SpO_2$), peripheral venous cannulation was made. Invasive blood pressure, radial artery cannulation was made for monitorization(B-Cat 2 22G, Bıçakçılar Medical Devices Company). Standard anesthesia protocol was carried out. Monitorization of body temperature was made using nasopharyngeal probe. Venous blood samples were drawn from 18G catheter (Secalon T®, BD Medical, Singapore) placed in right internal jugular vein. Exact localization of tip of catheter was confirmed with X-ray after operation.

Following skin antisepsis surgical site was covered with sterile drapes. After making skin and subcutaneous incisions median sternotomy was performed and pericardium was opened. After preparing vascular grafts anticoagulation was made with heparin at a dose of 4 mg/kg. Priming fluid was prepared using 1 gr cefazolin plus 50 mg heparin added into 1500 cc of lactated ringer. ACT levels were maintained above 410 seconds in order to proper anticoagulation. After performing standard aorta-atrial cannulation CPB was initiated. 24 F cannula for aortic cannulation and 36/51 F(two-stage) polyvinylchloride cannula (Maquet GmbH & Co. KG. Rostatt, Germany) for atrial cannulation were used. In Group R a roller pump (Stöckert SIII, Sorin Group Deutchland GMBH, München) was used where a centrifugal pump was used in Group C. Also a 25 µm arterial filter (Jostra, Anaheim, CA), an adult membrane oxygenator (Jostra, Anaheim, CA) and a hard-shell venous cardiotomyreservoire (Jostra, Anaheim, CA) were used.

Total pump stream was adjusted at 2,4lt/$m^2$/min and hemodilution was achieved via decreasing hematocrit levels to 26%. Pressure of pump stream was adjusted at 60-70 mmHg during CPB. Until withdrawing of cannulas, ACT( Hemochron® Jr Signature Plus Whole Blood Microcoagulation System, Tx, USA) measurement was done with 30 minutes intervals. Additional heparin administration was done when needed.

Cardioplegia solution was prepared using mixture of 40 mEqKCl, 20 mEq $NaHCO_3$ and 0,5 ml Ca Gluconate (0.9%) in 500 ml of isotonic saline. Following aortic cross clamping anterograde hypothermic (+8°C) blood cardioplegia solution (15 ml/kg) was infused. Cardioplegia infusion was repeated at 5 ml/kg dose at every 20 minutes intervals. Alpha stat pH measurements were done. Minimal body temperature measured via nasopharyngeal probe was 30 C.

After performing bypass grafting and distal anastomoses, cross clamp was removed and heart has started beating. When needed proximal anastomoses were made after aortic partial clamping. After achieving sufficient blood pressure and heart rate, CPB ended. Following decannulation and bleeding control, thoracic and/or mediastinal tubes were inserted and after the sternum was wired and patients were transferred to the ICU. In ICU blood pressure, heart rate, amounts of drainage and laboratory parameters were evaluated during first 6 hours in ICU.

Patients were followed in ICU at least 1 night, after weaning and extubationpatients were transferred to ward. Patients with a stable hemodynamic status, sufficient mobilization and completely improved consciousness level were discharged from hospital. Mean length of hospital stay was 6-7 days.

Two study groups (Group R: Roller pump group and Group C: Centrifugal pump group) were created. Platelet counts and albumin levels were measured before and after CPB; the amount of blood used during the pump, total blood amount used, percentage of patients using five or more units of blood during CPB, percentage of patients who didn't receive FFP (Fresh frozen plasma) or apheresis platelet concentrates were recorded.

*Statistical Analysis*

SPSS version 20,0 was used for statistical analysis. Data were expressed as mean ± standard deviation (SD). A p level <0.05 was considered as statistically significant. Kolmogorov-Smirnov test was used in order to determine normal distribution of data. Intergroup differences in normally distributed variables were evaluated using Student's t test. Data regarding two different time points -before and after CPB- within the same group were evaluated using paired t test. Variables such as sex and concomitant disease status of the groups were evaluated using Chi-square or Fisher's exact Chi-square tests.

## RESULTS

Demographical data of patientsin two study groups were similar(Table1). Cardiopulmonary bypass time, aortic cross-clamping time and number of vessels bypassed were found similar between study groups (Table 2).

**Table1.** Demographical data of patients in study groups [Mean ± SD, n ]

| | Group C (n=50) | Group R (n=50) | P |
|---|---|---|---|
| **Age (year)** | 58.22±9.21 | 59.66±8.35 | 0.415 |
| **Weight (kg)** | 78.00±10.67 | 76.58±11.74 | 0.525 |
| **Height (cm)** | 168.60±7.74 | 168.46±7.16 | 0.928 |
| **Sex (M/F)** | 37/13 | 36/14 | 0.822 |

**Table 2.** Operative data of the groups[Mean ± SD, n ]

| | Group C (n=50) | Group R (n=50) | P |
|---|---|---|---|
| **Cardiopulmonary bypass time (min)** | 110.76±35.84 | 101.30±36.95 | 0.197 |
| **Aortic cross-clamping time (min)** | 69.04±24.31 | 60.02±23.86 | 0.064 |
| **Number of vessels bypassed (n)** | 3.00±1.09 | 2.90±1.05 | 0.642 |

The amount of blood transfused during CPB was significantly lower in Group C than in Group R (0.28±0.08 U; 0.68±0.13) (p=0.010), while the total amount of blood transfused was significantly higher in Group R compared to Group C (p<0.0001). The total amount of blood used was recorded as 4.78 U in Group R and 3.08 U in Group C.Preoperative and postoperative platelet levels were similar between groups, but platelet levels were significantly lower in both groups compared to their preoperative levels (Group C, p<0.0001, Group R, p<0.0001).

When the preoperative serum albumin levels were compared, Group R had higher albumin levels than Group C(p=0.016), whereas postoperative albumin levels were significantly higher in Group C than Group R (p<0.0001).In both groups, albumin levels were significantly decreased compared to their preoperative values (Group C, p<0.0001; Group R, p<0.0001) (Table 3). The percentage of patients who didn't receive blood transfusion during CPB was significantly higher in Group C (p=0.011). While the percentage of patients who didn't receive FFP transfusion was significantly higher in Group C (p=0.002), the percentage of patients who didn't receive apheresis platelet concentrates transfusion was similar.

**Table 3.** Used blood products and albumin and platelet data [Mean ± SD]

| | Group C (n=50) | Group R (n=50) | P |
|---|---|---|---|
| **Pump blood (U)** | 0.28±0.08 | 0.68±0.13* | 0.010 |
| **Total Blood (U)** | 3.08±0.18 | 4.78±0.24* | <0.0001 |
| **Preoperative platelet** | 226924.00±11728.36 | 245268.00±12403.95 | 0.285 |
| **Postperative platelet** | 150686.00±7622.34+ | 140366.00±6829.63+ | 0.316 |
| **Preoperative albumin** | 3.86±0.08 | 4.12±0.08* | 0.016 |
| **Postperative albumin** | 2.54±0.06+ | 2.16±0.06*,+ | <0.0001 |
| **Apheresis (U)** | 0.08±0.03 | 0.18±0.07 | 0.205 |
| **FFP** | 1.06±0.18 | 1.70±0.16* | 0.009 |

***:** p<0.05 (when compared with Group C)
**+:** p<0.05 (when compared with data achieved before pump)

78% of thepatients in Group C and 54% of thepatients in Group R did not receive blood transfusion during CPB. Thepercentage of patientswhodid not receive blood transfusion during CPB wassignificantlyhigher in Group C ($X^2$=6.496, p=0.011) (Table 4). 14% of thepatients in Group C and 46% of thepatients in Group R received total blood transfusion of 5 U andmore.

The percentage of patients receiving five units and more blood was significantly higher in Group R ($X^2$=33.165, p<0.0001) (Table 4). FFP was not used in 46% of patients in Group C and 12% of patients in Group R. Thepercentage of patientswho received no FFP transfusion wassignificantlyhigher in Group C ($X^2$=6.896,p=0.002) (Table 4).Apheresis platelet concentrates were not used in 92% of patients in Group C and in 86% of patients in Group R, the rates were similar (Table 4).

**Table 4.** Percentage of blood products used in patients [n%]

| | Group C (n=50) | Group R (n=50) | P |
|---|---|---|---|
| **Pump blood (0-4)** | 39(78)/8(16)/3(6)/0(0)0(0) | 27(54)/15(30)/6(12)/1(2)1(2) | $X^2$=6.496 p=0.011 |
| **Total Blood (1-9)** | 4(8)/13(26)/17(34)/9(18) 5(10)/2(4)/0(0)/0(0)/0(0) | 0(0)/2(4)/9(18)/16(32) 10(20)/5(10)/1(2)/6(12)/1(2) | $X^2$=33.165 p<0.0001 |
| **Apheresis (0-2)** | 46(92)/4(8)/0(0) | 43(86)/5(10)/2(4) | $X^2$=2.985 p=0.204 |
| **FFP (0-4)** | 23(46)/13(26)/5(10)/6(12)3(6) | 6(12)/18(36)/15(30)/7(14)4(8) | $X^2$=16.896 p=0.002 |

***:** p<0.05 (when compared with Group C)

## DISCUSSION

In this study, we retrospectively compared the changes in hemostatic system in100 adult patients undergoing coronary artery bypass surgery by the same surgical team with CPB pump using roller versus centrifugal pumps. Improved clinical outcome with centrifugal pumps has been reported in pediatric and adult patients before (11-13). Centrifugal pump has been found to be related to less postoperative mediastinal bleeding and reduced transfusion requirements. Although we found that blood transfused during CPB was significantly lower in Group C than in Group R, while the total amount of blood transfused was significantly higher in Group R compared to Group C. In addition, the percentage of patients who didn't receive blood transfusion during CPB was significantly higher in Group C. In terms of hemolysis, complement activation and platelet activation the superiority of a centrifugal pumpover a rollerpump in adults has beenshownby a number of in-vitro and clinical (5,14–17). In our study, preoperative and postoperative platelet levels were similar between the groups, but postoperative platelet levels were significantly lower in both groups compared to their preoperative levels (Group C, p<0.0001, Group R, p<0.0001) and the percentage of patients who didn't receive apheresis platelet transfusion was similar also. In CPB patients, increased platelet activation (expressed by beta-thromboglobulin) has been reported 1–24 h after bypass with roller compared with centrifugal pumps by some authors (7,18), but not by others (19, 20). The superiority of a centrifugal pump over a roller pump in terms of hemolysis, complement activation and platelet activation have been shown by a number of in-vitro and clinical studies in adults (5,14-17). In our study, we additionally found out that when the preoperative albumin levels were compared, Group R had higher albumin levels than Group C, whereas postoperative albumin levels were significantly higher in Group C than in Group R.

Our findings indicate that usage of centrifugal pump when compared to roller pump has clear superiority in terms of effects on hemostatic system during CPB. Nevertheless, we believe that our results should be supported by advanced clinical and experimental studies.

**Conflict of interest**

No conflict of interest was declared by the authors.

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