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ORIGINAL ARTICLE / ÖZGÜN MAKALE

# Comparison of minimal invasive extracorporeal circulation versus standard cardiopulmonary bypass systems on coronary artery bypass surgery

*Koroner arter baypas cerrahisinde minimal invaziv ekstrakorporeal dolaşım ile standart kardiyopulmoner baypas sistemlerinin karşılaştırılması*

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***ABSTRACT***

***Background:*** In this study, we shared our experience with the minimal invasive extracorporeal circulation system for coronary artery bypass grafting patients.

***Methods:*** A total of 163 patients were included in the retrospective study, with 83 patients (63 males, 20 females; mean age: 61.9±8.9 years; range, 35 to 81 years) undergoing coronary artery bypass grafting with minimal invasive extracorporeal circulation and 80 patients (65 males, 15 females; mean age: 60.5±8.8 years; range, 43 to 82 years) undergoing coronary artery bypass grafting with conventional cardiopulmonary bypass between July 2021 and April 2023. Elective coronary bypass performed by same surgical team were included in the study. Mortality, major adverse cardiac and cerebrovascular event, hospital stays and transfusion requirements were evaluated.

***Results:*** There were no significant differences in sex distribution, age, comorbidities, and blood values between the two groups. Intraoperatively, the minimal invasive extracorporeal circulation group had a slightly higher number of distal anastomoses and comparable times for aortic cross-clamp and cardiopulmonary bypass. Postoperative outcomes such as tamponade, bleeding, atrial fibrillation, left ventricular ejection fraction improvement or reduction, and postoperative drainage were similar between the two groups. However, the minimal invasive extracorporeal circulation group had fewer transfusions of packed red blood cells and fresh frozen plasma and a shorter length of stay in the intensive care unit.

***Conclusion:*** The minimal invasive extracorporeal circulation system effectively preserves blood, works with lower activated clotting time values without additional complications in coronary artery bypass grafting, and could present a better option for patients with anemia or patients with a relatively high risk for high-dose heparinization.

***Keywords:*** Complications minimal invasive extracorporeal circulation, coronary artery bypass grafts, inflammatory response, pathophysiology.

***ÖZ***

***Amaç:*** Bu çalışmada koroner arter baypas grefti hastalarına yönelik minimal invaziv ekstrakorporeal dolaşım sistemi ile ilgili deneyimlerimizi paylaştık.

***Çalışma planı:*** Temmuz 2021 - Nisan 2023 tarihleri arasında minimal invaziv ekstrakorporeal dolaşım ile koroner arter baypas grefti uygulanan 83 hasta (63 erkek, 20 kadın; ort. yaş: 61.9±8.9 yıl; dağılım, 35-81 yıl) ve konvansiyel kardiyopulmoner baypas ile koroner arter baypas grefti uygulanan 80 hasta (65 erkek, 15 kadın; ort. yaş: 60.5±8.8 yıl; dağılım, 43-82 yıl) olmak üzere toplam 163 hasta retrospektif çalışmaya dahil edildi. Aynı ekip tarafından gerçekleştirilen elektif koroner baypas vakaları çalışmaya dahil edildi. Ölüm, majör advers kardiyak ve serebrovasküler olay, hastane yatışları ve transfüzyon gereksinimleri değerlendirildi.

***Bulgular:*** İki grup arasında cinsiyet dağılımı, yaş, komorbidite ve kan değerleri açısından anlamlı fark yoktu. Ameliyat sırasında, minimal invaziv ekstrakorporeal dolaşım grubunda distal anastomoz sayısı biraz daha fazlaydı ve aortik kros klemp ve kardiyopulmoner baypas için benzer süreler vardı. Tamponad, kanama, atriyal fibrilasyon, sol ventrikül ejeksiyon fraksiyonunda iyileşme veya azalma ve ameliyat sonrası drenaj gibi ameliyat sonrası sonuçlar iki grup arasında benzerdi. Bununla birlikte, minimal invaziv ekstrakorporeal dolaşım grubuna daha az paketlenmiş eritrosit ve taze donmuş plazma transfüzyonu yapıldı ve yoğun bakım ünitesinde kalış süresi daha kısaydı.

***Sonuç:*** Minimal invaziv ekstrakorporeal dolaşım sistemi kanı etkili bir şekilde korumaktadır, koroner arter baypas greftlemede ek komplikasyon olmadan daha düşük aktif pıhtılaşma zamanı değerleriyle çalışmaktadır ve anemisi olan veya yüksek doz heparinizasyon için nispeten yüksek riskli hastalar için daha iyi bir seçenek sunabilmektedir.

***Anahtar sözcükler:*** Komplikasyonlar minimal invaziv ekstrakorporeal dolaşım, koroner arter baypas greftleri, enflamatuar yanıt, patofizyoloji.

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Coronary artery bypass grafting (CABG), a frequent and life-saving cardiac procedure, is generally performed with a conventional cardiopulmonary bypass (CPB) system since the first days of cardiac surgery in the 1960s. Conventional CPB involves exposing blood to air and nonendothelial surfaces, leading to coagulation cascades, platelet activation, and the occurrence of microemboli and thromboembolic events.[1] To address these concerns, minimal invasive extracorporeal circulation (MiECC) has been established in the past decades.[2]

Current literature demonstrates that MiECC surpasses conventional CPB in various aspects, including reduced blood product usage, shorter hospital and intensive care unit (ICU) stays, decreased mortality and thromboembolic events, and improved myocardial protection.[2] Based on accumulating evidence, MiECC was recommended as class 2A evidence for blood preservation in the 2019 European Association for Cardio-Thoracic Surgery (EACTS)/European Association of Cardiothoracic Anaesthesiology (EACTA)/European Board of Cardiovascular Perfusion (EBCP) guideline on CPB in cardiac surgery and 2021 Society of Thoracic Surgeons (STS)/Society of Cardiovascular Anesthesiologists (SCA)/American Society of ExtraCorporeal Technology (AmSECT)/Society for the Advancement of Blood Management (SABM) update to the clinical practice guidelines on patient blood management.[3,4] Furthermore, Turkish national societies recommend the use of MiECC for specific indications as a measure to conserve blood and prevent the need for transfusions.[5]

This study aimed to assess the potential effects and benefits of MiECC on outcomes of isolated coronary surgery. The primary objective of the study was to evaluate the effectiveness of MiECC in protecting blood and reducing the usage of blood products. Additionally, the study aimed to assess the impact of MiECC on secondary endpoints, such as the reduction in length of stay in the ICU and the inpatient service.

## PATIENTS AND METHODS

This single-center retrospective observational study was carried out with 163 patients who underwent isolated elective CABG with sternotomy at the Koşuyolu High Specialization Training and Research Hospital, Department of Cardiovascular Surgery between July 2021 and April 2023. Among these patients, 83 (63 males, 20 females; mean age: 61.9±8.9 years; range, 35 to 81 years) underwent CABG with the use of MiECC, while 80 patients (65 males, 15 females; mean age: 60.5±8.8 years; range, 43 to 82 years) underwent CABG with conventional CPB. The same surgical team, specializing in both MiECC surgery and isolated coronary bypass, performed operations on both groups of patients. The elective cases were performed in the same operating theatre with the same anesthesiologists and perfusionists. In emergency cases, a perfusionist or anesthesiologist who could operate the MiECC system may not have been available. Additionally, a centrifugal pump was not present in all operating rooms. Therefore, in emergency cases, the operations could have been performed at different operating rooms that did not have a centrifugal pump to combine with the MiECC system. Since emergency cases were not included in the MiECC group, they were excluded from the conventional system group to achieve a sufficient comparison. Furthermore, since we did not have the experience of using MiECC systems in minimally invasive CABG and in cases where concomitant cardiac intervention is required, this group of patients was also excluded from the study.

### Surgical technique

All surgeries were conducted through standard median sternotomy under general anesthesia, utilizing grafts from the left internal mammary artery and the great saphenous vein. Both groups underwent standard aortic and single two-stage venous cannulation. Initially, intermittent cold blood cardioplegia with an antegrade approach was employed. Later, we changed our strategy and started using Del Nido cardioplegia in both groups.

A MiECC system (LivaNova, London, UK) with the Sorin Revolution Centrifugal pump, 3/8-inch coated tubing, and a hollow fiber oxygenator featuring an integrated arterial filter (Inspire 6F Phisio-coated; LivaNova, London, UK) was utilized in the MiECC group. The perfusion strategy evolved over time, initially incorporating type 2 and 3 MiECC systems with a soft-shell reservoir bag and venting system. As we adapted to the system, the type 1 MiECC system became the routine choice. Mild hypothermia (33-34°C) was maintained, with a target flow rate index of 2.5 L/min per square meter of body surface area using nonpulsatile flow. The system was primed with 800 to 1000 mL of Ringer solution along with 100 mL of mannitol. Retrograde autologous priming (RAP) was performed in hemodynamically stable cases. Heparin (100 IU/kg) was given intravenously to initiate perfusion. According to the position paper from the MiECTiS (Minimal Invasive Extracorporeal

Technologies International Society), the target activated clotting time (ACT) value for the CABG cases is around 300 to 350 sec.[6] Although the operations were initially performed with higher ACT values, over time, as our strategies were updated and the system became almost completely closed circuit, the operations were performed at lower ACT levels. The target ACT value was maintained between 250 and 350 sec. with close monitoring and repeated measurements during perfusion. After each ACT measurement, it was determined whether an additional dose of heparin would be administered by the joint decision of the surgeon, anesthesiologist, and perfusionist, considering the course of the operation and the estimated perfusion time. Initially, coronary suction was used in a few cases involving type 2 or 3 MiECC. The use of autotransfusion (cell saver) or coronary suction was avoided in the early stages of type 1 MiECC cases, and instead, we focused on strict bleeding control. However, after encountering high transfusion requirements and unnecessary blood loss in two to three cases, we decided to change our approach and began routinely using cell saver and type 1 MiECC systems. It is important to note that the tubing systems were coated with phosphorylcholine, and the priming fluid did not contain heparin.

The extracorporeal circuit in the CPB group was an open system, featuring 3/8 to 1/2-inch noncoated tubing (Bıçakcılar, İstanbul, Türkiye), an S5 heart-lung machine (LivaNova, London, UK), and a hollow fiber oxygenator with an integrated arterial filter (FX Terumo FX25; Terumo, Tokyo, Japan). Surgeries were conducted under moderate hypothermia (30-32°C). The system was primed with 1500 mL of Ringer solution supplemented with 150 mL of mannitol. Heparin (300-400 IU/kg) was given intravenously to initiate CPB, with a target ACT value of >450 sec. during the surgery. In the standard CPB group, only cardiotomy suction was routinely used. Cell saver was not used in this group.

### Data collection

Preoperative data were meticulously gathered by examining medical records from our department and cross-referencing them with the national electronic recording system. Intraoperative data were collected by reviewing surgical records. This involved documenting crucial information such as the number of distal anastomoses, aortic cross-clamp time, CPB time, initial hematocrit (Hct) levels, Hct levels after the operation, postoperative Hct difference, maximum ACT during the operation, and ACT after the operation.

Postoperative data were gathered from multiple sources, including ICU and general ward records, as well as national electronic health system records, to ensure a comprehensive approach. This allowed for the recording of vital variables such as tamponade, stroke, bleeding, atrial fibrillation, transfusion requirements including fresh frozen plasma (FFP) and packed red blood cells (PRBCs), postoperative drainage, postoperative troponin levels, postoperative hemoglobin (Hgb) levels, postoperative Hct levels, left ventricular ejection fraction, intubation time, ICU duration, and length of hospital stay.

Stage 1 acute kidney injury was defined as serum creatinine of 1.5 to 1.9 times of baseline. Stage 2 was defined as serum creatinine of 2.0 to 2.9 times of baseline. Stage 3 was defined as serum creatinine ≥3.0 times of baseline or new-onset dialysis.[7]

### Anemia and postoperative transfusion strategy

The cut-off values for normal Hgb were 13.5 g/dL for male and 12 g/dL for female patients. Symptomatic (e.g., hypotension, tachycardia, and dyspnea) patients with Hct values <25 were routinely transfused with 1 unit of PRBCs. In addition, all anemic patients were started on oral iron therapy.

### Statistical analysis

Statistical analysis was performed using the IBM SPSS version 22.0 software (IBM Corp., Armonk, NY, USA). The categorical data in this study were reported as percentages, reflecting the proportion of individuals within each category. Numerical data were presented as mean ± standard deviation (SD). To evaluate any differences, statistical analyses were performed using chi-square tests and measures such as Phi and Cramer's test for categorical variables. For numerical variables, Student's t-test was employed. A *p*-value <0.05 was considered statistically significant.

## RESULTS

### Patient characteristics

The sex distribution was similar between the MiECC and conventional CPB groups, with 24.1% female patients in the MiECC group compared to 18.8% in the CPB group (p=0.406). The mean age showed no significant difference between the groups (p=0.796). Other variables such as hypertension (p=0.916), type 2 diabetes mellitus (p=0.531), anemia (p=0.111), and left ventricular ejection fraction (p=0.142) were comparable between the two groups. In terms of blood values, the mean preoperative Hgb

**Table 1. Patient characteristics**

| | MiECC | | | Conventional CPB | | | |
|---|---|---|---|---|---|---|---|
| Variables | n | % | Mean±SD | n | % | Mean±SD | *p* |
| Age (year) | | | 61.9±8.9 | | | 60.5±8.8 | 0.796 |
| Sex | | | | | | | |
| Female | 20 | 24.1 | | 15 | 18.8 | | 0.406 |
| Hypertension | 14 | 16.9 | | 13 | 16.2 | | 0.916 |
| Peripheral arterial disease | 2 | 2.4 | | 2 | 2.5 | | 0.970 |
| Type 2 diabetes mellitus | 41 | 49.4 | | 35 | 43.8 | | 0.531 |
| Anemia | 36 | 43.4 | | 24 | 31.2 | | 0.111 |
| Left ventricular ejection fraction | | | 56.0±9.9 | | | 55.4±11.1 | 0.142 |
| Blood values | | | | | | | |
| Hemoglobin | | | 13.5±2.1 | | | 13.9±1.7 | 0.051 |
| Hematocrit | | | 40.4±5.6 | | | 41.5±4.5 | 0.059 |
| C-reactive protein | | | 6.5±7.7 | | | 5.4±5.7 | 0.036 |

MiECC: Minimal invasive extracorporeal circulation; CPB: Cardiopulmonary bypass; SD: Standard deviation.

levels were 13.5±2.1 g/dL in the MiECC group and 13.9±1.7 g/dL in the CPB group (p=0.051). Similarly, preoperative Hct levels were slightly lower in the MiECC group compared to the CPB group (p=0.059). However, the preoperative C-reactive protein (CRP) level was significantly higher in the MiECC group (p=0.036, Table 1).

Intraoperative findings were compared between the MiECC and conventional CPB groups, as shown in Table 2. The mean distal anastomosis count was 3.3±0.9 in the MiECC group and 3.1±0.8 in the CPB group, indicating a slightly higher number in the MiECC group (p=0.064). The mean aortic cross-clamp time was 56.0±21.1 min in the MiECC group and 60.0±20.4 min in the CPB group, with no significant difference (p=0.381). Similarly, the CPB time was comparable between the two groups, with a mean of 97.6±24.8 min in the MiECC group and 101.3±28.0 min in the CPB group (p=0.651).

Regarding blood parameters, the initially measured Hct levels were 37.6±6.4 in the MiECC group and 39.4±5.5 in the CPB group, with no significant difference (p=0.163). However, the perioperative difference in Hct levels (perioperative

**Table 2. Operative characteristics**

| | MiECC | Conventional CPB | |
|---|---|---|---|
| | Mean±SD | Mean±SD | *p* |
| Variables | | | |
| Distal anastomosis count | 3.3±0.9 | 3.1±0.8 | 0.064 |
| Aortic cross clamp time | 56.0±21.1 | 60.0±20.4 | 0.381 |
| Cardiopulmonary bypass time | 97.6±24.8 | 101.3±28.0 | 0.651 |
| Blood values | | | |
| Hematocrit at the beginning | 37.6±6.4 | 39.4±5.5 | 0.163 |
| Hematocrit at the end of operation | 33.6±6.2 | 31.7±5.7 | 0.472 |
| Perioperative hematocrit difference | 4.5±4.1 | 8.0±5.2 | 0.016 |
| Maximum activated clotting time | 316±53 | 580±127 | 0.001 |

MiECC: Minimal invasive extracorporeal circulation; CPB: Cardiopulmonary bypass; SD: Standard deviation.

**Table 3. Postoperative outcomes**

| | MiECC | | | Conventional CPB | | | |
|---|---|---|---|---|---|---|---|
| | n | % | Mean±SD | n | % | Mean±SD | *p* |
| Variables | | | | | | | |
| Postoperative tamponade | 1 | 1.2 | | 1 | 1.2 | | 0.979 |
| Postoperative bleeding | 0 | 0.0 | | 2 | 2.5 | | 0.244 |
| Postoperative AKI | 7 | 8.3 | | 11 | 14.5 | | 0.220 |
| Postoperative atrial fibrillation | 2 | 2.4 | | 4 | 5.1 | | 0.355 |
| Postoperative stroke | 0 | 0.0 | | 0 | 0.0 | | - |
| Postoperative TIA | 0 | 0.0 | | 0 | 0.0 | | - |
| Postoperative drainage | | | 513±288 | | | 630±297 | 0.254 |
| Transfused PRBCs | | | 1.0±1.3 | | | 1.6±1.9 | 0.004 |
| Transfused FFP | | | 0.1±0.3 | | | 0.4±0.8 | 0.001 |
| Postoperative LVEF | | | 56.2±9.4 | | | 57.0±9.3 | 0.747 |
| Intubation time (h) | | | 7.9±3.7 | | | 7.6±3.4 | 0.460 |
| LOS ICU (Days) | | | 1.2±0.5 | | | 1.5±1.1 | 0.001 |
| LOS ward (Days) | | | 6.1±1.7 | | | 6.6±2.2 | 0.221 |
| Blood values | | | | | | | |
| Postoperative hemoglobin D1 | | | 10.3±1.7 | | | 9.9±1.6 | 0.449 |
| Postoperative hemoglobin D3 | | | 8.7±1.3 | | | 8.4±1.4 | 0.498 |
| Postoperative hemoglobin D4 | | | 9.4±1.6 | | | 9.3±1.4 | 0.139 |
| Postoperative hematocrit D1 | | | 30.7±4.8 | | | 29.7±4.6 | 0.432 |
| Postoperative hematocrit D3 | | | 26.9±4.4 | | | 25.5±4.0 | 0.288 |
| Postoperative hematocrit D4 | | | 28.6±4.8 | | | 29.0±4.2 | 0.437 |
| Postoperative C-reactive protein D1 | | | 56 ±54 | | | 49±37 | 0.764 |
| Postoperative C-reactive protein difference | | | 50±48 | | | 49±36 | 0.643 |
| Postoperative C-reactive protein D3 | | | 179±74 | | | 178±75 | 0.554 |
| Postoperative Cr D1 | | | 1.08±0.51 | | | 0.99±0.31 | 0.118 |
| Postoperative Cr D3 | | | 1.05±0.75 | | | 0.98±0.45 | 0.271 |
| Postoperative Tr D1 | | | 0.576±0.616 | | | 0.622±0.886 | 0.425 |

MiECC: Minimal invasive extracorporeal circulation; CPB: Conventional cardiopulmonary bypass; SD: Standard deviation; AKI: Acute kidney injury; TIA: Transient ischemic attack; PRBCs: Packed red blood cells; D: Day; FFP: Fresh frozen plasma; LVEF: Left ventricular ejection fraction; LOS: Length of stay; ICU: Intensive care unit; Tr: Troponin.

Hct difference) was significantly higher in the CPB group (p=0.016). The course of the Hgb and Hct values are shown in Figure 1 and Figure 2. The maximum ACT during the procedure was 316±54 sec in the MiECC group and 580±127 sec in the CPB group, showing a significant difference (p=0.001).

Postoperative outcomes were compared between the MiECC and conventional CPB groups, as shown in Table 3. The occurrence of postoperative tamponade was similar between the two groups, with 1.2% (n=1) in both the MiECC and CPB groups (p=0.979). While no cases of postoperative reexploration for bleeding were reported in the MiECC group, 2.5% (n=2) of patients in the CPB group experienced reexploration for bleeding (p=0.244). Postoperative atrial fibrillation occurred in 2.4% (n=2) of patients in the MiECC group and 5.1% (n=4) in the CPB group, with no significant difference (p=0.355). Postoperative acute kidney injury was observed in 8.3% (n=7) of patients in the MiECC group and 14.5%

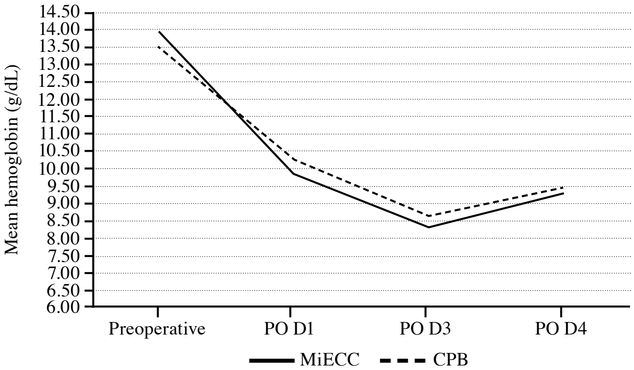


**Figure 1.** Course of hemoglobin values during the pre- and postoperative period.

PO: Preoperative; D: Day.

(n=11) of patients in the CPB group without statistical difference (p=0.220). There were no recorded cases of postoperative transient ischemic attack or stroke in either group.

The mean postoperative drainage was 513±288 mL in the MiECC group and 630±297 mL in the CPB group, showing no significant difference (p=0.254). However, a significant difference was observed in the transfusion of PRBCs and FFP. The MiECC group received a mean of 1.0±1.3 units of PRBCs compared to the 1.6±1.9 units in the CPB group (p=0.004). The transfusion of FFP was 0.1±0.3 units in the MiECC group and 0.4±0.8 units in the CPB group (p=0.001). The mean intubation time was similar between the MiECC and conventional CPB groups, with 7.9±3.7 h and 7.6±3.4 h, respectively (p=0.460). However, the length of stay in the ICU was significantly shorter in the MiECC group, with a mean of 1.2±0.5 days compared to 1.5±1.1 days in the conventional CPB group (p=0.001). The length of stay in the inpatient service did not show a statistically significant difference between the MiECC and CPB groups, with values of 6.1±1.7 days and 6.6±2.2 days, respectively (p=0.221).

Regarding blood values, no significant differences were observed between the MiECC and CPB groups in terms of postoperative Hgb levels (p=0.449). Similarly, there were no significant differences in postoperative Hct levels (p=0.432). The postoperative levels of CRP were also comparable between the MiECC and CPB groups, showing no statistically significant differences. Additionally, the postoperative troponin levels on the first day did not differ significantly between the MiECC and CPB groups, with values of 0.576±0.616 ng/mL and 0.622±0.886 ng/mL, respectively (p=0.425).

Although there was no statistically significant difference between groups, postoperative AKI incidence was lower in the MiECC group (8.5%) than in the CPB group (14.5%; odds ratio 1.69).

## DISCUSSION

This study, positioned among the most extensive investigations in Europe employing the state-of-the-art MiECC system, underscores the hematoprotective significance of MiECC. It unveils the practicality of performing CABG with reduced ACT values. The MiECC technique was developed to enhance biocompatibility and ensure more physiological perfusion during cardiac surgeries, serving as an alternative to conventional CPB. Theoretically, MiECC offers several advantages. First, it prevents air-blood contact, thereby reducing the risk of complications. Additionally, it minimizes inflammation, leading to reduced mechanical trauma compared to roller pumps.[2] Furthermore, MiECC maintains optimal perfusion efficiency by utilizing a lower prime volume, thereby preventing hemodilution. Numerous clinical

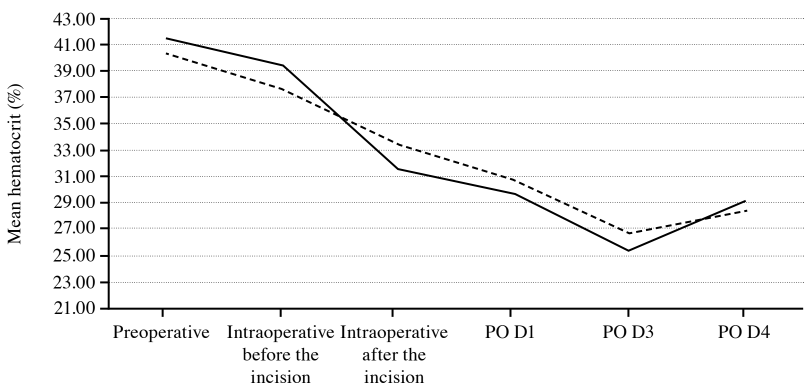


**Figure 2.** Course of hematocrit values during the pre- and postoperative period.

studies provided evidence supporting these theoretical advantages. In a meta-analysis encompassing 2,770 patients from 24 studies, MiECC demonstrated statistically significant superiority over conventional bypass in terms of systemic inflammatory response syndrome, hemodilution, and PRBC transfusion.[8]

This study covers our first cases and the adaptation period of surgeons, anesthesiologists, anesthesia technicians, and perfusionists during the transition from a more open MIECC system to a completely closed system. During this period, changes have occurred in our approaches and awareness on issues such as blood preservation, volume distribution, priming, heparin use, ACT management, and cardioplegia management. Over time, these changes have been reflected in our clinical practice in both MiECC systems and standard systems.

Postoperative hemorrhage exhibited a noteworthy reduction in the MiECC group; however, in contrast to reported findings in the extant literature, our investigation did not unveil a statistically significant disparity. The reason might be the use of type 2 or 3 MiECC systems in the initial period and working at high ACT levels. Furthermore, it is noteworthy that none of the patients in the MiECC cohort necessitated reexploration due to bleeding, whereas two patients in the CPB group underwent reexploration. The dedication to a conservative conventional CPB strategy, geared towards mitigating volume overload, coupled with an unwavering commitment to intensive bleeding control protocols, likely played a role in the comparatively marginal variance observed in postoperative drainage between the MiECC and CPB groups. Although this discrepancy failed to attain statistical significance, the meticulous adherence to these strategies underscores their potential impact on mitigating adverse postoperative outcomes.

With the implementation of MiECC, blood becomes less diluted, and the interaction between blood and foreign bodies is minimized, resulting in lower postoperative losses of Hct and Hgb. Consequently, MiECC is recommended in both general guidelines and blood conservation protocols to minimize the reliance on blood products.[3-5] Ellam et al.[9] observed a reduction in blood product usage and postoperative Hgb loss with the adoption of MiECC. In our investigation, we noted that MiECC effectively preserved blood and its components during cardiac surgery, leading to a significantly reduced perioperative Hct difference compared to the control group. However, the use of blood products led to a convergence of Hgb and hemostatic values between the two groups. Furthermore, the MiECC group exhibited a substantial decrease in the utilization of blood products throughout the entire hospitalization period. These findings highlight the efficacy of MiECC, specifically in anemic patients and those undergoing CABG with a relatively higher distal anastomosis count which correlates with current literature.[9,10] However, there was no statistically significant difference in the two patient groups on the first, third, and fourth days after surgery. It is possible for the blood products used in patients with decreased Hgb to have an effect. Accordingly, significantly more blood products were used in the conventional group than in the MiECC group. In other words, the similarity in postoperative days is due to the difference in the use of blood products.

There are many reasons that affect blood transfusion in on-pump CABG surgery. These factors include the patient's age, general health condition, anemia or clotting disorders, type and complexity of heart surgery, type of surgical procedure, amount of blood lost during surgery, and duration of surgery. Postoperative factors that affect the need for blood transfusion include chest tube drainage, systemic infection, or multiorgan dysfunction.[11-13]

One of the methods suggested to reduce postoperative transfusions is the use of cell savers. According to the EACTS/EACTA/EBCP guidelines, the use of cell savers in cardiac surgery has positive effects.[14] Likewise, according to the STS/SCA/AmSECT/SABM guidelines, positive effects of cell saver in cardiac surgery were stated without clear effects on mortality and morbidity.[4] On the other hand, it has been argued that large volumes of salvaged blood may disrupt the coagulation cascade.[15] In our study, the cell saver system was used only in the MiECC group, and cardiotomy suction was used only in the CPB group. Studies showing the positive effects of cell saver use in terms of transfusion generally compared the simultaneous use of a cell saver with a cardiotomy suction or the use of a cardiotomy suction alone. Therefore, when comparing the two groups in our study, we cannot clearly state whether the use of cell saver contributes to positive results in terms of transfusion need.

Another method proposed to reduce intra- or postoperative transfusion is autologous priming of the on-pump system. Guidelines state that RAP is a simple, safe, and effective process to decrease intraoperative and postoperative transfusion rates and should be done as much as possible.[4,14] In our study, there was no significant difference between the groups in terms of RAP. Therefore, we do not think that this approach will lead to a significant difference in terms of transfusion between the two groups.

Another significant finding from our study pertains to the optimization of ACT value, which aims to minimize the invasiveness of extracorporeal circulation.[16] In the MiECC group, the mean maximum ACT value recorded was 316±54 sec, compared to 580±127 sec in the conventional CPB group. Despite this substantial difference, neither group experienced any thromboembolic events, such as oxygenator or device-line thrombosis and stroke or transient ischemic attack, and the surgeries were safely completed. Existing literature suggests that MiECC can be implemented at an ACT value of around 350 sec, whereas our study demonstrates that MiECC can be safely conducted with lower ACT values.[17] This demonstrates that MiECC utilization allows for a more physiological and secure extracorporeal circulation, marked by significantly lower ACT values. This positions MiECC as a noteworthy alternative for anticoagulation, particularly beneficial for high-risk patients. Furthermore, the findings suggest that on-pump coronary bypass surgery can be safely conducted even with low ACT values, underscoring the procedure's safety and lack of complications.

As a secondary endpoint, we evaluated the length of stay in both the inpatient service and the ICU. The results indicated a shorter mean ICU stay with the utilization of MiECC; however, we did not observe a corresponding reduction in the length of stay in the inpatient service. We believe that one of the crucial factors influencing this lack of difference in length of stay is the strict adherence to the Enhanced Recovery After Surgery protocols at our clinic, allowing for prompt patient discharge from the facility.[18]

Contrary to the existing literature, this study did not reveal any inflammatory benefits associated with the use of MiECC. In our clinic, pre- and postoperative inflammatory markers, such as interleukin-6 or tumor necrosis factor-alpha, were not measured routinely. C-reactive protein is the only inflammatory marker that was measured routinely. Although preoperative CRP values were significantly higher in the MiECC group, there were no significant differences between groups in the postoperative period. However, CRP can be influenced by various confounding factors.[8,19]

Regarding renal outcomes, it is well documented in the literature that MiECC is associated with a reduced risk of renal injury and acute kidney injury, and its impact on this outcome is also emphasized in current clinical guidelines.[2,3,4,8,20] In this study, we observed an incidence of acute kidney injury in 8.5% of the MiECC group and 14.5% of the CPB group. Although the odds ratio of 1.69 was notable, the analysis revealed that this difference did not achieve statistical significance. Furthermore, we did not observe any statistically significant difference between postoperative creatinine values.

This study showed no significant difference in troponin values between the MiECC and conventional CPB groups, contrary to two studies in the literature.[8,21] We closely monitored cardioplegia and troponin levels during conventional CPB, which may have contributed to the lack of difference. Additionally, there are numerous cofactors that can trigger troponin elevation, and the present study may not have had enough patients to overcome these inherent differences.

The main limitations were that the study was nonrandomized and retrospective and contained a relatively limited sample size. The strength of this article lies in its comprehensive comparison of intraoperative and postoperative hemodynamic data between two groups with similar preoperative characteristics and a similar number of patients who were operated on by the same surgical team in a short period of time.

In conclusion, this study investigated the use of minimal invasive extracorporeal circulation compared to conventional conventional cardiopulmonary bypass in patients undergoing isolated coronary artery bypass surgery and revealed significant advantages in terms of hematological preservation and blood product utilization. The use of minimal invasive extracorporeal circulation was associated with a shorter length of stay in the intensive care unit, lower perioperative hematocrit difference, and a reduced need for transfusion of packed red blood cells and fresh frozen plasma. Furthermore, minimal invasive extracorporeal circulation allowed for the optimization of activated clotting time, achieving a more physiological extracorporeal circulation with lower activated clotting time values, revealing an alternative for patients at relatively high risk for anticoagulation. Although this study had limitations, it contributes to the growing body of evidence supporting the use of minimal invasive extracorporeal circulation in cardiac surgeries. Future research with larger sample sizes is warranted to further explore the potential benefits of minimal invasive extracorporeal circulation and its impact on patient outcomes.

**Ethics Committee Approval:** The study protocol was approved by the Kartal Kosuyolu High Specialization Training and Research Hospital Clinical Research Ethics Committee (date: 31.01.2023, no: 2023/02/666). The study was conducted in accordance with the principles of the Declaration of Helsinki.

**Patient Consent for Publication:** A written informed consent was obtained from each patient.

**Data Sharing Statement:** The data that support the findings of this study are available from the corresponding author upon reasonable request.

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