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# Assessing hemodynamic changes before and after pump in CABG surgery and its factors

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## Abstract

**BACKGROUND:** One of the main complications after coronary artery bypass grafting (CABG) is postoperative clinical and para-clinical changes, which present a significant challenge.

**METHODS:** This descriptive cross-sectional study included 109 patients who were candidates for CABG and were admitted to the surgical intensive care unit at Tehran Heart Center Hospital, selected using random sampling and a checklist. Relationships between variables were analyzed with the Kolmogorov-Smirnov (K-S) test, paired t-test, and regression.

**RESULTS:** The findings from the mean changes before and after the pump showed that blood sugar (28.23 ± 33.43), lactate (6.59 ± 5.63), potassium (0.75 ± 0.47), and heart rate (12.36 ± 15.46) increased significantly after the pump compared to before the pump ($p < 0.05$), while hemoglobin (-2.5 ± 1.28), hematocrit (-6.61 ± 3.44), pH (-0.03 ± 0.06), $PaO_2$ (-92.95 ± 94.01), bicarbonate (-1.83 ± 2.38), and mean blood pressure (-2.25 ± 13.01) decreased significantly ($p < 0.05$). Gender had a significant effect on cerebral oximetry values on both the right ($\beta = 5.461$, $p = 0.002$) and left ($\beta = 4.835$, $p = 0.004$) sides, hemoglobin ($\beta = 0.644$, $p = 0.017$), and hematocrit ($\beta = 2.055$, $p = 0.004$). In addition, patients' comorbidities also had a positive effect on $PaO_2$ ($\beta = 11.340$, $p = 0.044$).

**CONCLUSION:** The clinical and para-clinical status in patients undergoing CABG surgery changes after on-pump surgery. In addition, comorbidities of patients have a positive and significant effect on $PaO_2$, as well as gender, on cerebral oximetry, hemoglobin, and hematocrit values.

**Keywords:** Coronary Artery Bypass; Surgery; Comorbidity; Hematologic Tests, Blood Pressure

## Introduction

Coronary artery bypass grafting (CABG), a procedure also known as open-heart surgery, involves the use of a healthy artery or vein (i.e., graft) to bypass an obstructed coronary artery, with approximately 400,000 cases performed annually[1]. The first CABG was conducted by René Favaloro in 1967 at the Cleveland Clinic. Since then, CABG has evolved into one of the most common and effective primary surgical treatments for ischemic heart disease since its inception in the 1960s[2].

This procedure is employed to bypass atherosclerotic obstructions in a major coronary artery, thereby restoring blood supply to ischemic myocardial tissue[3]. Although cardiac surgery is a reliable method for improving myocardial perfusion, it is associated with numerous postoperative complications. Due to the use of extracorporeal circulation in open-heart surgery, a wide range of systemic disturbances can arise[4]. One common postoperative issue is hemodynamic instability. Patients often face significant complications shortly after surgery due to incomplete drainage of blood and fluids from the pericardial and pleural cavities, which directly or indirectly contribute to reduced cardiac pumping efficiency, blood pressure fluctuations, pulse irregularities, respiratory difficulties, arrhythmias, and extensive postoperative hemodynamic changes[5,6]. Consequently, in postoperative cardiac care, adequate drainage is essential and unavoidable to prevent hemodynamic alterations, increased blood volume, hypotension, and reduced cardiac output[7].

Several risk factors contribute to postoperative hemodynamic complications, including age, body mass index, the number of affected vessels, duration of extracorporeal circulation, preoperative blood pressure, duration of aortic cross-clamping, electrolyte levels, preoperative hemoglobin, and anesthesia duration, all of which are among the most significant factors influencing postoperative outcomes[6,7].

On-pump CABG is a technique that mitigates the adverse effects associated with aortic clamping and cardioplegic arrest[8]. This approach ensures continuous coronary perfusion to protect against myocardial injury. It utilizes cardiopulmonary bypass (CPB) to provide circulatory support and maintain hemodynamic stability during the procedure[9]. Despite CABG being an effective treatment option for patients with coronary artery disease, with significant technical and clinical advancements over the years, postoperative complications remain prevalent, particularly in the early days following surgery, especially within the first 24 hours[6,10]. Therefore, a deeper understanding of this treatment process can not only reduce complications but also contribute to lowering healthcare costs[11]. To this end, the present study evaluated the influence of demographic factors and comorbidities on pre- and post-pump clinical and para-clinical stability in CPB. The findings aim to inform the adoption of appropriate strategies and the implementation of necessary therapeutic and care measures to prevent and address complications of cardiac surgery, thereby optimizing patient outcomes.

## Methods

*Patients and setting*

This study is cross-sectional research. The samples in this study included 109 patients undergoing CABG surgery admitted to Tehran Heart Center Hospital in the years 2024–2025. The inclusion criteria for the study included elective CABG surgery, ages between 35 and 75 years, and ASA II and III. The ASA physical status classification system is used to assess and inform about comorbidities before anesthesia. This classification system (I to VI) can be useful in predicting intraoperative risks. ASA II is a patient with mild systemic disease, and ASA III is a patient with severe systemic disease[12]. Exclusion criteria included the presence of any mental or psychological disorders, pregnancy or breastfeeding, and patients with uncontrolled hypertension or diabetes. Patients were then enrolled in the study using a random sampling method from October to January 2025. The checklist was completed by patients immediately before surgery and one hour after surgery. Patients meeting the inclusion criteria were introduced to the study by the researcher, provided with an explanation of the study's purpose, and asked to sign a consent form. In this study, all ethical considerations related to the study were observed, including maintaining confidentiality of information, informed and voluntary participation in the study, the right to withdraw from the study without any problems or deprivation of treatment, etc. Written consents were obtained from the participants before conducting the research. Necessary permits were obtained before conducting the research. This study was approved by the Ethics Committee of Tehran University of Medical Sciences (Ethics Committee Reference Number: IR.TUMS.SPH.REC.1403.119).

*Data collection*

The data collection tool was a researcher-designed checklist (data collection form), and the data collection method involved reviewing recorded patient medical records. The checklist was divided into two sections:

1. The first section included questions related to the distribution of demographic factors (e.g., gender, age, and body mass index), clinical factors (e.g., hypertension, diabetes, history of myocardial infarction, hypothyroidism, addiction, and smoking).

2. The second section addressed patients' clinical and para-clinical stability, including heart rate, bispectral index, cerebral oximetry, oxygen saturation, systolic/diastolic blood pressure, respiratory rate, blood glucose, lactate, sodium, potassium, hemoglobin, hematocrit, pH, $PaCO_2$, $PaO_2$, $HCO_3$, and the distribution of inotrope use, and laboratory parameters (e.g., cholesterol, triglyceride, blood urea nitrogen, and creatinine) of the study participants.

All data (including demographic characteristics, height, weight, history of blood pressure, diabetes, heart attack, hypothyroidism, addiction, and smoking, etc.) were extracted from the patients' medical records and, if necessary, patients were asked before surgery to complete the information. Clinical and para-clinical stability was assessed at two time points: immediately before surgery and one hour after using the pump. Blood samples for blood tests were collected by a laboratory scientist after the patient had fasted for at least 8 hours, then analyzed and reported by the Tehran Heart Center laboratory using standard laboratory equipment. The definition of each test was based on the clinical normal range at this hospital and reliable sources, including Na (13–145 mEq/L), K (3.5–5 mEq/L), BUN (7–20 mg/dL), creatinine (0.7–1.4 mg/dL), hemoglobin in men (14 to 18 g/dL) and in women (12 to 16 g/dL), pH (7.35–7.45), carbon dioxide tension (35–45), bicarbonate (22–26)[13], high triglycerides (≥150 mg/dL), high-density lipoprotein cholesterol (HDL-C) <40 mg/dL in men or <50 mg/dL in women, high fasting blood glucose (FPG; ≥100 mg/dL)[14].

According to the European Society of Cardiology, SBP ≥140 mmHg or DBP ≥90 mmHg was considered high blood pressure, measured using a calibrated central sphygmomanometer on two occasions[15]. Also, a heart rate of 60–100 beats per minute was considered a normal range, which was continuously monitored with a central monitoring device[16]. Oxygen saturation levels ($SpO_2$) between 94–99% were considered the normal range, which was measured continuously using a pulse oximetry device[14]. Ejection fraction is used to measure the heart's pump function and is usually between 55 and 70%. Values below 40% may indicate heart failure. A cardiologist measured patients' EF preoperatively using an echocardiogram[17]. Bispectral index (BIS), which is a measure of brain wave activity that indicates the level of consciousness or depth of anesthesia, with values of 40 to 60 typically indicating a suitable level for general anesthesia, and lower values indicating a deeper state of anesthesia. This index was assessed using a bispectral index (BIS) measuring device[17]. Normal cerebral oximetry values in cardiac patients range from 60% to 80%, with values below 55–60% considered abnormal. This index was measured using a standard oximetry device[18]. Smoking (currently smoking at least one cigarette per day) was assessed based on patient self-report before surgery. Body mass index (BMI) was calculated using preoperative height and weight measurements. BMI = 25–29.9 and BMI ≥30 were considered overweight and obese, respectively[19].

To ensure the scientific validity of the data collection tool, the researcher developed the checklist based on content validity, drawing from relevant scientific books and articles aligned with the study's conceptual framework.

*Statistical Analysis*

The data were analyzed using SPSS version 27, employing both descriptive and inferential statistical methods. Continuous variables were presented as mean ± standard deviation. For analytical purposes, the normality of quantitative variables was assessed using the Kolmogorov-Smirnov test. For data analysis, paired t-tests were used to compare the mean of quantitative variables after the pump compared to before. Additionally, regression analysis was used to examine the effects of age, gender, underlying diseases, and other factors on the studied factors. In all analyses, a significance level of less than 0.05 was considered.

## Results

Of the 109 patients studied, the majority were male (68.8%) and aged between 56 and 75 years (73.4%). Most participants (75.2%) were overweight or obese, with a BMI greater than 25 kg/m². Regarding comorbidities and underlying conditions, 28.4% of participants had hypertension, 15.6% had diabetes mellitus, and 30.3% had both comorbidities. Additionally, 11.9% of the studied individuals exhibited a combination of diabetes, hypertension, and myocardial infarction, while 7.3% showed a combination of diabetes, hypertension, and hypothyroidism. Furthermore, 6.4% of the patients were smokers and opium users.

Regarding gender distribution, the number of male participants was approximately twice that of female participants. In terms of age distribution, the majority of participants (73.4%) were in the 56–75 age group, and most were overweight, with a BMI exceeding 25 (75.2%). Analysis of comorbidities revealed that the majority of patients had hypertension and type 2 diabetes, while a small number had a history of myocardial infarction or hypothyroidism.

Regarding laboratory parameters, the mean levels of triglycerides and cholesterol were 143.61 ± 62.85 mg/dL and 143.53 ± 44.19 mg/dL, respectively. Blood urea nitrogen and creatinine levels were within the normal range, with mean values of 35.19 ± 11.61 mg/dL and 0.99 ± 0.26 mg/dL, respectively. The mean ejection fraction was 48.22 ± 7.24%, indicating moderate cardiac function (Table 1).

According to Table 2, oxygen saturation before and after the pump was 99.88 ± 0.57 and 99.93 ± 0.45, respectively. The bispectral index before surgery was reported as 43.77 ± 5.83, which increased post-surgery to 44.86 ± 6.61, indicating some changes in the level of sedation. Based on the obtained results, cardiovascular health before pump surgery was relatively stable, with a mean heart rate of 71.06 ± 12.31 bpm and a mean blood pressure of 81.93 ± 11.15 mmHg. Post-surgery, the heart rate increased to 83.42 ± 12.33 bpm ($p < 0.001$), while blood pressure slightly decreased to 79.68 ± 9.11 mmHg. Analysis of blood glucose and lactate levels showed that glucose levels increased significantly from 121.91 ± 38.03 mg/dL to 150.14 ± 31.56 mg/dL ($p < 0.001$). Similarly, lactate levels significantly increased from a normal range of 9.30 ± 3.39 mg/dL to 15.89 ± 6.78 mg/dL ($p < 0.001$). Preoperatively, sodium (137.69 ± 10.39 mEq/L) and potassium (3.87 ± 0.32 mEq/L) were within normal limits, indicating a stable preoperative state. Postoperatively, potassium levels increased significantly, indicating metabolic and hemodynamic changes associated with the procedure.

Other parameters, such as the right and left oximetry values before surgery, were 63.51 ± 9.05 and 62.87 ± 9.32, respectively, which slightly decreased post-surgery to 63.22 ± 7.84 and 61.82 ± 9.29, respectively. The bispectral

**Table 1.** Distribution of the patient's demographic, clinical, and laboratory factors

| Characteristics | | Measurements |
|---|---|---|
| **Age Groups** | 35-55 years, n (%) | 29 (26.6) |
| | 56-75 years, n (%) | 80 (73.4) |
| **Gender** | Male, n (%) | 75 (68.8) |
| | Female, n (%) | 34 (31.2) |
| **Body Mass Index; kg/m²** | BMI ≤ 24.9, n (%) | 27 (24.8) |
| | BMI ≥ 25.0, n (%) | 82 (75.2) |
| **Hypertension, n (%)** | | 31 (28.4) |
| **Diabetes Mellitus, n (%)** | | 17 (15.6) |
| **Diabetes Mellitus + Hypertension, n (%)** | | 33 (30.3) |
| **Diabetes Mellitus + Hypertension + Myocardial Infarction, n (%)** | | 13 (11.9) |
| **Diabetes Mellitus + Hypertension + Hypothyroidism, n (%)** | | 4 (3.7) |
| **Smoker + Opium Addict, n (%)** | | 7 (6.4) |
| **No Diseases, n (%)** | | 4 (3.7) |
| **Triglyceride, mg/dL, (Mean ± SD)** | | 143.61 ± 62.85 |
| **Cholesterol, mg/dL, (Mean ± SD)** | | 143.53 ± 44.19 |
| **Blood Urea Nitrogen, mg/dL, (Mean ± SD)** | | 35.19 ± 11.61 |
| **Creatinine, mg/dL, (Mean ± SD)** | | 0.99 ± 0.26 |
| **Ejection Fraction (Mean ± SD)** | | 48.22 ± 7.24 |

**Table 2.** An overview of the measurements taken before and after the pump procedure and their comparison

| Variables | Measurements Mean ± SD | | Change (After-Before) Mean ± SD | *P*-Value |
|---|---|---|---|---|
| | Before Pump | After Pump | | |
| **Right Cerebral Oximetry, %** | 63.51 ± 9.05 | 63.22 ± 7.84 | -0.29 ± 8.50 | 0.719 |
| **Left Cerebral Oximetry, %** | 62.87 ± 9.32 | 61.82 ± 9.29 | -1.05 ± 8.00 | 0.172 |
| **Bispectral Index** | 43.77 ± 5.83 | 44.86 ± 6.61 | 1.09 ± 8.06 | 0.160 |
| **Heart Rate, bpm** | 71.06 ± 12.31 | 83.42 ± 12.33 | 12.36 ± 15.46 | <0.001 |
| **Oxygen Saturation, %** | 99.88 ± 0.57 | 99.93 ± 0.45 | 0.05 ± 0.74 | 0.518 |
| **Systolic Blood Pressure, mmHg** | 114.98 ± 15.52 | 112.57 ± 12.22 | -2.41 ± 19.32 | 0.195 |
| **Diastolic Blood Pressure, mmHg** | 65.39 ± 10.67 | 63.23 ± 9.34 | -2.16 ± 12.18 | 0.066 |
| **Mean Blood Pressure, mmHg** | 81.93 ± 11.15 | 79.68 ± 9.11 | -2.25 ± 13.01 | 0.074 |
| **Respiratory Rate, breaths/min** | 11.95 ± 0.25 | 11.96 ± 0.23 | 0.01 ± 0.10 | 0.320 |
| **Blood Glucose, mg/dL** | 121.91 ± 38.03 | 150.14 ± 31.56 | 28.23 ± 33.43 | <0.001 |
| **Lactate, mg/dL** | 9.30 ± 3.39 | 15.89 ± 6.78 | 6.59 ± 5.63 | <0.001 |
| **Sodium, mEq/L** | 137.69 ± 10.39 | 139.30 ± 3.27 | 1.61 ± 10.38 | 0.108 |
| **Potassium, mEq/L** | 3.87 ± 0.32 | 4.62 ± 0.52 | 0.75 ± 0.47 | <0.001 |
| **Hemoglobin, g/dL** | 12.33 ± 1.87 | 9.83 ± 1.34 | -2.5 ± 1.28 | <0.001 |
| **Hematocrit, %** | 36.72 ± 4.69 | 30.11 ± 3.44 | -6.61 ± 3.44 | <0.001 |
| **pH** | 7.40 ± 0.45 | 7.37 ± 0.50 | -0.03 ± 0.06 | <0.001 |
| **PaCO2, mmHg** | 39.32 ± 5.08 | 39.01 ± 4.28 | -0.31 ± 5.41 | 0.554 |
| **PaO2, mmHg** | 297.69 ± 70.66 | 204.74 ± 84.03 | -92.95 ± 94.01 | <0.001 |
| **HCO3, mEq/L** | 24.22 ± 2.19 | 22.39 ± 1.75 | -1.83 ± 2.38 | <0.001 |

index before surgery was reported as 43.77 ± 5.83, which increased post-surgery to 44.86 ± 6.61, indicating some changes in the level of sedation. Although parameters including oxygen saturation, blood pressures (systolic, diastolic, and mean), and $PaCO_2$ remained stable, with no significant differences (Table 2).

Regarding the distribution of inotrope use, the majority of patients (56%) did not require intervention. Among those who needed intervention, norepinephrine was the most commonly used (18.3%), followed by epinephrine (7.3%) and packed red blood cells (PRBC) (5.5%). Combination therapies, such as norepinephrine with PRBC (4.6%), were less frequently utilized, and other combinations were rare (each less than 1%). This indicates that most patients maintained stable hemodynamics, requiring minimal inotrope administration (Table 3).

The results of this study showed that a

**Table 3.** Inotropes and blood products used for patients on the pump

| Inotrope | N (%) |
|---|---|
| Norepinephrine | 20 (18.3) |
| Epinephrine | 8 (7.3) |
| PRBC | 6 (5.5) |
| Norepinephrine + Epinephrine | 1 (0.9) |
| FFP + PLT | 1 (0.9) |
| Norepinephrine + PRBC | 5 (4.6) |
| Epinephrine + PRBC + FFP | 1 (0.9) |
| Epinephrine + PRBC | 3 (2.8) |
| Norepinephrine + PLT | 1 (0.9) |
| Epinephrine + Norepinephrine + FFP | 1 (0.9) |
| Dobutamine + PRBC | 1 (0.9) |
| None | 61 (56.0) |

**Table 4.** ABG status in patients before and after the pump

| ABG | Before Pump, n (%) | After Pump, n (%) |
|---|---|---|
| Normal ABG | 54 (49.5) | 39 (35.8) |
| Respiratory Acidosis | 12 (11.0) | 8 (7.3) |
| Respiratory Alkalosis | 19 (17.4) | 10 (9.2) |
| Metabolic Acidosis | 10 (9.2) | 38 (34.9) |
| Metabolic Alkalosis | 6 (5.5) | 2 (1.8) |
| Mix | 8 (7.3) | 12 (11.0) |
| Total = 109 | | |

significant decrease in pH, $PaO_2$, bicarbonate ($HCO_3$), hemoglobin, and hematocrit postoperatively, compared to preoperatively, indicated the development of metabolic acidosis ($p < 0.001$) (Table 2). In this regard, in comparing the frequency of arterial blood gas (ABG) groups before and after the pump operation, a significant decrease in normal ABG values was observed, which decreased from 49.5% pre-pump to 35.8% post-pump. Metabolic acidosis showed a significant increase, rising from 9.2% to 34.9%, indicating a significant metabolic disorder that is probably related to this operation. Conversely, respiratory acidosis and respiratory alkalosis showed a decreased frequency postoperatively, while combined acid-base disorders slightly increased from 7.3% to 11.0% (Table 4).

Table 5 shows the effect of demographic factors on clinical and para-clinical stability. Gender showed a significant effect on cerebral oximetry values in both the right and left sides ($\beta = 5.461$ with $p = 0.002$ and $\beta = 4.835$ and 0.004, respectively). Gender also affected hemoglobin ($\beta = 0.644$ and $p = 0.017$) and hematocrit ($\beta = 2.055$ and $p = 0.004$). Additionally, patients' comorbidities had a positive effect on $PaO_2$ ($\beta = 11.340$, $p = 0.044$). Other factors did not affect clinical and para-clinical stability ($p > 0.05$).

## Discussion

Coronary artery bypass grafting is associated with certain complications, with significant clinical and para-clinical stability post-surgery being a common issue[20]. The present study evaluated the influence of demographic factors and comorbidities on pre- and post-pump clinical and para-clinical stability in 109 patients following CABG performed with CPB. According to the results of the present study, the changes include increased heart rate, respiratory rate, glucose, lactate, and potassium levels, as well as decreased systolic and diastolic blood pressure, hemoglobin, hematocrit, pH, $PaO_2$, and bicarbonate. Additionally, patients' comorbidities have a positive and significant impact on $PaO_2$, while gender has a significant effect on cerebral oximetry, hemoglobin, and hematocrit values.

In our study, although diabetes was one of the most common comorbidities, we did not find a statistically significant association between diabetes and clinical and para-clinical stability.

**Table 5.** Investigating the impact of demographic factors on changes in clinical and para-clinical indicators

| Factors | Variables | β | Coefficients Std. Error | 95% confidence interval | P-value |
|---|---|---|---|---|---|
| **Age** | Right Cerebral Oximetry | 1.620 | 1.819 | -1.988 – 5.228 | 0.375 |
| | Left Cerebral Oximetry | 0.211 | 1.722 | -3.205 – 3.627 | 0.903 |
| | Bispectral Index | -1.072 | 1.792 | -4.625 – 2.482 | 0.551 |
| | Heart Rate | 5.182 | 3.422 | -1.604 – 11.968 | 0.133 |
| | Oxygen Saturation | 0.119 | 0.164 | -0.206 – 0.443 | 0.469 |
| | Systolic Blood Pressure | -2.749 | 4.334 | -11.343 – 5.845 | 0.527 |
| | Diastolic Blood Pressure | 2.029 | 2.686 | -3.297 – 7.355 | 0.452 |
| | Mean Blood Pressure | 0.451 | 2.900 | -5.300 – 6.203 | 0.877 |
| | Respiratory Rate | 0.010 | 0.021 | -0.032 – 0.053 | 0.629 |
| | Blood Glucose | -0.934 | 7.490 | -15.788 – 13.920 | 0.901 |
| | Lactate | -0.786 | 1.259 | -3.282 – 1.710 | 0.534 |
| | Sodium | -2.799 | 2.286 | -7.332 – 1.733 | 0.223 |
| | Potassium | -0.012 | 0.105 | -0.220 – 0.195 | 0.906 |
| | Haemoglobin | 0.304 | 0.279 | -0.249 – 0.856 | 0.278 |
| | Haematocrit | -0.474 | 0.740 | -1.940 – 0.993 | 0.523 |
| | pH | 0.013 | 0.012 | -0.011 – 0.038 | 0.280 |
| | PaCO2 | -1.249 | 1.206 | -3.641 – 1.142 | 0.303 |
| | PaO2 | -11.550 | 20.557 | -52.316 – 29.216 | 0.575 |
| | HCO3 | 0.245 | 0.533 | -0.812 – 1.303 | 0.646 |
| **Gender** | Right Cerebral Oximetry | 5.461 | 1.731 | 2.029 – 8.893 | 0.002 |
| | Left Cerebral Oximetry | 4.835 | 1.638 | 1.586 – 8.084 | 0.004 |
| | Bispectral Index | -0.779 | 1.704 | -4.159 – 2.601 | 0.649 |
| | Heart Rate | 2.944 | 3.255 | -3.511 – 9.399 | 0.368 |
| | Oxygen Saturation | -0.072 | 0.156 | -0.381 – 0.236 | 0.642 |
| | Systolic Blood Pressure | 0.178 | 4.122 | -7.996 – 8.353 | 0.966 |
| | Diastolic Blood Pressure | -0.909 | 2.555 | -5.975 – 4.157 | 0.723 |
| | Mean Blood Pressure | -0.536 | 2.759 | -6.007 – 4.935 | 0.846 |
| | Respiratory Rate | -0.013 | 0.020 | -0.054 – 0.027 | 0.511 |
| | Blood Glucose | 0.705 | 7.125 | -13.424 – 14.835 | 0.921 |
| | Lactate | -0.472 | 1.197 | -2.846 – 1.902 | 0.694 |
| | Sodium | -0.847 | 2.174 | -5.158 – 3.465 | 0.698 |
| | Potassium | -0.084 | 0.100 | -0.281 – 0.114 | 0.403 |
| | Haemoglobin | 0.644 | 0.265 | 0.118 – 1.169 | 0.017 |
| | Haematocrit | 2.055 | 0.704 | 0.660 – 3.450 | 0.004 |
| | pH | 0.004 | 0.012 | -0.019 – 0.028 | 0.701 |
| | PaCO2 | -0.326 | 1.147 | -2.601 – 1.949 | 0.777 |
| | PaO2 | -9.440 | 19.555 | -48.217 – 29.337 | 0.630 |
| | HCO3 | 0.376 | 0.507 | -0.630 – 1.382 | 0.460 |
| **BMI** | Right Cerebral Oximetry | -2.319 | 1.870 | -6.027 – 1.388 | 0.218 |
| | Left Cerebral Oximetry | -2.170 | 1.770 | -5.680 – 1.340 | 0.223 |
| | Bispectral Index | 2.747 | 1.841 | -0.904 – 6.399 | 0.139 |
| | Heart Rate | 0.515 | 3.517 | -6.459 – 7.488 | 0.884 |
| | Oxygen Saturation | -0.245 | 0.168 | -0.578 – 0.089 | 0.149 |
| | Systolic Blood Pressure | 0.363 | 4.453 | -8.469 – 9.194 | 0.935 |
| | Diastolic Blood Pressure | 1.771 | 2.760 | -3.702 – 7.243 | 0.523 |
| | Mean Blood Pressure | 1.300 | 2.980 | -4.610 – 7.210 | 0.664 |
| | Respiratory Rate | 0.013 | 0.022 | -0.031 – 0.057 | 0.556 |
| | Blood Glucose | -3.719 | 7.697 | -18.983 – 11.545 | 0.630 |
| | Lactate | 0.924 | 1.293 | -1.640 – 3.489 | 0.476 |
| | Sodium | -3.350 | 2.349 | -8.008 – 1.307 | 0.157 |
| | Potassium | -0.001 | 0.108 | -0.215 – 0.212 | 0.989 |
| | Haemoglobin | 0.087 | 0.286 | -0.481 – 0.655 | 0.762 |
| | Haematocrit | -0.622 | 0.760 | -2.129 – 0.885 | 0.415 |
| | pH | -0.021 | 0.013 | -0.046 – 0.004 | 0.092 |
| | PaCO2 | 1.133 | 1.239 | -1.325 – 3.590 | 0.363 |
| | PaO2 | -27.834 | 21.125 | -69.725 – 14.057 | 0.191 |
| | HCO3 | -0.220 | 0.548 | -1.307 – 0.867 | 0.689 |

**Table 5.** Investigating the impact of demographic factors on changes in clinical and para-clinical indicators

| Factors | Variables | β | Coefficients Std. Error | 95% confidence interval | P-value |
|---|---|---|---|---|---|
| Comorbidities | Right Cerebral Oximetry | -0.107 | 0.492 | -1.083 – 0.869 | 0.828 |
| | Left Cerebral Oximetry | -0.101 | 0.466 | -1.025 – 0.824 | 0.829 |
| | Bispectral Index | -0.201 | 0.485 | -1.162 – 0.761 | 0.680 |
| | Heart Rate | -0.559 | 0.926 | -2.396 – 1.277 | 0.547 |
| | Oxygen Saturation | 0.022 | 0.044 | -0.066 – 0.110 | 0.618 |
| | Systolic Blood Pressure | -0.602 | 1.173 | -2.927 – 1.724 | 0.609 |
| | Diastolic Blood Pressure | -1.241 | 0.727 | -2.682 – 0.201 | 0.091 |
| | Mean Blood Pressure | -1.029 | 0.785 | -2.585 – 0.527 | 0.193 |
| | Respiratory Rate | 0.001 | 0.006 | -0.011 – 0.012 | 0.919 |
| | Blood Glucose | -1.424 | 2.027 | -5.443 – 2.596 | 0.484 |
| | Lactate | 0.146 | 0.341 | -0.530 – 0.821 | 0.670 |
| | Sodium | -0.382 | 0.619 | -1.609 – 0.845 | 0.538 |
| | Potassium | -0.023 | 0.028 | -0.079 – 0.034 | 0.425 |
| | Haemoglobin | -0.006 | 0.075 | -0.155 – 0.144 | 0.941 |
| | Haematocrit | 0.058 | 0.200 | -0.339 – 0.455 | 0.771 |
| | pH | 0.004 | 0.003 | -0.003 – 0.010 | 0.271 |
| | PaCO2 | -0.187 | 0.326 | -0.834 – 0.460 | 0.568 |
| | PaO2 | 11.340 | 5.563 | 0.309 – 22.372 | 0.044 |
| | HCO3 | 0.055 | 0.144 | -0.231 – 0.342 | 0.702 |

Studies have shown that diabetes mellitus can significantly affect hemodynamic changes after CABG[21]. For example, in a study by Wang et al.[22], a significant association between diabetes and hemodynamic changes after CABG was reported. This discrepancy in the results of our study with other studies could be since the patients' blood sugar levels were within acceptable ranges, which is due to the appropriate management of diabetes by patients and physicians before surgery.

Systolic and diastolic hypotension is another vital variable investigated in the present study. The reasons for the drop in blood pressure in the patients in this study include the effect of medications used during surgery, a drop in hemoglobin and hematocrit, a decrease in fluid volume, etc. Ay Kılıçaslan et al. reported in a study that the risk of hypotension is increased due to intravascular volume loss, fluid volume changes, pain from sternotomy and analgesics (opioids) used for pain management, prolonged bed rest, and use of antihypertensive and diuretic drugs after cardiac surgery[23]. Ferreira et al. also reported that hypotension after CABG is due to systemic inflammatory response, vasoplegia, myocardial dysfunction, hypovolemia, rewarming effects, electrolyte imbalance, and drug effects[24], which is consistent with the results of our study.

Our study showed a significant increase in heart rate and respiratory rate. This rise, observed following CABG using the pump method, is primarily attributed to the systemic inflammatory response, which triggers heightened sympathetic activity and leads to early postoperative tachycardia[4]. Cardiac surgery-induced sympathetic stimulation triggers the release of catecholamines (e.g., epinephrine and norepinephrine). These hormones increase heart rate by stimulating beta-adrenergic receptors, resulting in tachycardia[25]. Other factors contributing to the elevated heart rate and respiratory rate post-surgery include pain from sternotomy incisions or chest drainage tubes, reduced blood oxygenation (hypoxemia), and electrolyte imbalances[6].

The reduction in hemoglobin and hematocrit levels following CABG with the pump method can be attributed to factors such as hemodilution from fluids in the CPB circuit, intraoperative and postoperative bleeding, hemolysis due to mechanical stress from CPB, fluid shifts, inflammatory responses, and decreased red blood cell production[26]. In a study by Ahmadi et al.[5], hemoglobin and hematocrit levels were identified as factors associated with postoperative hemodynamic changes, specifically an increase in central venous pressure. ABG analysis is a valuable parameter that provides critical information regarding patients' acid-base status, oxygenation, and ventilation. In the present study, a comparison of the frequency of ABG categories before and after using the pump revealed that the proportion of normal ABG values decreased post-pump (from 49.5% to 35.8%). Notably, before the pump, the majority of patients had normal ABG values.

A decrease in pH (metabolic or respiratory acidosis) may result from hyperlactatemia, hypoperfusion, or hypoventilation. Similarly, a reduction in $PaO_2$ (hypoxemia) can occur due to atelectasis, pulmonary shunting, pulmonary edema, or respiratory restriction caused by pain[27]. The consumption of bicarbonate due to elevated lactate levels or hypoperfusion may also be a primary cause of decreased $HCO_3$ levels. Wynne et al.[28] reported that atelectasis occurs in 50–70% of CABG patients and is associated with reduced $PaO_2$ and hypoxemia. Maillet et al.[29] reported a decrease in $HCO_3^-$ in 60% of CABG patients within the first 6 hours post-surgery, primarily due to elevated lactate levels.

Regarding the use of inotropes and blood products (such as packed red blood cells, platelets, and fresh frozen plasma), our findings showed that only a small number of patients required inotropic support. The primary reason for inotrope use during cardiac surgery is typically low cardiac output, which often occurs in patients with heart failure, renal impairment, low preoperative hemoglobin, or prolonged CPB[30]. In our study, the preoperative hemoglobin level, renal function tests, and mean ejection fraction in patients were within acceptable and standard ranges, which could be one of the reasons for the reduced need for inotropes in our study.

Our results showed that post-pump, the level of sedation increased from moderate to a higher level. Studies suggest cerebral oximetry values may change during and after CABG with the pump method, often experiencing a temporary decrease. Still, in most cases, they return to baseline or near-baseline levels post-surgery. Regional oxygen saturation ($rSO_2$) reduction is primarily attributed to hypoperfusion, embolism, hemodynamic changes, and inflammation induced by CPB. However, in patients with high-risk factors, these changes may be more persistent and could lead to neurological complications. The results of a meta-analysis demonstrated that interventions aimed at maintaining $rSO_2$ within the normal range (such as adjusting blood pressure or increasing pump flow) can reduce cerebral complications[31].

A comparison of on-pump and off-pump CABG in a study by Colak et al.[32] revealed that the on-pump method, due to the use of CPB, is associated with a greater reduction in $rSO_2$. However, this difference typically does not significantly impact long-term neurological outcomes. According to Murkin et al.[33], a decrease in $rSO_2$ during CPB is associated with an increased risk of postoperative cognitive dysfunction and neurological complications. Their study findings indicated that $rSO_2$ reduction in both hemispheres occurs in 70–80% of CABG patients undergoing CPB, but a significant difference between hemispheres is observed in only 5–10% of cases, often linked to embolism or localized hypoperfusion. The study emphasized that continuous near-infrared spectroscopy monitoring can aid in the early detection of hypoperfusion. In the current research, women had higher triglycerides, and men had slightly elevated creatinine levels before the pump. These findings are consistent with those reported by Koch et al.[34], who found that women had higher preoperative triglyceride levels but lower serum creatinine levels compared to men.

The regression statistical test in the present study showed that gender has a significant effect on cerebral oximetry, hemoglobin, and hematocrit values. In addition, patients' comorbidities also had a positive effect on $PaO_2$. Patlolla et al. reported in a study on patients undergoing CABG that several factors, such as age, gender, hospital location and status, underlying diseases, etc., have a significant impact on the surgical outcomes of patients. Also, regression analysis showed that female gender, advanced age, and underlying diseases significantly affect the clinical characteristics and surgical outcomes of patients, and each of these factors was an independent predictor of in-hospital mortality of patients[35]. The results of this study are consistent with the present study. Chiong et al. also confirmed the role and impact of gender on cerebral oximetry in patients undergoing cardiac surgery in a meta-analysis study. These researchers recommended considering this variable in cardiac surgeries because monitoring and maintaining standard levels of cerebral oximetry during surgery play an important role in subsequent outcomes in patients[36]. In this regard, the effect of gender and comorbidities on some clinical parameters (such as hemoglobin, blood oxygen, etc.) in patients undergoing CABG surgery has been reported and confirmed by several studies[37,38].

## Conclusions

Finally, the results of this study showed that the clinical and para-clinical status of patients undergoing CABG surgery changes after on-pump surgery. Therefore, it is suggested that careful monitoring and timely interventions be carried out according to the patients' conditions for better management and stabilization of the clinical and para-clinical status of patients.

### *Strengths and limitations*

A strength of this study was the inclusion of 109 participants, which is a relatively large sample for a single-center study involving detailed hemodynamic assessments. Another key strength was the analysis of several hemodynamic variables before and after pump usage, along with consideration of potential confounding factors such as patients' comorbidities. A limitation of the study was that it was conducted at a single center. Furthermore, the focus on short-term perioperative changes may not fully capture long-term hemodynamic shifts following CABG.


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## Conflict of interests

The authors declare no conflict of interest.


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## Author's Contributions

Study Conception or Design: MDF, SHM, AS, MS
Data Acquisition: MDF, SHM, AS
Data Analysis or Interpretation: SHM, AS
Manuscript Drafting: MDF, SHM, AS
Critical Manuscript Revision: SHM, AS, MS
All authors have approved the final manuscript and are responsible for all aspects of the work.

## References


1. McGonegal C, Bhatti S, Carrasquillo J, Potesta MA, Kavulich J, Toldi J. Effectiveness of Osteopathic Manipulative Treatment on Hemodynamic and Pulmonary Response in Coronary Artery Bypass Graft Patients: A Meta-Analysis. Cureus. 2024 Aug 27;16(8):e67968. https://doi.org/10.7759/cureus.67968
2. Kassab GS. Hemodynamic Design of Coronary Artery Bypass Graft, in Coronary Circulation: Mechanobiology, Growth, Remodeling, and Clinical Implications 2024, Springer. 339-406.
3. Bachar BJ, Manna B. Coronary artery bypass graft. StatPearls Publishing. 2023.
4. Kim H, Bae SH, Lim SH, Park JH. Predictors of health-related quality of life after coronary artery bypass graft surgery. Sci Rep. 2022 Sep 27;12(1):16119. https://doi.org/10.1038/s41598-022-20414-1
5. Ahmadi N, Reza Masouleh S, Shekani Z, Kazem Nezhad Leili E. Hemodynamic changes and related factors in patients undergoing coronary artery bypass grafting surgery. JHNM 2012; 22 (2) :1-10.
6. Engelman DT, Ben Ali W, Williams JB, Perrault LP, Reddy VS, Arora RC, et al. Guidelines for Perioperative Care in Cardiac Surgery: Enhanced Recovery After Surgery Society Recommendations. JAMA Surg. 2019 Aug 1;154(8):755-66. https://doi.org/10.1001/jamasurg.2019.1153
7. Jahangirifard A, Mirtajani S, Jabbari A, Saliminejad

L, Ghaheri M, Hossein Ahmadi Z. A Narrative Review of Cardiac Output Measurement in Cardiac Surgery. Arch Anesth & Crit Care. 2023;9(Supp. 2):541-8. https://doi.org/10.18502/aacc.v9i6.14453

8. Phothikun A, Nawarawong W, Tantraworasin A, Phinyo P, Tepsuwan T. The outcomes of three different techniques of coronary artery bypass grafting: On-pump arrested heart, on-pump beating heart, and off-pump. PLoS One. 2023 May 31;18(5):e0286510. https://doi.org/10.1371/journal.pone.0286510
9. Macedo FI, Rodriguez Y, Salerno TA. Myocardial preservation: beating heart techniques. Semin Thorac Cardiovasc Surg. 2011 Winter;23(4):314-7. https://doi.org/10.1053/j.semtcvs.2011.12.007
10. Shevchenko YL, Ermakov DY, Borshchev GG, Vakhrameeva AY, Ulbashev DS. Long-term Outcomes of Coronary Artery Bypass Grafting and Staged Hybrid Myocardial Revascularization in Patients With Ischemic Heart Disease. Open Cardiovasc Med J 2024;18(1):1-10. http://dx.doi.org/10.2174/0118741924331868241010093845
11. Kilpatrick, T. and L. Dryden, Anaesthesia for off-pump coronary artery bypass grafting. Anaesth Intensive Care Med 2024;25(4):244-8. https://doi.org/10.1016/j.mpaic.2024.01.004
12. American Society of Anaesthesiologists (ASA). Statement on ASA Physical Status Classification System. Committee on Economics 2020 December 13.
13. Massoumi G, Mansouri M, Khamesipour S. Comparison of the incidence and severity of delirium and biochemical factors after coronary artery bypass grafting with dexmedetomidine: A randomized double-blind placebo-controlled clinical trial study. ARYA Atheroscler. 2019 Jan;15(1):14-21. https://doi.org/10.22122/arya.v15i1.1748
14. Joseph JJ, Deedwania P, Acharya T, Aguilar D, Bhatt DL, Chyun DA, et al. Comprehensive Management of Cardiovascular Risk Factors for Adults With Type 2 Diabetes: A Scientific Statement From the American Heart Association. Circulation. 2022 Mar;145(9):e722-59.
15. McCarthy CP, Bruno RM, Rahimi K, Touyz RM, McEvoy JW. What Is New and Different in the 2024 European Society of Cardiology Guidelines for the Management of Elevated Blood Pressure and Hypertension? Hypertension 2025;82(3):432-44. https://doi.org/10.1161/HYPERTENSIONAHA.124.24173
16. Sobieraj P, Siński M, Lewandowski J. Resting Heart Rate and Cardiovascular Outcomes during Intensive and Standard Blood Pressure Reduction: An Analysis from SPRINT Trial. J Clin Med. 2021 Jul 24;10(15):3264. https://doi.org/10.3390/jcm10153264
17. Karedath J, Nazly S, Murtaza SF, Bhandari S, Sharma A, Talpur S, et al. Comparison of Early and Long-Term Mortality in Patients With Reduced and Preserved Ejection Fraction Undergoing Coronary Artery Bypass Graft: A Systematic Review and Meta-Analysis. Cureus. 2023 Aug 9;15(8):e43245. https://doi.org/10.7759/cureus.43245
18. Liu X, Nakano M, Yamaguchi A, Bush B, Akiyoshi K, Lee JK, et al. The association of bispectral index values and metrics of cerebral perfusion during cardiopulmonary bypass. J Clin Anesth. 2021 Nov;74:110395. https://doi.org/10.1016/j.jclinane.2021.110395
19. Weir CB, Jan A. BMI Classification Percentile and Cut Off Points. 2023 Jun 26. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025 Jan.
20. SSquiers JJ, Schaffer JM, Banwait JK, Ryan WH, Mack MJ, DiMaio JM. Long-Term Survival After On-Pump and Off-Pump Coronary Artery Bypass Grafting. Ann Thorac Surg. 2022 Jun;113(6):1943-52. https://doi.org/10.1016/j.athoracsur.2021.07.037
21. Wang R, Serruys PW, Gao C, Hara H, Takahashi K, Ono M, et al. Ten-year all-cause death after percutaneous or surgical revascularization in diabetic patients with complex coronary artery disease. Eur Heart J. 2021 Dec 28;43(1):56-67. https://doi.org/10.1093/eurheartj/ehab441
22. Whang W, Bigger JT Jr. Diabetes and outcomes of coronary artery bypass graft surgery in patients with severe left ventricular dysfunction: results from The CABG Patch Trial database. The CABG Patch Trial Investigators and Coordinators. J Am Coll Cardiol. 2000 Oct;36(4):1166-72. https://doi.org/10.1016/s0735-1097(00)00823-8
23. Kılıçaslan B, Bulut H, Kurtoğlu M. Incidence of orthostatic hypotension during early postoperative mobilization in cardiac surgery patients. J Gen Health Sci. 2024;6(3):491–503. https://doi.org/10.51123/jgehes.2024.144
24. Ferreira LO, Vasconcelos VW, Lima JDS, Neto JRV, Costa GED, Esteves JDC, et al. Biochemical Changes in Cardiopulmonary Bypass in Cardiac Surgery: New Insights. J Pers Med. 2023 Oct 18;13(10):1506. https://doi.org/10.3390/jpm13101506
25. Korhan GÇ. Inflammatory response in cardiopulmonary bypass process. MEHES J 2024;2(4):24-36. https://doi.org/10.5281/zenodo.14569321
26. Soliman R, Saad D, Abukhudair W, Abdeldayem S. The neurocognitive outcomes of hemodilution in adult patients undergoing coronary artery bypass grafting using cardiopulmonary bypass. Ann Card

Anaesth. 2022 Apr-Jun;25(2):133-40. https://doi.org/10.4103/aca.aca_206_20
27. Surabhi S, Kumar M. Comparison of ringer's lactate and plasmalyt-a as cardiopulmonary bypass prime for bypass associated acidosis in valve replacement surgeries. Ann Card Anaesth. 2021 Jan-Mar;24(1):36-41. https://doi.org/10.4103/aca.aca_104_19
28. Wynne R, Botti M. Postoperative pulmonary dysfunction in adults after cardiac surgery with cardiopulmonary bypass: clinical significance and implications for practice. Am J Crit Care. 2004 Sep;13(5):384-93.
29. Maillet JM, Le Besnerais P, Cantoni M, Nataf P, Ruffenach A, Lessana A, Brodaty D. Frequency, risk factors, and outcome of hyperlactatemia after cardiac surgery. Chest. 2003 May;123(5):1361-6. https://doi.org/10.1378/chest.123.5.1361
30. Mathis MR, Janda AM, Kheterpal S, Schonberger RB, Pagani FD, Engoren MC, et al. Patient-, Clinician-, and Institution-level Variation in Inotrope Use for Cardiac Surgery: A Multicenter Observational Analysis. Anesthesiology. 2023 Aug 1;139(2):122-41. https://doi.org/10.1097/aln.0000000000004593
31. Ding X, Zha T, Abudurousuli G, Zhao C, Chen Z, Zhang Y, et al. Effects of regional cerebral oxygen saturation monitoring on postoperative cognitive dysfunction in older patients: a systematic review and meta-analysis. BMC Geriatr. 2023 Mar 6;23(1):123. https://doi.org/10.1186/s12877-023-03804-6
32. Colak Z, Borojevic M, Bogovic A, Ivancan V, Biocina B, Majeric-Kogler V. Influence of intraoperative cerebral oximetry monitoring on neurocognitive function after coronary artery bypass surgery: a randomized, prospective study. Eur J Cardiothorac Surg. 2015 Mar;47(3):447-54. https://doi.org/10.1093/ejcts/ezu193
33. Murkin JM, Adams SJ, Novick RJ, Quantz M, Bainbridge D, Iglesias I, et al. Monitoring brain oxygen saturation during coronary bypass surgery: a randomized, prospective study. Anesth Analg. 2007 Jan;104(1):51-8. https://doi.org/10.1213/01.ane.0000246814.29362.f4
34. Koch CG, Khandwala F, Nussmeier N, Blackstone EH. Gender profiling in coronary artery bypass grafting. J Thorac Cardiovasc Surg. 2003 Dec;126(6):2044-51. https://doi.org/10.1016/s0022-5223(03)00955-3
35. Patlolla SH, Kanwar A, Cheungpasitporn W, Doshi RP, Stulak JM, Holmes DR Jr, et al. Temporal Trends, Clinical Characteristics, and Outcomes of Emergent Coronary Artery Bypass Grafting for Acute Myocardial Infarction in the United States. J Am Heart Assoc. 2021 Aug 3;10(15):e020517. https://doi.org/10.1161/jaha.120.020517
36. Chiong XH, Wong ZZ, Lim SM, Ng TY, Ng KT. The use of cerebral oximetry in cardiac surgery: A systematic review and meta-analysis of randomized controlled trials. Ann Card Anaesth. 2022 Oct-Dec;25(4):384-98.
37. Harik L, Perezgrovas-Olaria R, Jr Soletti G, Dimagli A, Alzghari T, An KR, et al. Sex differences in coronary artery bypass graft surgery outcomes: a narrative review. J Thorac Dis. 2023 Sep 28;15(9):5041-54. https://doi.org/10.21037/jtd-23-294
38. Matyal R, Qureshi NQ, Mufarrih SH, Sharkey A, Bose R, Chu LM, et al. Update: Gender differences in CABG outcomes-Have we bridged the gap? PLoS One. 2021 Sep 15;16(9):e0255170. https://doi.org/10.1371/journal.pone.0255170