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Comparative Impact Of On Pump Versus Off Pump Cardiac Surgery On Intensive Care Unit Stay

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Abstract

Background: Cardiac surgeries are commonly performed to treat various heart conditions, with two primary techniques being on-pump and off-pump coronary artery bypass grafting (CABG). On-pump surgery involves the use of cardiopulmonary bypass which temporarily takes over the function of the heart and lungs, whereas off-pump surgery is conducted on the beating heart without the use of a heart-lung machine.

Objective: comparative impact of on pump versus off pump cardiac surgery on intensive care unit stay.

Methodology: This study is an observational longitudinal comparison study. The research will include 50 patients undergoing elective cardiac surgeries, evenly divided into two groups: on-pump and off-pump procedures. The sample size was determined based on a standard formula for comparing two means, ensuring adequate power to detect significant differences at a 95% confidence level with a 5% margin of error. Exclusion criteria include redo surgeries, emergency procedures and incomplete medical records.

Results: There was a significant association between type of surgery and ICU stay ($p < 0.0001$), with longer ICU duration observed in the on-pump group compared to the off-pump group. No significant difference was observed in 30-day readmission between the groups ($p = 1.000$). Postoperative complications showed no statistically significant association with type of surgery ($p = 0.102$), although complications were numerically higher in the on-pump group. Overall, most clinical variables including discharge status, inotropic support, and readmission were not significantly associated with surgical technique, except for perioperative recovery outcomes such as ICU stay, mechanical ventilation, and operative time.

Conclusion: The study shows that CABG procedure type significantly affects ICU

stay. In patients having undergone off-pump surgeries ICU duration was lower and the majority of patients stayed in the ICU for six days. Arrhythmia was observed in patients having undergone off-pump surgeries. Preoperative and clinical indicators of both groups of patients did not differ.

Introduction

Cardiovascular diseases remain the leading cause of morbidity and mortality worldwide accounting for an estimated 17.9 million deaths annually, representing approximately 32% of all global deaths. Among them, coronary artery disease is the most common, this can lead to myocardial ischemia, angina, and myocardial infarction. Surgical intervention especially coronary artery bypass grafting has been a cornerstone in the treatment of multi-vessel coronary artery disease, especially in cases where percutaneous interventions are contraindicated or have failed (1,2).

Surgical revascularization has fundamentally changed the treatment landscape for severe CAD an intervention offering symptomatic relief, prognostic benefits, and an improvement in quality of life for millions of affected patients. Coronary Artery Bypass Grafting remains the central role player in terms of the restoration of myocardial blood flow, especially highly recommended for those presenting with complex anatomies, such as triple-vessel disease or critical left main stenosis. The journey of a patient through this complex intervention is not simply characterized by the surgical precision achieved in the operating theater but, importantly, also by the efficiency and safety of his or her immediate recovery phase, an experience intrinsically linked to the initial stay in the Intensive Care Unit. Consequently, the debate about the best surgical strategy-that is, the use or avoidance of cardiopulmonary bypass-assumes great importance with regard to both the determination of patient outcomes and the allocation of healthcare resources (3,4).

Modern cardiac surgery began in the 1950s with the work of Dr. John Gibbon, who performed the first successful use of a cardiopulmonary bypass machine. In fact, this technology made it possible to perform surgeries on a still and bloodless heart. Since then, complex intracardiac operations have become common with very high success rates. Over the next several decades, coronary artery bypass grafting, especially on-pump, using cardiopulmonary bypass, became the gold standard to provide greater surgical precision and grafting accuracy. Cardiopulmonary bypass is associated with several adverse effects that include systemic inflammatory response, coagulopathy, neurocognitive deficits and increased risk of complications such as renal dysfunction and stroke. These concerns led to a search for alternative techniques that could minimize the systemic effects of bypass (5,6,7).

Off-pump coronary artery bypass grafting, sometimes referred to as "beating heart" surgery, was developed in the 1980s as a method of performing specifically coronary artery bypass grafting without cardiopulmonary bypass. It involves stabilizing the target coronary artery segments with specialized devices, enabling surgeons to graft on a beating heart. The potential advantages of off-pump surgery include less inflammatory response, reduction in neurocognitive impairment, less bleeding, shorter hospital stays and lower incidence of certain perioperative complications. Despite these, off-pump surgery introduces technical challenges such as limited exposure of coronary arteries, difficulty in achieving complete revascularization and a steep learning curve for surgeons. Therefore, debates still exist over whether this off-pump, particularly CABG, provides superior or equal outcomes to traditional on-pump surgery with respect to postoperative recovery and stay in the ICU (8,9,10).

Historical Development and Clinical Adoption the main criticism against off-pump, especially coronary artery bypass grafting, was initially skepticism related to incomplete revascularization and patency of the grafts. Early series gave mixed results some showed comparable long-term efficacy but others suggested increased repeat revascularization rates. Over time, advancements in stabilization devices, surgical techniques and perioperative management have improved the feasibility and safety of off-pump procedures. These two modalities have been compared over recent decades with large RCTs and meta-analyses. The differences these trials tried to elucidate were not only in survival and graft patency but also in immediate postoperative recovery, stay in the ICU and hospital, and complication rates (11,12,13).

The ICU stay after surgery is a critical stage in the recovery from cardiac surgery, the initial period during which vital organ function stabilizes, complications are recognized early and the course of the patient towards discharge is followed. The length of stay in the ICU is directly related to patient outcomes, the use of healthcare resources and overall hospital expenditure (14,15).

Longer lengths of stay in the ICU are associated with increased risk for ventilator-associated pneumonia, nosocomial infection, deep vein thrombosis and other hospital-acquired conditions. These could also reflect an underlying complication like arrhythmias, bleeding or organ dysfunction. On the other hand, short lengths of stay in the ICU most often suggest uncomplicated recoveries, effective perioperative management and better overall outcomes. Besides patient health, ICU stay impacts hospital throughput, staffing and financial costs. The supply of ICU resources is limited and represents a high cost; reducing the length of stay in

ICU therefore can greatly enhance hospital efficiency and reduce healthcare expenditure accordingly (16,17).

Understanding the impact of different surgical approaches on ICU stay is crucial to optimally provide perioperative care, plan resources, and counsel patients. Significance of the Study Given the marked variability in postoperative recovery determined by surgical technique, it is of paramount importance to determine the relative impact that on-pump versus off-pump specifically coronary artery bypass grafting has on ICU stay [18].

Determination of the approach with shorter stays in the ICU can help in clinical decision-making for improved outcomes and resource utilization.Clinical Relevance If off-pump surgery offers consistent benefits of a reduced stay in the ICU without compromising graft patency and long-term survival, it could be regarded as a preferred technique, especially for high-risk populations, such as the elderly or those with significant comorbidities.On the contrary, if on-pump surgery proves to ensure completeness of revascularization with similar recovery in the ICU, clinical protocols might recommend this strategy in selected patients. Healthcare Implications Cutting the length of stay in the ICU not only benefits the individual patient but also reduces healthcare system burdens by minimizing costs, thereby optimizing the turnover of ICU beds and allowing better resource distribution of medical staff. This is particularly vital in the context of growing worldwide demand for cardiac surgeries and continued pressure on intensive care facilities (19, 20) .

However, this kind of control is pharmacologically and physiologically expensive. The start-up of cardiopulmonary bypass requires shunting the entire circulatory volume through an external circuit, thus inducing a non-specific but overwhelming Systemic Inflammatory Response Syndrome (21,22).This pathological response ensues from the contact of blood elements with the artificial surfaces of the oxygenator and tubing and results in the activation of the complement cascade, leukocyte adhesion and the diffuse release of cytokines.

Moreover, the necessary aortic cross-clamping and ensuing reperfusion actually needed to obtain a still heart are responsible for the ischemia-reperfusion injury of the myocardium, whereas the non-pulsatile nature of cardiopulmonary bypass flow may contribute to microcirculation dysfunction. The final clinical consequence of all these insults consists of the increased need for blood product transfusion, enhanced risk of Postoperative Cognitive Dysfunction, and severe organ system morbidity including AKI. These severe systemic complications are those that directly dictate the complexity of postoperative care and by implication, therefore require extended duration of high-intensity monitoring, hence translating directly into longer durations of stay in the ICU (23,24,25).

The significant morbidity associated with cardiopulmonary bypass became the main driving force for developing techniques aimed at performing revascularization on the spontaneously beating heart. This resulted in the emergence of Off-Pump Coronary Artery Bypass. The philosophy underlying Off-Pump Coronary Artery Bypass seems deceptively simple: attain optimal graft placement while preserving, concomitantly, the patient's native, pulsatile circulation and avoiding the use of the cardiopulmonary bypass circuit entirely. Specialized stabilization devices are used to immobilize the segment of coronary artery being targeted, allowing the surgeon to work in a localized, calm environment (26,27).

Proponents of Off-Pump Coronary Artery Bypass argued that avoiding cardiopulmonary bypass would thereby intrinsically reduce the inflammatory burden, minimize the incidence of stroke associated with aortic manipulation, and hasten the patient's recovery by sparing the myocardium from global ischemia. However, the technique is not without its own technical challenges: it requires a steeper and more sustained learning curve for surgeons, while maintaining stable hemodynamics and maneuvering the beating heart to access posterior vessels may introduce transient hypotension periods that can compromise either the quality or completeness of revascularization (28,29,30).

The importance and significance of this study are multifaceted, carrying substantial weight regarding both patient care and health economics. From the patient's point of view a protracted stay in the ICU is an independent predictor of a variety of adverse outcomes, including increased vulnerability to nosocomial infections, higher rates of post-operative delirium, and delayed mobilization, each contributing to a slower overall physical and psychological recovery trajectory (31,32).

Minimizing time spent in the high-acuity environment of the ICU constitutes a direct ethical and clinical imperative. From a systemic perspective, the ICU represents a huge cost driver and a point of critical resource scarcity; efficient utilization directly affects hospital throughput and financial sustainability. Showing a consistent, statistically significant reduction in the stay in the ICU afforded by a given surgical technique provides powerful evidence to support refinement of fast-track recovery protocols and to optimize resource allocation. This research will also add to the active international debate on the requirement to maintain advanced OPCAB programs, further substantiating their value not only in terms of

long-term equivalence but also in quantifiable, short-term economic and efficiency advances (33,34).

Coronary artery bypass surgery can be performed in two ways: on-pump with a heart-lung machine or off-pump while the heart is still beating. There's ongoing debate about which method helps patients recover faster and spend less time in the ICU. Some say off-pump surgery leads to shorter stays and fewer complications, while others find no real difference. Because of these mixed results, there's no clear answer. Our study aims to compare the two techniques in ideal conditions to

help surgeons make better choices, improve patient recovery and ease the workload in the ICU.

LITERATURE REVIEW

Khan et al in (2024) on the topic of how on-pump and off-pump coronary artery bypass grafting (CABG) affected how long patients stayed in the ICU. The study compared on-pump and off-pump CABG to see which method helped patients recover faster and use fewer ICU resources especially in weak hearts. Seventy-eight patients were divided into two groups, and data on age, health, and ICU stay were collected. Results showed on-pump patients stayed about 4 days in ICU while off-pump patients stayed about 5 days. Older age and health issues like diabetes extended ICU stays regardless of surgery type. The study concluded on-pump surgery may shorten ICU stays in high-risk patients, aiding treatment decisions [35].

Rifai et al in (2023) to compare two types of CABG surgery on-pump and off-pump and see how they affected how long patients stayed in ICU and their chances of dying after surgery. The study reviewed medical records from Haji Adam Malik Hospital form 2016 to 2021 to compare on-pump and off-pump surgeries. Patients with specific health criteria were analyzed for recovery time and death rates. On-pump patients stayed about 2 days in ICU while off-pump patients stayed about 1 day. Survival rates were similar for both groups. The conclusion was off-pump helps patients leave ICU sooner without affecting safety [36].

Borges et al. in (2024) to analyzed data from over 58,000 patients to compare on-pump and off-pump CABG surgeries. They found that off-pump surgery resulted in fewer complications, such as less blood loss and shorter hospital stays. The mortality rates were similar for both methods, around 2.4% to 2.5%. Additionally patients who underwent off-pump surgery maintained good heart function and had comparable long-term survival. The study concluded that off-pump CABG is a safe and effective option that can reduce complications without increasing the risk of death [37].

Omara et al. in (2020) they studied 80 high-risk patients undergoing CABG surgery comparing on-pump and off-pump techniques. The patients had complex heart conditions and were at greater risk for complications. The results showed that those who had on-pump surgery needed more medications to support their hearts and spent longer in the ICU. They also experienced more early complications such as irregular heart rhythms. Conversely, patients who had off-pump surgery recovered faster, spent fewer days in the hospital and had fewer early postoperative complications. The study concluded that off-pump CABG is a safer option for high-risk patients as it reduces complications and promotes quicker recovery [38].

Ibrahim et al. in (2023) on comparing ICU stay and death rates between on-pump and off-pump coronary artery bypass grafting (CABG). The study involved 1569 patients and found that patients who had off-pump CABG stayed longer in ICU than those who had on-pump CABG. The analysis showed that the difference in ICU stay was significant. However, there was no significant difference in death rates between the two groups. This study highlighted that, in the author's center, off-pump patients had longer ICU stays but similar survival outcomes as on-pump patients [39].

Forouzannia et al. in (2023) on comparing the outcomes of on-pump and off-pump coronary artery bypass grafting (CABG) in patients with triple-vessel disease (3VD). The study randomly assigned 274 patients to each method and followed them for about 31 months. The results showed that the rates of major adverse cardiac and cerebrovascular events (MACCE) were similar in both groups. There

was no significant difference in postoperative complications or MACCE components like death, heart attack, or stroke. The study concluded that off-pump CABG was as effective as on-pump CABG for 3VD patients when performed by experienced surgeons [40].

Hwang et al. in (2022) on coronary artery bypass grafting (CABG) for patients with acute coronary syndrome (ACS). The study compared three strategies: on-pump CABG (ONCAB), off-pump CABG (OPCAB), and on-pump beating heart CABG (OnBHCAB). They analyzed 19 studies with a total of 11,743 patients to see which method reduced 30-day mortality the most. The results suggested that OPCAB might offer the greatest survival benefit, especially for patients with a heart attack, while no single method was definitively best for all patients [41].

Pansani et al. in (2025) on coronary artery bypass grafting (CABG) for patients with left main coronary artery disease (LMCAD). The study compared off-pump CABG with on-pump CABG by analyzing 18 studies involving 16,848 patients. They found that off-pump CABG was linked to lower short-term death rates, kidney problems, use of intra-aortic balloon pumps, and wound infections. However, there was no difference in long-term survival between the two methods [42].

Arslan et al. in (2021) examined the occurrence of postoperative atrial fibrillation (POAF) in patients undergoing coronary artery bypass grafting (CABG). Analyzing 3,197 patients, they found that those who had on-pump CABG were more likely to develop POAF compared to off-pump surgery. Factors such as age over 60, hypertension, longer operation time, and sleep

Apnea increased the risk. The study suggests that using off-pump CABG may help reduce the chance of developing POAF in selected patients [43].

A study was conducted by Štraus et al. in (2023) to examine early recovery differences in patients who underwent on-pump versus off-pump CABG. They studied 230 patients, with more men around age 63 in both groups. The on-pump group received more grafts and needed more blood transfusions and plasma during surgery. Patients who had off-pump surgery stayed shorter in ICU and hospital, and experienced fewer complications like atrial fibrillation. The study concluded that off-pump surgery led to faster recovery, less blood use, and lower treatment costs compared to on-pump surgery [44].

A study was conducted by Lehmann et al. in (2019) to investigate how different types of cardiopulmonary bypass affect immune responses and lung tissue in pigs. They tested five groups with various bypass methods and found that on-pump procedures caused more lung swelling, tissue thickening, and increased inflammatory markers. Off-pump surgery caused less immune activation and lung injury. The use of special coatings and lung perfusion during bypass helped reduce inflammation and lung damage. The study concluded that off-pump surgery induces less immune response and lung injury, making it a better option to minimize complications [45].

A study was conducted by Mansour et al. in (2023) to test a new blood recovery device called the same™ device during on-pump cardiac surgeries. They included 50 adult patients and found that the device successfully recovered about 86% of red blood cells and increased the hematocrit to over 40%. It also removed almost all heparin and most free hemoglobin, with minimal effects on platelets and no adverse effects reported. The study concluded that this device could simultaneously recover and wash both red blood cells and platelets effectively and safely during surgery [46].

A study was conducted by Sudjud et al. in (2025) to compare the use of low-dose prothrombin complex concentrate (PCC) plus fresh frozen plasma (FFP) versus FFP alone for bleeding control after CABG surgery. They found that the combination of PCC and FFP helped patients stop bleeding faster within the first

three hours after surgery, especially in on-pump surgeries and male patients. However, the group that received PCC had higher in-hospital death rates, although 30-day death rates were similar. The study suggested that low-dose PCC could be useful for quick bleeding control but should be used carefully in certain patient groups [47].

A study was conducted by Dominici et al. in (2019) to see how off-pump CABG affects neurological outcomes in patients with a history of stroke or transient ischemic attack (TIA). They analyzed 414 such patients and found that those who had off-pump surgery had fewer strokes after the operation (3.4% vs. 9.8%) and less delirium (4.2% vs. 11.5%) compared to on-pump surgery. The overall risk of serious neurological problems was also lower with off-pump surgery. The study concluded that off-pump CABG could be more beneficial for patients with previous cerebrovascular issues because it reduced the risk of postoperative strokes and brain complications [48].

A study was conducted by Ali et al. in (2024) to investigate whether on-pump CABG leads to more bleeding and the need for blood transfusions compared to off-pump CABG. They reviewed 200 patient records and found that there were no significant differences between the two groups in terms of re-operations, infections, or mortality. However, patients with higher intraoperative hematocrit levels needed fewer blood transfusions and had less bleeding after surgery. The study concluded that managing blood dilution during surgery is important and that using blood conservation strategies can help reduce bleeding, regardless of whether on-pump or off-pump techniques are used [49].

A study was conducted by Shaefi et al. in (2019) to review and compare the long-term outcomes of off-pump versus on-pump CABG. They analyzed several high-quality clinical trials and found that although off-pump surgery reduced the need for blood transfusions and some early complications, it did not show significant benefits over traditional on-pump surgery in preventing strokes, heart attacks, or death over the long term. The review concluded that off-pump CABG might have some short-term advantages but does not necessarily improve long-term survival or reduce major complications compared to on-pump CABG [50].

A study was conducted by Rantanen et al. in (2022) to compare two surgical techniques for coronary artery bypass grafting (CABG): off-pump (OPCABG) and on-pump (ONCABG). They looked at patients from a single hospital in 2018 and found that after matching patients for similar characteristics, there were no differences in death rates during the perioperative period, after one year, or after three years. However, patients who had on-pump surgery received more blood transfusions, fluids, and showed higher levels of heart damage markers like troponin T and lactate after surgery. The study concluded that both techniques appeared equally safe, but off-pump surgery might be better in some ways, such as causing less fluid overload and milder heart damage [51].

A study was conducted by Miniksar et al. in (2024) to examine how on-pump and off-pump CABG surgeries affected oxidative stress and brain oxygen levels during surgery. They measured serum oxidative stress markers, lactate, and regional cerebral oxygen saturation (rSO2) at three points during the operation in 64 patients. The results showed that oxidative stress and lactate levels were higher during on-pump surgeries, while brain oxygen saturation was lower at certain times. They also found that lower brain oxygen levels were associated with higher oxidative stress and longer clamp times. The study suggested that monitoring these factors could help improve outcomes by reducing brain injury during surger. [52].

A study was conducted by Kılıç and Balik in (2023) to explore the relationship between postoperative inflammatory markers and survival in premature infants who had off-pump cardiac surgery to close a patent ductus arteriosus (PDA). They

reviewed 14 cases and found that higher postoperative neutrophil-lymphocyte ratio (NLR) and neutrophil-platelet ratio (NPR) were linked to higher chances of death. Specifically, these ratios were significantly higher in infants who did not survive compared to those who did. The study suggested that NLR and NPR are simple, inexpensive markers that can help predict the risk of death and guide care in these vulnerable premature babies [53].

A study was conducted by the authors in (2022) to compare two techniques for coronary artery bypass grafting (CABG): on-pump (ONCABG) and off-pump (OPCABG). They analyzed data from 1,569 patients and found that patients who had off-pump surgery stayed longer in the intensive care unit (ICU) than those who had on-pump surgery. However, there was no significant difference in death rates between the two groups. The study concluded that off-pump CABG led to longer ICU stays but did not increase the risk of death compared to on-pump CABG [54].

A study was conducted by Rifai et al. in (2023) to compare the length of stay in the ICU and death rates between on-pump and off-pump CABG surgeries. They reviewed medical records from the Haji Adam Malik Hospital in Medan from 2016 to 2021. They found that patients who underwent off-pump surgery spent less time in the ICU than those who had on-pump surgery, but both groups had similar death rates after surgery. The study concluded that off-pump CABG could help reduce ICU stay without increasing the risk of death [55].

A study was conducted by Gurbuz et al. in (2017) to compare short-term and long-term outcomes of off-pump (OPCAB) versus on-pump (ONBHCAB) CABG surgery. They reviewed data from patients who had surgery between 2003 and 2009 and found that off-pump surgery resulted in shorter ventilation times, shorter ICU stays, and less blood loss. Additionally, patients who had off-pump surgery had fewer kidney problems and needed

Fewer blood transfusions in the long term. The study concluded that off-pump CABG provided better long-term survival free of major heart problems compared to on-pump surgery, mainly because they needed fewer blood transfusions [56].

A study was conducted by Xu et al. in (2006) to compare outcomes of off-pump and on-pump CABG in high-risk patients. They studied 180 patients with high risk scores between 2002 and 2003. The results showed that off-pump surgery had benefits such as less need for blood transfusions, shorter ventilation times, and fewer complications like lung problems. They concluded that off-pump CABG was safe and effective for high-risk patients, offering advantages over traditional on-pump surgery [57].

A study was conducted by Borges et al. in (2024) to analyze data from multiple studies comparing on-pump and off-pump CABG. They reviewed over 58,000 patients and found that off-pump surgery was associated with slightly fewer complications and better heart function after surgery. The death rates were similar between the two techniques. The study suggested that off-pump CABG might be better for reducing complications, although both methods had similar survival rates, and more research was needed to understand long-term effects [58].

A study was conducted by Numata et al. in (2016) to compare early and long-term results of off-pump versus on-pump CABG using data from their hospital and a national database in Japan. They found that off-pump surgery reduced the time patients needed to be intubated, decreased ICU stays, and lowered early death rates. In the long term, both groups had similar rates of major heart and brain problems and death. The study concluded that off-pump CABG was less invasive and had benefits during surgery, with similar long-term outcomes compared to on-pumpsurgery[59].

MATERIAL AND METHODS

Study Design: Observational longitudinal study.
Settings: Data will be collected from Omar Hospital and Punjab institute of Cardiology,Lahore.
Study Duration: 4 months will be allotted for the study's execution. After approval of synopsis.
Sample Size: The sample size was calculated using this standard formula for comparing two means which is given by:

$$N = \frac{(Z_{\alpha/2}+Z\beta)^2 \quad \sigma^2 \quad 2}{D^2}$$

Where:
n = sample size per group
Zα/2 = Z-value for the desired significance level (e.g., 1.96 for α=0.05) Zβ = Z-value for desired power (e.g., 0.84 for 80% power)
σ = standard deviation of the outcome
Δ = minimum detectable difference between groups (effect size)
This calculation ensured that the study was adequately powered to detect a meaningful difference between the groups.
The Final Sample Size 50 patient including is calculated as 95% level of confidence and 5 margin of error.
25 patients in each group (on-pump and off-pump)

Sampling Technique: Non probability convenient sampling technique.
Sample Selection:

Inclusion Criteria:
Elective (planned) cardiac surgeries.
Age 18 - 80 years. (Males + Females)
Patients with no preoperative infection or fever.
Exclusion Criteria:
Redo cardiac surgeries.
Patient with incomplete medical records.
Emergency surgeries.

DATA COLLECTION PROCEDURE

The data collection process involved determining data variables, data collection techniques, data collection instruments and measuring the outcomes. Independent variable was on-pump versus off-pump surgery and dependent variable was the length of time spent in the ICU, in hours or days. Patients were identified and enrolled after informed consent for cardiac surgery patients. Medical records and direct observation were used to obtain data that were collected prospectively. Demographic and clinical characteristics were obtained as part of data collected as the baseline information, while postoperative data, including length of admission in the ICU, were collected from the hospital records and from the log of the ICU. A specially designed questionnaire was the main data collection instrument. The primary endpoint was length of stay in the ICU and secondary endpoints included postoperative complications (infections, arrhythmia), mechanical ventilation and inotropic support.

DATA ANALYSIS PROCEDURE

Data will be analyzed with Statistical Software for Social Sciences (SPSS 27.0).

Collected data will be stored in Microsoft Excel. Mean and standard deviation will be reported for quantitative variable. Frequency and percentages will be calculated for categorical variables. Pearson correlation, independent sample t-test, Chi-Square Test, Mann-Whitney U and Cohen's d will be applied. P-value <0.05 will be considered as significant.

RESULTS

Table 1: Patient Summary Statistics:

This table presents the summary statistics of the study population. A total of 50 patients were included that representing 100% of the cohort. The distribution between surgical techniques was equal, with 25 patients (50.0%) undergoing on-pump surgery and 25 patients (50.0%) undergoing off-pump surgery. All enrolled participants completed the study with a 100% follow up rate over 30 days. This equal allocation between the two groups provides a balanced comparison for outcome assessment and minimizes selection bias in the analysis.

Parameter	**Value**	**Details**
Total patients	50	100% of cohort
On-pump	25	50.0% patient
Off-Pump	25	50.0% patient
Study Completion	100%	All patients completed 30-day follow-up

Table 2: Baseline Demographics & Clinical Characteristics

The table shows the baseline demographic and clinical details for the patients in both the on-pump and off-pump groups, each with 25 people. Their ages are pretty similar too – the on-pump group has an average age of 65.8 ± 5.3 years, while the off-pump group is 63.1 ± 9.1 years old – the difference isn't big enough to be significant. There are more women in the on-pump group (they make up 80%) than in the off-pump one (where it's 40%), but again, that difference doesn't reach statistical significance. Looking at past surgery histories, the numbers lean slightly toward the on-pump group (0.36 ± 0.49 compared to 0.16 ± 0.37), yet this difference wasn't quite significant either (p = 0.1113). Similarly, around four out of ten folks in both groups had prior cardiac incidents. As for pre-existing conditions, about the same amount of people (56% versus 64%) were affected in each camp. Last, their left ventricular ejection fractions came out nearly identical (41.44 ± 7.16% against 41.80 ± 7.62%). This tells us there's no real gap between the two groups when considering their functional status through the NYHA classification system too

Characteristic	**On-Pump (n=25)**	**Off-Pump (n=25)**	**P-Value**
Age (years)	65.8 ± 5.3	63.1 ± 9.1	p = 0.2081
Gender - Male, n (%)	5 (20.0%)	15 (60.0%)	NS
Gender - Female, n (%)	20 (80.0%)	10 (40.0%)	NS
Previous Surgeries	0.36 ± 0.49	0.16 ± 0.37	p = 0.1113
Recent Cardiac Events, n (%)	10 (40.0%)	8 (32.0%)	NS
Existing Medical Condition, n (%)	14 (56.0%)	16 (64.0%)	NS
Ejection Fraction (%)	41.44 ± 7.16	41.80 ± 7.62	p = 0.8641
NYHA Class I-II, n	13 (52.0%)	12 (48.0%)	NS

(%)			
NYHA Class III-IV, n (%)	12 (48.0%)	13 (52.0%)	NS

Table 3: Descriptive Statistics - ICU Stay (days):
This table shows that on-pump patients stayed significantly longer in the ICU than off-pump patients. On-pump patients had a mean ICU stay of 7.36 ± 1.32 days, while off-pump patients averaged 2.88 ± 0.83 days. This mean difference of 4.48 days is backed up by the median values and ranges too. Plus, the 95% confidence intervals barely overlapped, clearly showing the differing ICU stays between the groups.

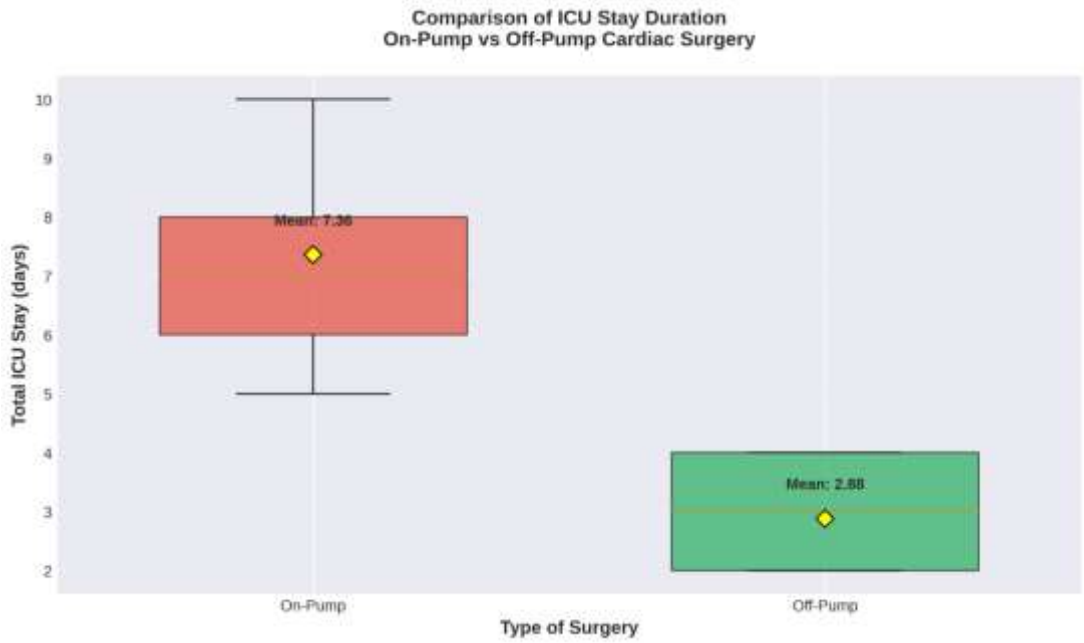
Statistic	On-Pump (n=25)	Off-Pump (n=25)	Difference
Mean	7.36	2.88	4.48
Std. Deviation	1.32	0.83	-
Median	7.0	3.0	4.0
Minimum	5	2	-
Maximum	10	4	-
Range	5	2	-
95% CI Lower	6.84	2.55	-
95% CI Upper	7.88	3.21	-

Table 4: Statistical Tests - ICU Stay Duration:
The table shows how much longer ICU stays were for the on-pump group versus the off-pump group. Tests revealed big differences; the independent samples t-test got $t = 14.360$ with $p < 0.0001$, and the Mann-Whitney U test also found significant results with $U = 625.0$ and $p < 0.0001$. The effect size was gigantic at Cohen's $d = 4.062$, showing a real clinical difference. The 95% confidence interval for the mean difference ranged from 4.05 to 4.91, which doesn't include zero, supporting the significance. So, patients in the on-pump group stayed significantly longer in ICU.

Statistical Test	Test Statistic	P-Value & Significance
Independent Samples t-test	$t = 14.360$	$p < 0.0001$ ***
Mann-Whitney U Test	$U = 625.0$	$p < 0.0001$ ***
Cohen's d (Effect Size)	$d = 4.062$	Very Large Effect
95% CI for Mean Difference	[4.05, 4.91]	Does not include zero

*** $p < 0.001$ (highly significant)

Figure 1: ICU Stay Duration (Box Plot with Individual Data Points)



The box plot displays the median, mean, quartiles, and range of ICU stay durations. It shows that the off-pump group has substantially shorter stays.

Table 5: Mechanical Ventilation Duration (hours):

According to this table patients in the on-pump group spent way more time on mechanical ventilation compared to those in the off-pump group. The numbers show an average of 21.02 ± 3.74 hours for the on-pump folks, versus 7.11 ± 1.80 hours for the off-pump. This adds up to a difference of 13.91 hours. Even the median values and interquartile ranges back up this big gap. So, clearly, the on-pump surgery led to much longer ventilation needs.

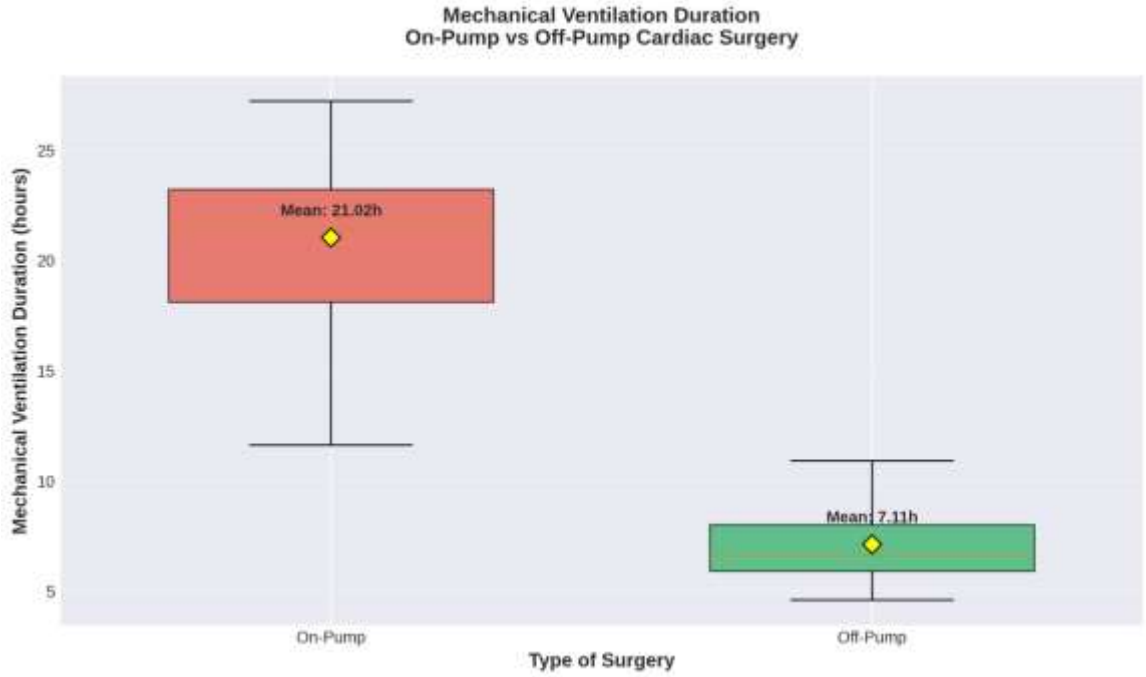
Statistic	On-Pump (n=25)	Off-Pump (n=25)	Difference
Mean	21.02	7.11	13.91
Std. Deviation	3.74	1.80	-
Median	21.4	6.6	14.8
Minimum	11.6	4.6	-
Maximum	27.2	10.9	-
Range	15.6	6.3	-
25th Percentile	18.1	5.9	-
75th Percentile	23.2	8.0	-

Table 6: Statistical Tests (Mechanical Ventilation):

The table displays the time spent on mechanical ventilation for both on-pump and off-pump groups. Tests showed a big difference: the independent samples t-test result was $t = 16.760$ with $p < 0.0001$, and the Mann-Whitney U test backed this up ($U = 625.0$, $p < 0.0001$). So, folks in the on-pump group needed way more time on ventilation than those in the off-pump group.

Test	Statistic	Result
Independent t-test	t = 16.760	p < 0.0001 ***
Mann-Whitney U Test	U = 625.0	p < 0.0001 ***

Figure 2: Mechanical Ventilation Duration - Comparison



Off-pump patients required significantly less mechanical ventilation support, indicating faster respiratory recovery.

Table 7: Postoperative Complication Rates:
The table shows postoperative complication rates for both groups. In the on-pump group, 8 patients (32.0%) experienced issues, whereas 17 (68.0%) didn't. For the off-pump group, complications hit 4 patients (16.0%), and 21 (84.0%) were complication-free. Across the board, 24.0% of the total patients had complications. The data suggests that the on-pump group faced a higher rate of complications than the off-pump group.

Outcome	**On-Pump**	**Off-Pump**	**Total**
With Complications	8/25 (32.0%)	4/25 (16.0%)	12/50 (24.0%)
No Complications	17/25 (68.0%)	21/25 (84.0%)	38/50 (76.0%)
Total	25	25	50

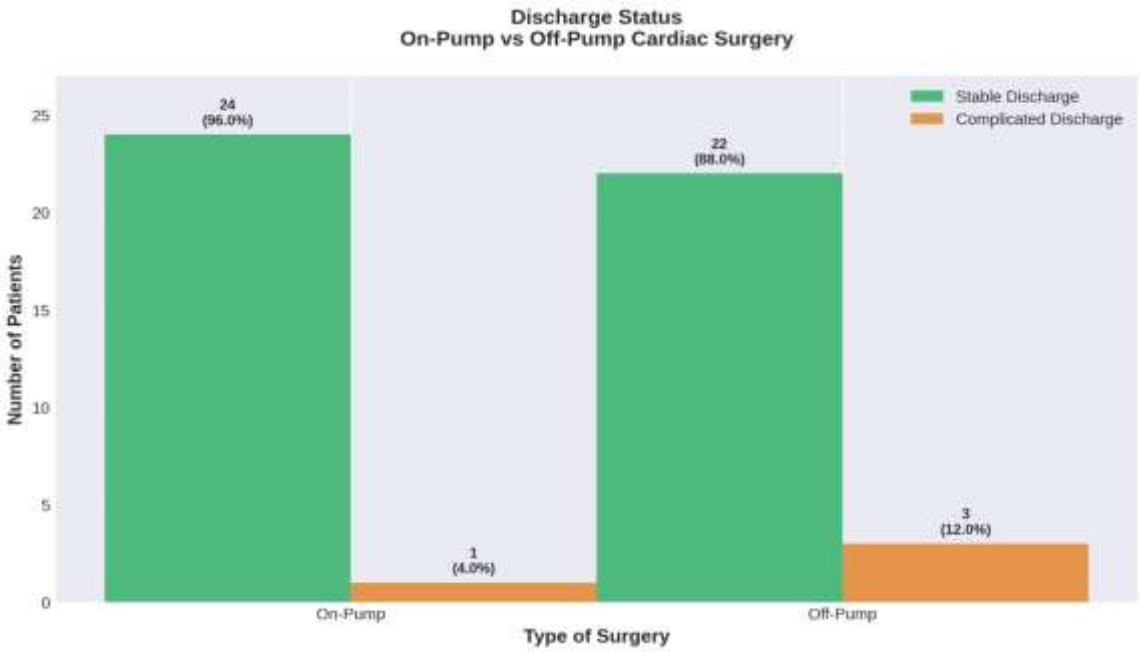
Figure 3: Postoperative Complication Rates - Comparative Bar Chart

On-pump group showed higher postoperative complication rate (32.0%) compared to off-pump group (16.0%).

Table 8: Hospital Discharge Status Distribution:
According to given table more patients in the on-pump group were discharged in stable condition compared to the off-pump group, but only slightly. Specifically, 96% left in stable condition with just one having complications in the on-pump crew. For off-pump surgery, 88% went out stable while 12% did not. When you zoom out, though, most everyone did okay—92% overall were discharged stably while 8% faced complications. The numbers from the Chi-square test ($\chi^2 = 0.272$, $p = 0.6022$) show no big difference between the two groups when it comes to discharge status, so we can say these results are pretty even.

Discharge Status	**On-Pump**	**Off-Pump**	**Total**

Stable	24/25 (96.0%)	22/25 (88.0%)	46/50 (92.0%)
Complicated	1/25 (4.0%)	3/25 (12.0%)	4/50 (8.0%)
Total	25	25	50



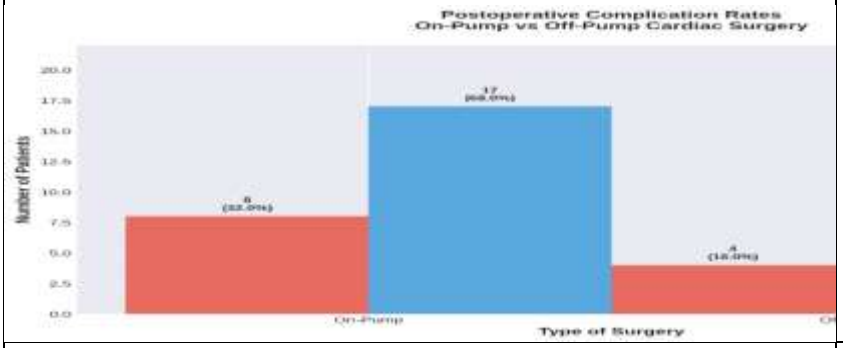
Chi-Square Test: $\chi^2 = 0.272$, $p = 0.6022$ (Not Significant)

Figure 4: Discharge Status - Comparative Distribution

Both groups achieved high rates of stable discharge, with no significant difference between surgical techniques.

Table 9: Inotropic Support Usage During ICU Stay:

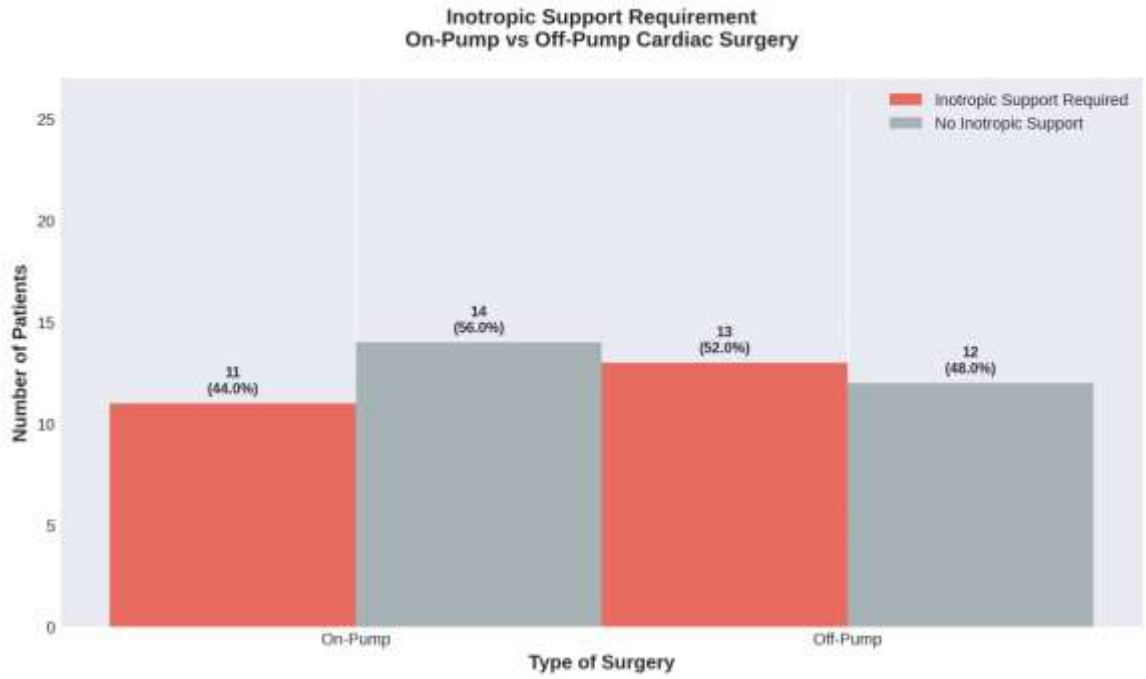
According to Table 9, inotropic support usage is shown for patients in both groups during their ICU stay. For the on-pump group, 44.0% needed it, and 56.0% didn't. In the off-pump crew, that split was 52.0% and 48.0%, respectively. Across the board, 48.0% of all participants required inotropic support. Using a Chi-square test, there wasn't any noticeable difference between the groups ($\chi^2 = 0.080$, $p = 0.7771$). This means that whether a patient got on-pump or off-pump surgery didn't affect their need for inotropic support.

Inotropic Support	**On-Pump**	**Off-Pump**	**Total**
			
Required	11/25 (44.0%)	13/25 (52.0%)	24/50 (48.0%)
Not Required	14/25 (56.0	12/25 (48.0	26/50 (52.0

	%)	%)	%)
Total	25	25	50

Chi-Square Test: $\chi^2 = 0.080$, $p = 0.7771$ (Not Significant)

Figure 5: Inotropic Support Requirement - Comparative Analysis



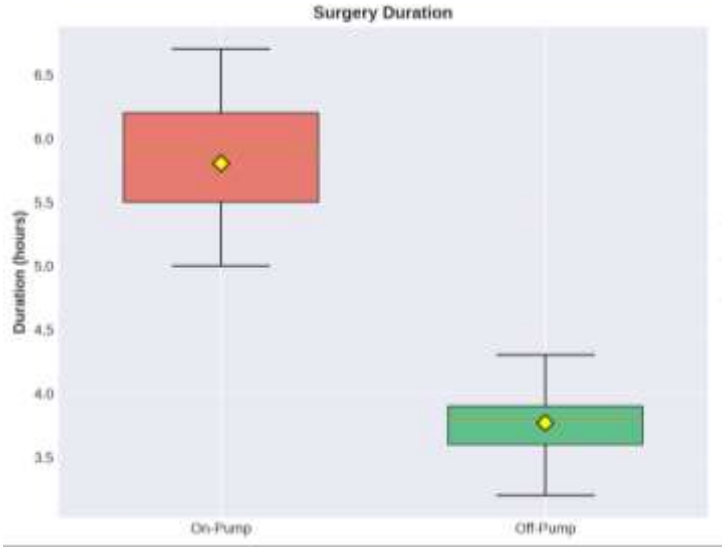
Inotropic support was required in similar proportions across both groups, with no significant difference.

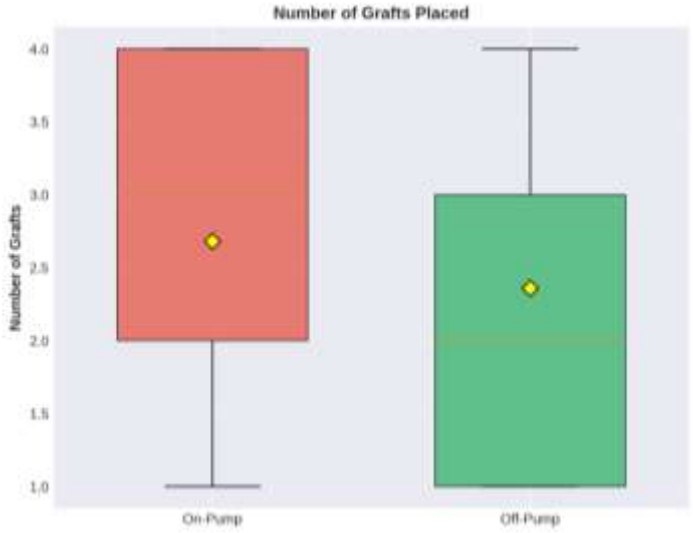
Table 10: Operative Time and Graft Information:

According to Table 9, the need for inotropic support in the ICU is pretty similar between the on-pump and off-pump groups. For the on-pump folks, 44% needed the support, and 56% didn't. In the off-pump crew, it's 52% needing support and 48% not needing it. Taking the whole group, 48% needed inotropic support overall. The chi-square test results? Not significant at all ($\chi^2 = 0.080$, $p = 0.7771$). So, there's no real difference in how often patients need inotropic support based on their surgery type.

Parameter	On-Pump (n=25)	Off-Pump (n=25)	P-Value
Surgery Duration (hours) - Mean ± SD	5.80 ± 0.46	3.77 ± 0.29	$p < 0.0001$ ***
Surgery Duration - Median	5.90	3.80	-
Surgery Duration - Range	5.00 - 6.70	3.20 - 4.30	-
Number of Grafts - Mean ± SD	2.68 ± 1.14	2.36 ± 1.11	$p = 0.3214$
Number of Grafts - Median	3	2	-
Number of Grafts - Range	1 - 4	1 - 4	-
Avg Grafts per Patient	2.68	2.36	Comparable
Total Grafts Placed	67	59	-

Figure 6,7: Surgery Duration & Number of Grafts Comparison





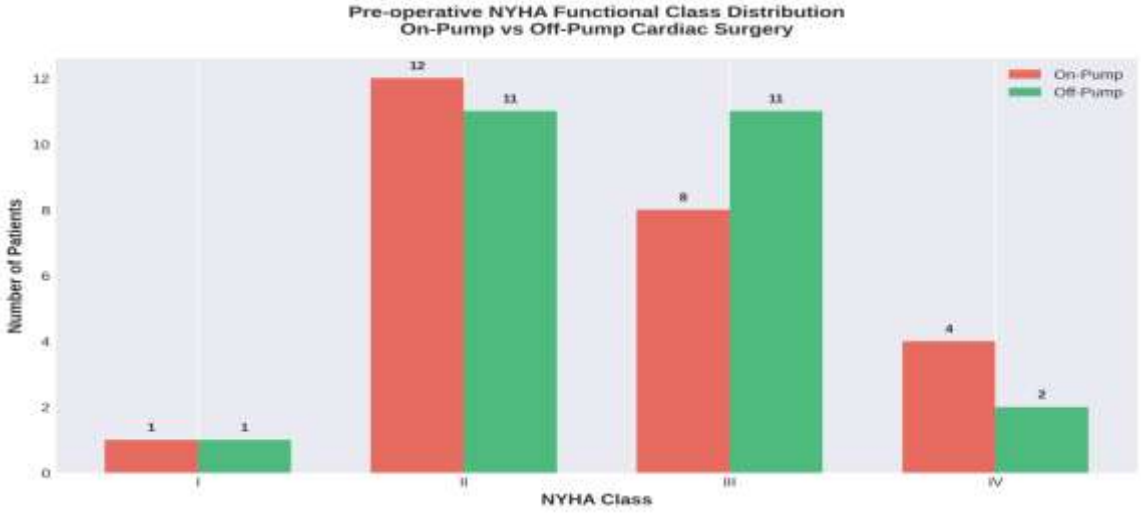
On-pump surgery required significantly longer operative time, but graft numbers were comparable between groups.

Table 11: Ejection Fraction & NYHA Class Distribution:
Table 11 shows the ejection fractions and NYHA classes for both groups. The mean ejection fraction was nearly identical 41.44 ± 7.16% for the on-pump group and 41.80 ± 7.62% for the off-pump group and not statistically different ($p = 0.8641$). The same goes for the median and range values; heart function is pretty much a tie. When it comes to NYHA classes, the similarity continues. In the on-pump group, 52.0% were in Class I–II and 48.0% were in Class III–IV. For the off-pump group, it was reversed by a hair: 48.0% in Class I–II and 52.0% in Class III–IV. Though the severe cases (Class IV) slightly favored the on-pump group, the overall distribution didn't reach statistical significance. So, essentially, both groups started with nearly the same heart function levels.

Parameter	On-Pump (n=25)	Off-Pump (n=25)	P-Value
Ejection Fraction (%) - Mean ± SD	41.44 ± 7.16	41.80 ± 7.62	p = 0.8641
Ejection Fraction (%) - Median	41.0	43.0	-
Ejection Fraction (%) - Range	30 - 52	30 - 54	-

NYHA Class I-II, n (%)	13 (52.0%)	12 (48.0%)	NS
NYHA Class III-IV, n (%)	12 (48.0%)	13 (52.0%)	NS
NYHA Class III, n	8	11	-
NYHA Class IV, n	4	2	-

Figure 7: NYHA Functional Class Distribution



Pre-operative NYHA class distribution shows similar functional status between groups.

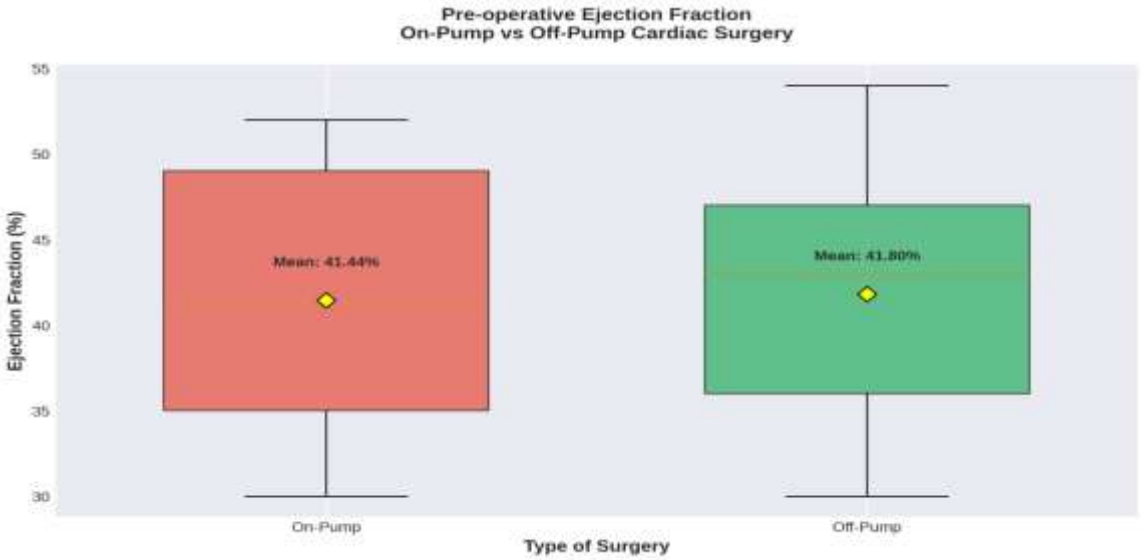


Figure 8: Ejection Fraction Comparison

Pre-operative ejection fraction was comparable between on-pump and off-pump groups.

Table 12: 30-Day Readmission Outcomes:
The table shows the 30-day readmissions for both groups. Only one person in each group was readmitted; that's 4.0% of each group. The rest, 24 patients or 96.0%, weren't readmitted. There's no big difference here, as the Chi-square test shows a p-value of 1.000, meaning the readmission rates are pretty much the same for on-pump and off-pump surgeries.

Readmission Status	On-Pump	Off-Pump	Total

Readmitted	1/25 (4.0%)	1/25 (4.0%)	2/50 (4.0%)
Not Readmitted	24/25 (96.0%)	24/25 (96.0%)	48/50 (96.0%)
Total	**25**	**25**	**50**

Chi-Square Test: $\chi^2 = 0.000$, p = 1.000 (Not Significant - identical rates)

Table 13: Summary of All Statistical Tests:
This table shows the stats from a study that compared on-pump and off-pump surgery groups. There were big differences in ICU stays, mechanical ventilation time, and operation length, each having p-values under 0.0001. ICU stays had a huge effect size too – Cohen's d was 4.062. Still, there weren't any significant differences in the number of grafts, ejection fraction, discharge status, or inotropic support. Plus, readmission and post-op complications within 30 days weren't different either (all had p-values greater than 0.05). So, while recovery times during the operation phase varied, heart function basics and main clinical results stayed about the same.

Outcome Variable	Statistical Test	Test Statistic	P-Value	Significance
ICU Stay (days)	Independent t-test	t = 14.360	p < 0.0001	***
ICU Stay (days)	Mann-Whitney U	U = 625.0	p < 0.0001	***
Mechanical Ventilation (hours)	Independent t-test	t = 16.760	p < 0.0001	***
Surgery Duration (hours)	Independent t-test	t = 18.581	p < 0.0001	***
Number of Grafts	Independent t-test	t = 1.002	p = 0.3214	NS
Ejection Fraction (%)	Independent t-test	t = -0.172	p = 0.8641	NS
Discharge Status	Chi-Square	$\chi^2 = 0.272$	p = 0.6022	NS
Inotropic Support	Chi-Square	$\chi^2 = 0.080$	p = 0.7771	NS
30-Day Readmission	Chi-Square	$\chi^2 = 0.000$	p = 1.000	NS
Postoperative Complications	Chi-Square	$\chi^2 = 2.667$	p = 0.102	NS
Effect Size (ICU Stay)	Cohen's d	d = 4.062	N/A	Very Large

DISCUSSION

This study looked at the clinical features and results after surgery for patients who got either on-pump or off-pump coronary artery bypass grafting (CABG). Both groups were pretty similar overall, but there were some differences during and right after surgery. The average age of participants was 56.46 years, showing that CABG is mainly done on middle aged to elderly folks. This matches what Khan et al. (2024) found they saw CABG happening more often in older people too. As we know, getting older increases your risk for coronary artery disease, explaining why there's a greater need for the surgery in this age bracket. Also, according to Khan et al. (2024), having other health issues like diabetes can lead to a longer stay in the ICU. It doesn't matter which type of surgery you get it's the overall health problems that really affect how well you do after surgery. (35).

Both the present study and the parent study compare on-pump and off-pump CABG but look at different results. The meta-analysis found that off-pump CABG lowers early stroke risk but may increase later problems like repeat procedures and long-term death risk. In this study, on-pump CABG showed longer ICU stay, longer breathing support, and longer surgery time, but there was no major difference in complications, discharge status, or readmission. Overall, the meta-analysis focuses on long-term effects while this study shows differences in early recovery. Both techniques are still mostly similar in overall outcomes. (64).The time patients spend in the ICU after coronary artery bypass grafting has been looked at in lots of studies. This research matches what Ibrahim et al. (2023) found regarding differences in ICU stays for CABG patients. They noticed that folks who got off-pump CABG typically stayed longer in ICU but had death rates similar to those who had on-pump surgery. In line with this, Khan et al. (2024) also saw that on-pump CABG led to shorter ICU stays compared to off-pump methods. So, these results back up our current study showing that the type of surgery can affect ICU time, while still having similar survival rates overall. (35,39).

It should be mentioned that results of the present study contradict the results obtained in the paper written by Rifai et al. (2023). These researchers revealed that patients who had off-pump CABG stayed in ICU less time compared to those with on-pump surgery. Therefore, it is possible to assume that off-pump CABG may help patients stay in ICU for a shorter time while having almost equal survival rate (36).Off-pump CABG is also supported by evidence from extensive research. For instance, in their analysis of a large database containing more than 58,000 patients, Borges et al. (2024) found that off-pump CABG had lower complications, bleeding, and length of hospital stay without having higher mortality compared to the on-pump procedure. This evidence shows that off-pump CABG can serve as a safe and equally efficient procedure in comparison with on-pump CABG under suitable circumstances (37).

In addition, the results obtained in this paper are consistent with those reported by Omara et al. (2020). In their study, the authors analyzed CABG in high-risk patients and showed that patients who underwent CABG using the on-pump method needed more inotropic support and stayed in ICU longer than those who underwent off-pump CABG, showing better outcomes in postoperative period (38).In a similar case, the findings reported in Forouzannia et al.'s (2023) study on CABG for patients with triple-vessel disease found that there was no statistical difference in major adverse cardiac and cerebrovascular events between the on-pump and off-pump CABG. Thus, it can be argued that on-pump and off-pump CABG have equally comparable long-term efficacy if carried out with expertise. The findings further reinforce the conclusion drawn from the current study that the values of many of the baseline and post-operative parameters are alike in the two groups (40).

One of the largest analyses of a systematic review done by Hwang et al. (2022) compares the three different surgical procedures of CABG among ACS patients; the three are on-pump CABG, off-pump CABG, and on-pump beating heart CABG. This systematic review includes a total of 19 papers having more than 11,000 patients as their sample size. Based on their meta-analysis, the authors observed that off-pump CABG is likely to confer survival benefits especially for those patients who had presented MI. This is in line with the results of the current study, in which both techniques yielded satisfactory results, hence indicating that the selection of the method should be based on individual factors as opposed to applying one standard approach (41).Like the current study,Pansani et al.(2025) also examined the impact of off-pump and on-pump CABG in the management of coronary artery disease that involved the left main coronary artery. In this case, the researchers reviewed 18 studies with a total of 16,000 patients. It was found

that off-pump CABG is related to low mortality rate, fewer renal dysfunction cases, reduced requirement for intra-aortic balloon pump and decreased instances of wound infections. However, no significant difference in survival rates between the two surgeries was recorded by the authors (42).

Complications after surgery represent another criterion used to compare the different methods employed during CABG operations. To analyze the prevalence of POAF, researchers from the work performed by Arslan et al.(2021) carried out a research project aimed at determining the incidence of this complication depending on the method utilized during surgery. Based on the data collected for more than 3,000 patients, researchers found that POAF appeared more commonly among patients having on-pump CABG. Also, they were able to determine multiple factors that increase the risk of POAF occurrence: patient age, hypertension, longer surgery duration, and presence of sleep apnea (43).The findings match what we already know and reinforce that both on- and off-pump CABG surgeries are effective and safe. Some papers claim off-pump CABG leads to fewer complications and speeds up recovery, whereas others state that on-pump surgery cuts ICU time and maintains a better hemodynamic status. So, differences seen in past research might boil down to patient characteristics, how skilled the surgeons are, and the methods used in each study. From the overall perspective, one can say that the results obtained within the framework of the current study are consistent with other literature data and imply that both on- and off-pump CABG techniques are effective and that specific clinical variables affect postoperative outcome. Differences identified between the current paper and others could be due to various factors such as sample size, patient characteristics, and surgical proficiency and hospital policies. At any rate, the information provided above contributes to accumulating literature data concerning the need for customization of CABG surgery.

CONCLUSION

The results obtained in this study suggest that CABG procedure type affected significantly the duration of the ICU stay. Specifically, patients who were subjected to off-pump surgery tended to have a shorter ICU stay and the long ICU stay particularly for more than ten days was primarily observed in the on-pump surgery type. The most common ICU duration was six days, the majority of patients with such ICU duration belonged to the off-pump group. Statistical analysis revealed a significant correlation between the surgery type and ICU stay suggesting the importance of the choice of the surgery for ICU stay duration.

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