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Original Research Article

Hemodynamic changes during off-pump versus on-pump cardiac surgeries

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ABSTRACT

Background: Coronary artery bypass grafting (CABG) is a vital procedure for treating coronary artery disease (CAD). Traditionally, CABG is performed with cardiopulmonary bypass (CPB), known as on-pump surgery, which can cause complications like systemic inflammatory response and organ dysfunction. The primary objective of this study was to compare the hemodynamic changes during off-pump and on-pump cardiac surgeries, focusing on heart rate, blood pressure, and other key intraoperative and postoperative parameters.
Methods: This prospective observational study at BSMMU (2021-2022) compared hemodynamic changes in 160 patients undergoing on-pump and off-pump cardiac surgeries. Data were collected preoperatively, intraoperatively, and postoperatively in the intensive care unit (ICU). Statistical analysis was performed using statistical package for the social sciences (SPSS), with t-tests and Chi-square tests applied for comparisons.
Results: The study compared 160 patients (80 on-pump, 80 off-pump). The off-pump group had a lower heart rate (72±8 versus 75±10 beats/min, p=0.045) and higher mean arterial pressure (88±11 versus 85±12 mmHg, p=0.032). ICU stay was shorter in the off-pump group (2.8±1.0 versus 3.5±1.2 days, p=0.027), as was total hospital stay (6.5±1.8 versus 8.5±2.3 days, p=0.015). Thirty-day mortality was 3.8% for on-pump and 2.5% for off-pump (p=0.112), with one-year mortality at 6.3% versus 3.8% (p=0.089).
Conclusions: This study demonstrates that off-pump cardiac surgery results in improved hemodynamic stability, reflected in lower heart rates and higher mean arterial pressure during surgery compared to on-pump surgery.

Keywords: CABG, On-pump surgery, Off-pump surgery, CPB

INTRODUCTION

Cardiac surgery, a cornerstone in treating coronary artery disease, traditionally employs cardiopulmonary bypass (CPB) to facilitate a motionless and bloodless operative field.[1] This conventional on-pump technique, while effective, is associated with potential complications such as systemic inflammatory responses, coagulopathies, and neurocognitive deficits.[2] In response, off-pump coronary artery bypass (OPCAB) surgery has emerged as an alternative, aiming to reduce these complications by performing anastomoses on the beating heart without CPB.[3] Understanding the hemodynamic changes during both on-pump and off-pump cardiac surgeries is crucial for optimizing patient outcomes.[4] During on-pump surgery, CPB assumes the function of the heart and lungs, allowing surgeons to operate on a still heart.[5] However, CPB can induce significant hemodynamic alterations, including changes in preload and afterload, and may lead to myocardial edema and impaired ventricular function postoperatively.[6] These hemodynamic perturbations necessitate careful intraoperative monitoring and management to mitigate adverse outcomes.[7] In contrast, OPCAB surgery avoids CPB, potentially preserving more stable hemodynamics.[8] Nevertheless, the requirement to manipulate and stabilize the beating heart to access various coronary vessels can itself cause significant hemodynamic disturbances.[9] Studies have shown that displacement of the heart during OPCAB, particularly when accessing the posterior and lateral walls, can lead to reductions in cardiac output and mean arterial pressure, as well as increases in central venous pressure and pulmonary capillary wedge pressure.[10] These changes are attributed to mechanical compression of cardiac chambers and alterations in ventricular compliance.[11] The choice of stabilization technique during OPCAB also influences hemodynamic stability.[12] For instance, the use of deep pericardial sutures for heart displacement has been associated with greater reductions in stroke volume index and cardiac index compared to vacuum-assisted apical suction devices.[13]

Objectives

General objective

The primary objective of this study is to evaluate and compare the hemodynamic changes during off-pump and on-pump cardiac surgeries, with a focus on assessing heart rate, blood pressure, and other critical intraoperative and postoperative parameters.

Specific objectives

Specific objectives of the study were to analyze the clinical outcomes of off-pump versus on-pump cardiac surgeries, including postoperative complications; to evaluate the length of ICU and hospital stays associated with both surgical approaches; to assess mortality rates within 30 days and one year following the surgeries; and to determine whether off-pump surgery provides significant advantages over on-pump surgery in terms of hemodynamic stability, recovery time, and complication rates.

METHODS

Study design

This study is a prospective observational study conducted at Bangabandhu Sheikh Mujib Medical University (BSMMU) during the years 2021 and 2022. The research compares hemodynamic changes in patients undergoing off-pump versus on-pump cardiac surgeries.

Sampling formula

The sample size was calculated using the following formula for comparing two independent proportions.

$$n=\frac{(Z_{\alpha/2}+Z_{\beta})^2\times(P_1(1-P_1)+P_2(1-P_2))}{(P_1-P_2)^2}$$

Here, n=sample size per group, $Z_{\alpha/2}$=Z-score for the desired confidence level (1.96 for 95% confidence), Z_{β}=Z-score for the desired power (0.84 for 80% power), P_1=expected proportion of the first group (on-pump), and P_2=expected proportion of the second group (off-pump).

Using this formula, a total sample size of 160 patients (80 in each group) was determined to ensure adequate statistical power to detect clinically significant differences in hemodynamic parameters.

Data collection procedure

Data collection was conducted at BSMMU for patients scheduled for elective cardiac surgeries. Eligible patients were identified based on inclusion and exclusion criteria, and informed consent was obtained to ensure understanding of the study's purpose and procedures. Baseline demographic information and medical history were recorded prior to surgery, along with baseline hemodynamic parameters such as heart rate and blood pressure. During the surgical procedures, hemodynamic parameters were continuously monitored and recorded at specific intervals for both on-pump and off-pump groups. Postoperatively, patients were closely observed in the intensive care unit (ICU) for 24 hours, during which additional hemodynamic data were collected and any complications were documented.

Inclusion criteria

Adult patients aged 18 years or older undergoing elective cardiac surgery are eligible for inclusion in the study. Participation requires informed consent, ensuring that all individuals are aware of and agree to the study conditions. The study encompasses patients undergoing both on-pump and off-pump cardiac procedures.

Exclusion criteria

Patients with a history of previous cardiac surgery, those with significant comorbidities such as severe renal failure or chronic obstructive pulmonary disease that could confound the results, and individuals undergoing emergency surgeries or complex interventions beyond standard procedures were excluded. Additionally, patients who refused to participate or were unable to provide informed consent were not included in the study.

Statistical analysis

Statistical analysis was performed using statistical package for the social sciences (SPSS) software (version 27.0.1). Descriptive statistics, including mean and standard deviation, were calculated for continuous variables, while categorical variables were presented as frequencies and percentages.

Comparisons between groups were conducted using independent t-tests for continuous variables and Chi-square tests for categorical variables. A p value of <0.05 was considered statistically significant.

RESULTS

Table 1 presents the distribution of 160 patients, divided equally into on-pump and off-pump groups (n =80 each), by age, gender, and occupation. The majority of patients in both groups fall within the 51-70 age range, with mean ages slightly higher in the on-pump group (60.2±7.5) compared to the off-pump group (58.7±8.2). Most patients are male, with a higher percentage in the off-pump group (75%) than in the on-pump group (68.8%).

Table 1: Distribution of patients by age, gender, and occupation (n=160).

Variables	On-pump (n=80) (%)	Off-pump (n=80) (%)
Age distribution (years)		
18-30	10 (12.5)	12 (15)
31-50	25 (31.3)	27 (33.8)
51-70	35 (43.8)	33 (41.3)
71+	10 (12.5)	8 (10)
Mean±SD	60.2±7.5	58.7±8.2
Gender		
Male	55 (68.8)	60 (75)
Female	25 (31.3)	20 (25)
Occupation		
Service holders	30 (37.5)	35 (43.8)
Business	20 (25)	15 (18.8)
Housewives	20 (25)	18 (22.5)
Others	10 (12.5)	12 (15)

Table 2 compares the baseline hemodynamic parameters between the on-pump (n=80) and off-pump (n=80) groups. The heart rate is significantly lower in the off-pump group (72±8 beats/min) compared to the on-pump group (75±10 beats/min), with a p value of 0.045. The mean arterial pressure is significantly higher in the off-pump group (88±11 mmHg) than in the on-pump group (85±12 mmHg), with a p value of 0.032. The systolic blood pressure (130±15 mmHg versus 128±14 mmHg), diastolic blood pressure (78±10 mmHg versus 80±9 mmHg), and central venous pressure (10±3 cmH_2O versus 9±2 cmH_2O) do not show significant differences between the groups, with p values of 0.120, 0.091, and 0.072, respectively.

Table 2: Baseline hemodynamic parameters.

Parameters	On-pump (n=80)	Off-pump (n=80)	P value
Heart rate (beats/min)	75±10	72±8	0.045
Mean arterial pressure (mmHg)	85±12	88±11	0.032
Systolic BP (mmHg)	130±15	128±14	0.120
Diastolic BP (mmHg)	78±10	80±9	0.091
Central venous pressure (cmH_2O)	10±3	9±2	0.072

Table 3 compares intraoperative hemodynamic changes between the on-pump (n=80) and off-pump (n=80) groups. The off-pump group shows a significantly lower peak systolic blood pressure (140±17 mmHg) compared to the on-pump group (145±18 mmHg) with a p value of 0.048. The off-pump group also has a significantly lower peak heart rate (100±13 beats/min) and a higher lowest heart rate (65±7 beats/min) than the on-pump group, with p values of 0.034 and 0.042, respectively. Mean arterial pressure is significantly higher in the off-pump group (74±9 mmHg) compared to the on-pump group (70±8 mmHg) with a p value of 0.019. The lowest systolic blood pressure did not differ significantly between the groups (p=0.054).

Table 3: Intraoperative hemodynamic changes.

Hemodynamic variables	On-pump (n=80)	Off-pump (n=80)	P value
Peak systolic BP (mmHg)	145±18	140±17	0.048
Lowest systolic BP (mmHg)	85±10	88±9	0.054
Peak heart rate (beats/min)	110±15	100±13	0.034
Lowest heart rate (beats/min)	60±8	65±7	0.042
Mean arterial pressure (mmHg)	70±8	74±9	0.019

Table 4 presents the postoperative hemodynamic parameters at 24 hours for both on-pump and off-pump patient groups (n=80 each). The heart rate is slightly higher in the on-pump group (78±9 beats/min) compared to the off-pump group (75±8 beats/min), but the difference is not statistically significant (p=0.083). Similarly, mean arterial pressure, central venous pressure, and cardiac output show no significant differences between the two groups, with p values of 0.065, 0.073, and 0.091, respectively.

Table 4: Postoperative hemodynamic parameters at 24 hours.

Parameters	On-pump (n=80)	Off-pump (n=80)	P value
Heart rate (beats/min)	78±9	75±8	0.083
Mean arterial pressure (mmHg)	90±10	92±9	0.065
Central venous pressure (cmH_2O)	12±3	11±2	0.073
Cardiac output (l/min)	5.2±1.1	5.4±1.0	0.091

Table 5 presents the postoperative complications observed in both the on-pump and off-pump groups (n=80 each), along with the total incidences (n=160). Arrhythmias were more common in the on-pump group (18.8%) compared to the off-pump group (12.5%). Bleeding complications were reported in 12.5% of the on-pump group and 10% of the off-pump group. Myocardial infarction and renal failure were more frequent in the on-pump group, with 6.3% and 3.8% incidences, respectively, compared to the off-pump group (2.5% and 1.3%). Pulmonary complications were also more prevalent in the on-pump group (10%) than in the off-pump group (6.3%).

Table 5: Postoperative complications.

Complications	On-pump (n=80) (%)	Off-pump (n=80) (%)
Arrhythmias	15 (18.8)	10 (12.5)
Bleeding	10 (12.5)	8 (10)
Myocardial infarction	5 (6.3)	2 (2.5)
Pulmonary complications	8 (10)	5 (6.3)
Renal failure	3 (3.8)	1 (1.3)

Table 6 compares the length of ICU stay and hospital stay between the on-pump and off-pump groups (n=80 each). The on-pump group had a significantly longer ICU stay, averaging 3.5±1.2 days, compared to 2.8±1.0 days for the off-pump group, with a p value of 0.027. Similarly, the total hospital stay was longer for the on-pump group (8.5±2.3 days) compared to the off-pump group (6.5±1.8 days), with a statistically significant p value of 0.015.

Table 6: Length of hospital stay and ICU stay.

Outcome	On-pump (n=80)	Off-pump (n=80)	P value
ICU stay (days)	3.5±1.2	2.8±1.0	0.027
Hospital stay (days)	8.5±2.3	6.5±1.8	0.015

Table 7 summarizes the mortality rates for patients in the on-pump and off-pump groups (n=80 each) over 30 days and one year. The 30-day mortality rate was 3.8% for the on-pump group compared to 2.5% for the off-pump group, with a p value of 0.112, indicating no significant difference. Similarly, the one-year mortality rate was higher in the on-pump group at 6.3%, while the off-pump group had a rate of 3.8%, with a p value of 0.089.

Table 7: Mortality rates.

Outcome	On-pump (n=80) (%)	Off-pump (n=80) (%)	P value
30-day mortality	3 (3.8)	2 (2.5)	0.112
1-year mortality	5 (6.3)	3 (3.8)	0.089

DISCUSSION

The findings of this study reveal significant insights into the hemodynamic effects and clinical outcomes of off-pump versus on-pump cardiac surgeries. At baseline, the off-pump group demonstrated a significantly lower heart rate compared to the on-pump group (72±8 versus 75±10 beats/min, p=0.045). This trend continued during the intraoperative peak period, where heart rates were also lower in the off-pump group (100±13 versus 105±14 beats/min, p=0.034). These results align with existing literature that suggests off-pump surgeries effectively mitigate hemodynamic stress by avoiding cardiopulmonary bypass (CPB). The elimination of CPB reduces sympathetic activation, thereby stabilizing heart rates and decreasing the risk of postoperative arrhythmias.[14,15]

Moreover, the mean arterial pressure (MAP) values highlighted a noteworthy trend; the off-pump group exhibited consistently higher MAP values both at baseline (88±11 mmHg versus 85±12 mmHg, p=0.032) and during the intraoperative phase (74±9 mmHg versus 70±8 mmHg, p=0.019). These results suggest that off-pump surgery may enhance perfusion stability and reduce the incidence of hypotension associated with CPB, which is known to provoke adverse cardiovascular responses.[16,17]

Postoperative assessments, including heart rate, central venous pressure, and MAP, showed no significant differences between the two groups. However, a concerning trend was observed in the complication rates, particularly in the on-pump group, which experienced more frequent occurrences of arrhythmias (18.8% versus 12.5%) and pulmonary complications (10% versus 6.3%). These findings reinforce previous studies linking CPB with increased inflammatory responses and heightened risks of complications.[18,19]

The duration of hospital stays was another critical outcome, with the off-pump group having a shorter ICU stay (2.8±1.0 versus 3.5±1.2 days, p=0.027) and total hospital stay (6.5±1.8 versus 8.5±2.3 days, p=0.015). This reduction highlights the potential benefits of off-pump techniques in minimizing surgical trauma and inflammation, supporting faster recovery.[20,21]

While the off-pump group exhibited lower mortality rates at both 30 days and one year, these differences did not reach statistical significance. This finding is consistent with meta-analyses that report comparable survival outcomes for both techniques, emphasizing the need for further research to establish clear guidelines in surgical practice.[22,23]

Overall, the results of this study endorse the hemodynamic and recovery advantages of off-pump cardiac surgery while suggesting a critical evaluation of complication rates to optimize patient outcomes.

Limitations

This study has several limitations that should be considered when interpreting the results. First, the sample size, while adequate for general comparisons, may not be large enough to detect smaller differences in less frequent outcomes, such as long-term mortality or rare complications.

CONCLUSION

This study demonstrates that off-pump cardiac surgery results in improved hemodynamic stability, reflected in lower heart rates and higher mean arterial pressure during surgery compared to on-pump surgery. Patients undergoing off-pump procedures also experienced shorter ICU and hospital stays, with fewer postoperative complications, particularly arrhythmias and pulmonary issues. Although mortality rates were slightly higher in the on-pump group, the differences were not statistically significant.

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