

Original article

Comparative Assessment of ICU Stay, Mechanical Ventilation Duration, and Early Recovery Following On-Pump versus Off-Pump Coronary Artery Bypass Grafting: A Prospective Observational Study

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Abstract

Background: Coronary artery bypass grafting (CABG) may be performed using cardiopulmonary bypass (on-pump CABG) or on the beating heart without cardiopulmonary bypass (off-pump CABG). Avoidance of cardiopulmonary bypass may attenuate systemic inflammatory responses and potentially facilitate early postoperative recovery.

Objectives: To compare duration of mechanical ventilation, intensive care unit (ICU) stay, early mobilization, postoperative complications, and early recovery between patients undergoing on-pump and off-pump CABG.

Materials and Methods: This prospective observational study was conducted over six months and included 35 adult patients undergoing isolated CABG. Patients were classified according to the surgical technique into an on-pump group (n=18) and an off-pump group (n=17). Demographic characteristics, operative variables, mechanical ventilation duration, ICU stay, postoperative complications, time to mobilization, and hospital stay were recorded. Continuous and categorical variables were compared using appropriate statistical tests, with $p < 0.05$ considered statistically significant.

Results: Baseline characteristics were comparable between groups. Mean mechanical ventilation duration was lower in the off-pump group (7.1 ± 2.5 hours) than in the on-pump group (10.6 ± 4.1 hours; $p = 0.004$). ICU stay was also shorter following off-pump CABG (2.1 ± 0.7 vs. 2.8 ± 0.9 days; $p = 0.015$). Off-pump patients demonstrated earlier mobilization and a shorter postoperative hospital stay. Postoperative complications were numerically less frequent following off-pump CABG, although most individual differences were not statistically significant.

Conclusion: In this small observational cohort, off-pump CABG was associated with shorter mechanical ventilation, reduced ICU stay, and earlier postoperative recovery. Larger prospective studies with adjustment for operative selection and patient risk are required.

Keywords: Coronary artery bypass grafting; off-pump CABG; cardiopulmonary bypass; mechanical ventilation; intensive care unit; early recovery.

Introduction

Coronary artery disease remains a major contributor to cardiovascular morbidity and mortality worldwide. Coronary artery bypass grafting (CABG) is an established revascularization strategy for patients with complex multivessel or left-main coronary artery disease. Conventionally, CABG is performed using cardiopulmonary bypass (CPB), which provides a motionless and bloodless operative field and facilitates precise coronary anastomosis. However, exposure of blood to the extracorporeal circuit, aortic manipulation, myocardial arrest,

and ischemia-reperfusion may trigger systemic inflammatory, coagulation, pulmonary, renal, and neurological consequences.

Off-pump coronary artery bypass grafting (OPCAB) was developed to avoid CPB and cardioplegic arrest while maintaining spontaneous cardiac activity. Potential advantages include reduced inflammatory activation, decreased transfusion requirements, earlier extubation, and reduced respiratory morbidity, although concerns remain regarding technical complexity, completeness of revascularization, and long-term graft patency. Large randomized trials have generally demonstrated similar major early outcomes between appropriately performed on-pump and off-pump CABG, while certain short-term recovery measures may differ between techniques [1–5]. Early postoperative recovery is particularly important because prolonged mechanical ventilation and ICU stay increase morbidity and resource utilization. The present study therefore compared mechanical ventilation duration, ICU stay, postoperative complications, and early recovery following on-pump and off-pump CABG.

Objectives

The primary objectives were to compare duration of postoperative mechanical ventilation and length of ICU stay between patients undergoing on-pump and off-pump CABG. Secondary objectives were to compare postoperative complications, time to mobilization, inotropic requirement, postoperative hospital stay, and early clinical recovery between the two groups.

Materials and Methods

Study Design and Setting

A prospective observational comparative study was conducted in the Department of Cardiovascular and Thoracic Surgery of a tertiary-care teaching hospital over a period of six months.

Study Population

Thirty-five consecutive adult patients undergoing isolated CABG during the study period and fulfilling the eligibility criteria were included. Patients were categorized according to the operative technique selected by the treating cardiac surgical team.

The on-pump CABG group included 18 patients, while the off-pump CABG group included 17 patients.

The selection of operative technique was based on coronary anatomy, aortic pathology, ventricular function, haemodynamic condition, comorbidities, surgeon preference, and technical feasibility. Surgical technique was not assigned for research purposes.

Inclusion Criteria

Adult patients aged 18 years or above undergoing elective or urgent isolated CABG for significant coronary artery disease were included. Patients undergoing either conventional on-pump CABG or off-pump CABG and providing informed consent for participation were eligible.

Exclusion Criteria

Patients undergoing emergency salvage surgery, concomitant valve or aortic surgery, redo CABG, major congenital cardiac procedures, preoperative mechanical ventilation, severe preoperative haemodynamic instability requiring mechanical circulatory support, or patients with incomplete perioperative records were excluded.

Preoperative Assessment

Detailed demographic and clinical information was recorded, including age, sex, body mass index, hypertension, diabetes mellitus, smoking status, chronic obstructive pulmonary disease, previous myocardial infarction, left ventricular ejection fraction (LVEF), and angiographic extent of coronary artery disease. Routine haematological,

biochemical, electrocardiographic, echocardiographic, and coronary angiographic assessments were performed according to institutional protocols.

Operative Technique

In the on-pump group, median sternotomy was followed by systemic heparinization, aortic and venous cannulation, initiation of cardiopulmonary bypass, aortic cross-clamping, cardioplegic myocardial protection, and construction of distal and proximal graft anastomoses according to standard institutional practice.

In the off-pump group, grafting was performed on the beating heart using mechanical stabilization and positioning techniques. Intracoronary shunts were used when clinically indicated. Conversion to cardiopulmonary bypass, if required for haemodynamic or technical reasons, was documented.

Internal mammary artery and saphenous vein conduits were used according to coronary anatomy and surgeon preference.

Anaesthesia and Postoperative Management

A standardized balanced general anaesthesia protocol was used. Following surgery, patients were transferred intubated to the cardiac surgical ICU. Haemodynamic monitoring, analgesia, sedation, fluid management, vasoactive therapy, glycaemic control, chest physiotherapy, and ventilator management were performed according to institutional protocols.

Extubation was undertaken after achievement of adequate consciousness, haemodynamic stability, satisfactory gas exchange, acceptable respiratory mechanics, normothermia, and absence of significant postoperative bleeding.

Outcome Measures

The **primary outcomes** were duration of postoperative mechanical ventilation in hours and ICU length of stay in days.

Secondary outcomes included postoperative inotropic requirement, postoperative blood transfusion, acute kidney injury, new-onset atrial fibrillation, respiratory complications, re-exploration for bleeding, time to first mobilization, postoperative hospital stay, and in-hospital mortality.

Early recovery was assessed using extubation, ICU discharge, first ambulation, and postoperative discharge as pragmatic clinical milestones.

Statistical Analysis

Data were entered into Microsoft Excel and analyzed using appropriate statistical software. Continuous variables were expressed as mean±standard deviation and categorical variables as frequency and percentage. Independent-samples Student's t-test or an appropriate non-parametric test was used for continuous variables depending on data distribution. Categorical variables were compared using Chi-square or Fisher's exact test. A two-sided p-value <0.05 was considered statistically significant.

Ethical Considerations

The study was conducted after approval from the Institutional Ethics Committee. Written informed consent was obtained from participating patients. Confidentiality of patient information was maintained throughout the study.

Results

A total of 35 patients undergoing isolated CABG were studied. Eighteen underwent on-pump CABG and 17 underwent off-pump CABG. The demographic and major preoperative clinical characteristics were broadly comparable between the two groups.

Table 1. Baseline demographic and clinical characteristics

Parameter	On-pump CABG (n=18)	Off-pump CABG (n=17)	p-value
Age, years	61.8±7.6	60.4±8.1	0.601
Male, n (%)	14 (77.8%)	13 (76.5%)	0.927
BMI, kg/m ²	25.7±3.1	25.2±2.9	0.626
Diabetes mellitus, n (%)	9 (50.0%)	8 (47.1%)	0.862
Hypertension, n (%)	12 (66.7%)	11 (64.7%)	0.902
Smoking history, n (%)	7 (38.9%)	6 (35.3%)	0.826
Previous myocardial infarction, n (%)	6 (33.3%)	5 (29.4%)	0.803
Mean LVEF, %	48.6±7.4	49.8±8.0	0.647
Triple-vessel disease, n (%)	14 (77.8%)	12 (70.6%)	0.626

There were no statistically significant baseline differences, although the limited sample size means that absence of statistical significance should not be interpreted as proof of equivalence.

Table 2. Operative and principal early postoperative outcomes

Parameter	On-pump CABG (n=18)	Off-pump CABG (n=17)	p-value
Operative duration, min	247.5±38.6	224.2±35.4	0.071
Number of distal grafts	3.2±0.7	3.0±0.8	0.437
Mechanical ventilation, hours	10.6±4.1	7.1±2.5	0.004
ICU stay, days	2.8±0.9	2.1±0.7	0.015
Inotropic support >12 h, n (%)	8 (44.4%)	4 (23.5%)	0.192
Blood transfusion, n (%)	9 (50.0%)	5 (29.4%)	0.214
First mobilization, hours	31.6±8.8	25.1±6.7	0.020
Postoperative hospital stay, days	7.8±1.6	6.7±1.3	0.033

The duration of postoperative mechanical ventilation was significantly shorter among off-pump patients. Mean ventilation duration was 7.1±2.5 hours in the off-pump group compared with 10.6±4.1 hours in the on-pump group (p=0.004), representing an unadjusted mean difference of approximately 3.5 hours.

Mean ICU stay was similarly reduced from 2.8±0.9 days following on-pump CABG to 2.1±0.7 days following off-pump CABG (p=0.015).

Patients undergoing off-pump surgery achieved first mobilization earlier (25.1±6.7 versus 31.6±8.8 hours; p=0.020). Postoperative hospital stay was also shorter (6.7±1.3 versus 7.8±1.6 days; p=0.033).

Table 3. Postoperative complications and early recovery outcomes

Outcome	On-pump CABG (n=18)	Off-pump CABG (n=17)	p-value
New-onset atrial fibrillation	4 (22.2%)	2 (11.8%)	0.658
Acute kidney injury	3 (16.7%)	1 (5.9%)	0.603
Respiratory complication	3 (16.7%)	1 (5.9%)	0.603
Re-exploration for bleeding	1 (5.6%)	0	1.000
Prolonged ventilation >24 h	2 (11.1%)	0	0.486
Wound infection	1 (5.6%)	1 (5.9%)	1.000
Stroke	0	0	—
In-hospital mortality	0	0	—

Individual postoperative complications were uncommon. Numerically fewer episodes of acute kidney injury, atrial fibrillation, respiratory complications, prolonged ventilation, and re-exploration were observed in the off-pump group; however, these comparisons were not statistically significant. No stroke or in-hospital death occurred in either group.

Discussion

The present prospective observational study compared early postoperative recovery following on-pump and off-pump CABG in 35 patients treated over six months. The principal findings were shorter postoperative mechanical ventilation, reduced ICU stay, earlier mobilization, and shorter postoperative hospitalization among patients undergoing off-pump CABG. Individual postoperative complications were numerically less frequent following off-pump surgery, but the small number of patients and events precluded reliable demonstration of differences in complication rates.

The physiological rationale for potential early recovery benefits following off-pump CABG relates principally to avoidance of cardiopulmonary bypass. Conventional CPB exposes circulating blood to artificial surfaces and produces haemodilution, complement activation, leukocyte activation, coagulation abnormalities, and a systemic inflammatory response. Pulmonary consequences may include increased vascular permeability, interstitial oedema, impaired gas exchange, and transient deterioration of pulmonary mechanics [6,7]. Contemporary CPB management has substantially reduced these adverse effects, but the biological distinction between procedures performed with and without extracorporeal circulation remains relevant.

Our most prominent finding was a reduction in mechanical ventilation duration from 10.6 hours following on-pump CABG to 7.1 hours following off-pump surgery. Earlier liberation from mechanical ventilation can facilitate mobilization, reduce sedation exposure, and potentially decrease ventilator-associated complications. Current ACC/AHA/SCAI guidance notes evidence that off-pump CABG can be associated with earlier extubation and reduced mechanical ventilation, particularly in patients with increased pulmonary risk [8].

These observations are also directionally consistent with the CORONARY trial. Lamy et al. randomized 4,752 patients to off-pump or on-pump CABG and found no significant difference in the primary composite of death, myocardial infarction, stroke, or new renal failure requiring dialysis at 30 days. Nevertheless, off-pump surgery reduced transfusion, reoperation for bleeding, acute kidney injury, and respiratory complications [2]. These findings demonstrate an important distinction: avoidance of CPB may influence selected perioperative outcomes without necessarily translating into major differences in composite cardiovascular endpoints.

In the present study, ICU stay was approximately 0.7 day shorter following off-pump surgery. ICU discharge after cardiac surgery depends on several interconnected factors, including ventilation, haemodynamic stability, bleeding, renal function, rhythm disturbances, vasoactive support, and institutional discharge protocols. The shorter ventilation period and numerically lower requirement for prolonged inotropic support in the off-pump group could therefore have contributed to earlier ICU discharge.

However, the evidence regarding ICU and hospital length of stay is not uniform. The GOPCABE randomized trial evaluated more than 2,500 elderly patients and found broadly comparable major outcomes between off-pump and on-pump CABG, with similar postoperative ICU and hospital stays [4]. Such differences across studies highlight the importance of institutional protocols, surgical expertise, case selection, anaesthetic management, and enhanced-recovery practices.

Earlier mobilization was another finding in the present cohort. Patients undergoing off-pump CABG ambulated approximately six hours earlier on average. Early mobilization is an important component of postoperative cardiac rehabilitation because it supports pulmonary expansion, functional recovery, gastrointestinal motility, and prevention of complications associated with prolonged bed rest. Nevertheless, time to mobilization is a composite recovery measure and can be influenced by staffing and institutional protocols in addition to physiological recovery.

Postoperative hospital stay was approximately one day shorter following off-pump surgery. This observation may be clinically relevant because even modest reductions in hospitalization can affect bed utilization and cost in high-volume cardiac centres. However, discharge timing is susceptible to non-clinical factors, and the difference should not be attributed exclusively to surgical technique without adjustment for potential confounders.

The present study found numerically fewer transfusions in the off-pump group. Avoidance of the CPB circuit can reduce haemodilution and activation of coagulation pathways. The CORONARY trial reported significantly lower blood-product transfusion with off-pump surgery [2]. Reduced transfusion may itself contribute to recovery by decreasing transfusion-associated complications.

Acute kidney injury occurred in three patients after on-pump CABG and one patient after off-pump surgery. Although the difference was not statistically significant, CPB may influence renal function through haemodilution, non-pulsatile perfusion, inflammation, microembolization, and alterations in renal oxygen delivery. CORONARY similarly demonstrated a reduction in acute kidney injury with off-pump CABG at 30 days [2]. The small sample size of the present study prevents meaningful conclusions regarding renal protection.

The choice between off-pump and on-pump CABG must nevertheless extend beyond early recovery outcomes. The ROOBY trial randomized 2,203 patients and demonstrated no significant difference in the 30-day composite endpoint but reported less favourable composite outcomes with off-pump surgery at one year [1]. Five-year follow-up of the ROOBY population subsequently demonstrated worse long-term outcomes in the off-pump group [9]. These results raised concerns regarding graft quality and completeness of revascularization when off-pump surgery is performed in settings with variable operator experience.

Conversely, the large international CORONARY trial found broadly similar clinical outcomes at five years between on-pump and off-pump strategies [3]. This difference between major trials reinforces the role of surgeon expertise and technical quality. Off-pump CABG is technically demanding, particularly when grafting lateral and posterior coronary territories, and intraoperative conversion to CPB may carry additional risk.

GOPCABE specifically studied patients aged 75 years or older and demonstrated no significant difference between the two approaches in its major composite endpoint at 30 days or one year [4]. Its five-year follow-up similarly contributed evidence that a carefully performed off-pump strategy can achieve acceptable long-term outcomes in appropriately selected elderly patients [10].

Accordingly, the objective should not be to regard either technique as universally preferable. On-pump CABG provides a stable, motionless operative field and may facilitate technically complete revascularization in patients with complex multivessel coronary anatomy. Off-pump CABG may be particularly useful when avoiding CPB or aortic manipulation has specific clinical advantages. The 2021 ACC/AHA/SCAI revascularization guideline states that techniques avoiding aortic manipulation, including off-pump approaches, are reasonable in patients with significant aortic calcification when performed by experienced surgeons and that off-pump surgery may be reasonable in patients with significant pulmonary disease [8].

Contemporary CPB itself has also evolved considerably. Improvements in extracorporeal circuits, anticoagulation management, temperature management, perfusion monitoring, organ-protection strategies, and patient blood management have improved the safety profile of on-pump surgery. The recent EACTS/EACTAIC/EBCP guidance emphasizes standardized, evidence-based CPB practice and multidisciplinary perfusion management [11].

Meta-analytic evidence has historically been heterogeneous. Møller et al. evaluated randomized trials comparing on-pump and off-pump CABG and highlighted concerns about mortality and fewer distal anastomoses in off-pump cohorts, although study quality and operator experience varied considerably [12]. Consequently, perioperative benefits must be considered alongside completeness and durability of revascularization.

The findings of our study should therefore be interpreted primarily as observations regarding **early postoperative recovery**, rather than evidence that one surgical strategy provides superior overall clinical outcomes. Within our institutional cohort, off-pump CABG was associated with earlier extubation, ICU discharge, mobilization, and hospital discharge. Larger risk-adjusted studies are required to establish whether these differences remain after controlling for patient selection, disease complexity, surgeon experience, and perioperative protocols.

Conclusion

In this six-month prospective observational cohort of 35 patients undergoing isolated CABG, off-pump surgery was associated with shorter postoperative mechanical ventilation, reduced ICU stay, earlier mobilization, and shorter postoperative hospitalization compared with on-pump CABG. Postoperative complications such as atrial fibrillation, acute kidney injury, respiratory complications, and prolonged ventilation were numerically less frequent following off-pump surgery, but individual differences were not statistically significant.

These findings suggest that avoidance of cardiopulmonary bypass may facilitate selected components of early postoperative recovery in appropriately selected patients. However, the small sample size, non-randomized design, and potential for surgical selection bias prevent conclusions regarding overall superiority of either technique. Choice of CABG strategy should remain individualized according to coronary anatomy, patient risk profile, aortic pathology, ventricular function, and surgical expertise. Larger prospective and adequately adjusted studies incorporating long-term graft and clinical outcomes are warranted.

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