

COMPARISON OF FACTORS ASSOCIATED WITH POST-OPERATIVE PROLONGED VENTILATION IN PATIENTS UNDERGOING ON-PUMP VERSUS OFF-PUMP CABG

Muhammad Saleem¹, Ziyad Humayun Akhtar², Muhammad Ahsan Fareed³, Momina Arshad⁴

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Corresponding Author:

Dr. Muhammad Saleem,

Email: drsaleem6001@hotmail.com

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¹Associate Professor Cardiac Surgery, FCPS, FRCS (Glasgow), FRCS(CTh)-England, Department of Cardiac Surgery, Faisalabad Institute of Cardiology, Faisalabad, Pakistan

²Specialist Registrar, Department of Cardiac Surgery, Jinnah Institute of Cardiology, Lahore, Pakistan

³Resident MD Interventional Cardiology, MD Cardiology, Faisalabad Institute of Cardiology, Faisalabad, Pakistan

⁴SilverQuill Pakistan, Lahore, Pakistan

ABSTRACT

Background: The aim is to determine the frequency of on-pump coronary artery bypass grafting (CABG) and compare prolonged postoperative mechanical ventilation (PMV) and associated clinical factors between on-pump and off-pump CABG. **Materials and Methods:** This prospective comparative observational study included 230 adults undergoing elective CABG at the Punjab Institute of Cardiology, Lahore, Pakistan, between May and November 2023. Patients were enrolled consecutively. PMV was defined as postoperative invasive ventilation lasting more than 24 hours. Between-group PMV frequencies were compared using Pearson's chi-square test; sparse subgroup comparisons used Fisher's exact test. Multivariable logistic regression adjusted for age, sex, and body mass index (BMI). Ventilation duration was compared using the Mann-Whitney U test in an exploratory analysis. **Result:** Of 230 patients, 180 (78.3%) underwent on-pump and 50 (21.7%) underwent off-pump CABG. PMV occurred in 29 patients (12.6%): 26/180 (14.4%) after on-pump versus 3/50 (6.0%) after off-pump CABG ($P = 0.112$; risk ratio, 2.41; 95% confidence interval [CI], 0.76–7.63). The adjusted odds ratio for on-pump versus off-pump CABG was 2.75 (95% CI, 0.79–9.54; $P = 0.112$). Median ventilation duration was 5.0 hours (interquartile range [IQR], 4.0–7.0) in the on-pump group and 4.0 hours (IQR, 4.0–5.0) in the off-pump group (exploratory $P = 0.003$). **Conclusion:** Although PMV was numerically more frequent after on-pump CABG, the primary and adjusted comparisons did not demonstrate a statistically significant association with surgical technique. The difference in overall ventilation duration should not be interpreted as evidence of a reduction in PMV. Larger, adequately powered studies incorporating comprehensive perioperative risk factors are needed to clarify the determinants of delayed extubation.

INTRODUCTION

Coronary artery bypass grafting (CABG) remains an important revascularization strategy for patients with complex coronary artery disease, yet recovery is frequently complicated by delayed liberation from invasive ventilation.^[1] Prolonged mechanical ventilation (PMV), defined in this study as ventilation for more than 24 hours after surgery, is associated with pulmonary complications, longer intensive care requirements and increased mortality.^[2,3] Reported determinants include age, obesity and pre-existing disease to cardiopulmonary

bypass exposure, intraoperative instability and postoperative organ dysfunction, making early identification difficult.^[4,5]

On-pump CABG provides a relatively motionless operative field but exposes patients to cardiopulmonary bypass, whereas off-pump CABG avoids extracorporeal circulation; whether this difference consistently shortens ventilatory support remains uncertain.^[6] One comparative study found longer postoperative ventilation after on-pump surgery, while a propensity-matched fast-track cohort found no meaningful difference in ventilation time.^[6,7] Comparative surgical studies and

contemporary meta-analyses also describe competing benefits and disadvantages of the two techniques, with short-term morbidity findings not necessarily predicting long-term revascularization outcomes.^[8,9,10] A recent Pakistani high-risk cohort reported more re-intubation after on-pump CABG, but did not directly resolve the frequency or predictors of ventilation exceeding 24 hours in routine elective cases.^[11]

This gap warrants a focused comparison in the local surgical population rather than assuming that pump status alone determines respiratory recovery.^[11,12] Pakistani reports document important postoperative complications, intensive care burden and differences in operative support, but provide limited directly comparable evidence on the specified >24-hour ventilation endpoint.^[13,15] Therefore, the proposed study will compare PMV frequency following on-pump and off-pump CABG and examine recorded patient characteristics alongside bypass and cross-clamp duration where applicable. Such evidence may support better preoperative counselling, risk stratification and postoperative resource planning, while informing future adequately powered, adjusted investigations.

MATERIALS AND METHODS

Study design, setting, and objectives: A prospective comparative observational study was conducted in the Department of Cardiac Surgery, Punjab Institute of Cardiology, Lahore, Pakistan, from May to November 2023. The source population comprised patients with ischemic heart disease undergoing elective CABG. The objectives were to determine the frequency of on-pump CABG and compare the frequency of PMV after on-pump and off-pump CABG.

Sample size and participant selection: A non-probability consecutive sampling approach yielded 230 patients. The sample size was calculated using the single-population proportion formula, assuming an expected frequency of on-pump coronary artery bypass grafting (CABG) of 97.8%¹⁶, a 95% confidence level, and a 2% absolute margin of error. The initial calculated sample size was 207 patients. After allowing for a 10% anticipated nonresponse or incomplete-data rate, the required sample size increased to 230 patients. Eligible patients were aged 20–70 years, of either sex, and scheduled for CABG for ischemic heart disease. Protocol exclusions were critical preoperative illness (inotropic or intra-aortic balloon pump support, acute renal failure, respiratory support, or preceding cardiopulmonary resuscitation), acute myocardial infarction requiring emergency surgery, concomitant valvular disease, repeat cardiac surgery, left ventricular ejection fraction <30%, and intraoperative conversion from off-pump to on-pump CABG.

Data collection and outcome definition: Following written informed consent, patient data were recorded

on a structured proforma. Recorded variables included CABG technique, age, sex, smoking, diabetes mellitus, hypertension, dyslipidemia, height, weight, body mass index (BMI), New York Heart Association class, and postoperative ventilation duration in hours. The protocol defined diabetes, hypertension, and dyslipidemia using thresholds for random glucose (>200 mg/dL), blood pressure (>160/90 mmHg), and total cholesterol (>200 mg/dL), respectively. PMV was defined as invasive ventilation for strictly more than 24 hours after CABG and was derived from recorded ventilation hours. Extubation criteria were normothermia, hemodynamic stability, absence of significant mediastinal bleeding, adequate muscle strength and respiratory effort (tidal volume >5 mL/kg), and wakefulness with the ability to follow commands. Surgery was performed by surgeons experienced with both techniques.

Ethical considerations: The Ethical approval was obtained from the College of Physicians and Surgeons Pakistan (CPSP) under reference no. CPSP/REU/CDS-2021-070-342. Written informed consent was obtained from each participant before enrollment.

Statistical analysis: The SPSS v. 21 was used for analysis. Continuous variables were summarized as mean $\pm$ standard deviation; skewed ventilation duration was additionally described using median and interquartile range. Baseline continuous variables were compared using Welch's t-test and categorical variables using Pearson's chi-square test. The primary comparison of PMV by CABG technique used Pearson's chi-square test, with Wilson 95% confidence intervals (CIs) for group proportions, a Newcombe CI for the risk difference, and a logarithmic CI for the risk ratio. Prespecified subgroup comparisons covered age, sex, BMI, hypertension, and dyslipidemia; age categories were recalculated from recorded age, while BMI categories (<25, 25–29.9, and ≥ 30 kg/m²) were defined for analysis. Fisher's exact test replaced chi-square when expected cell counts were sparse. Multivariable logistic regression estimated the association between CABG technique and PMV after adjustment for age (per 10 years), sex, and BMI (per 5 kg/m²), reporting adjusted odds ratios and 95% CIs. Additional exploratory analyses included univariable logistic models and a two-sided Mann–Whitney U test for ventilation duration. Sensitivity analyses used the originally recorded PMV indicator and excluded two implausible height measurements from a separate BMI-adjusted model. All tests were two-sided; $P \leq 0.05$ was considered statistically significant. Exploratory and subgroup analyses were not corrected for multiplicity.

RESULTS

Baseline demographic and clinical characteristics: The study included 230 CABG patients. On-pump

CABG was recorded in 180 cases (78.3%) and off-pump CABG in 50 (21.7%). The overall mean age was 53.7 ± 11.6 years, 160 patients (69.6%) were male, and the mean body mass index (BMI) was 28.2

$\pm 5.5 \text{ kg/m}^2$. Smoking was recorded in 114 on-pump patients (63.3%) and 43 off-pump patients (86.0%; $P = 0.002$). Other recorded baseline characteristics are presented in [Table 1].

Table 1: Baseline demographic and clinical characteristics by CABG technique

Characteristic	Overall (n = 230)	On-pump (n = 180)	Off-pump (n = 50)	P value
Age (years), mean $\pm$ SD	53.7 ± 11.6	53.8 ± 11.6	53.5 ± 11.7	0.890
Weight (kg), mean $\pm$ SD	76.4 ± 13.0	76.8 ± 12.6	75.3 ± 14.2	0.508
Height (cm), mean $\pm$ SD	165.1 ± 10.6	165.5 ± 10.9	163.8 ± 9.8	0.296
BMI (kg/m^2), mean $\pm$ SD	28.2 ± 5.5	28.2 ± 5.8	28.0 ± 4.4	0.779
Male sex, n (%)	160 (69.6%)	123 (68.3%)	37 (74.0%)	0.441
NYHA class III–IV, n (%)	28 (12.2%)	23 (12.8%)	5 (10.0%)	0.595
Hypertension, n (%)	165 (71.7%)	127 (70.6%)	38 (76.0%)	0.449
Diabetes mellitus, n (%)	119 (51.7%)	95 (52.8%)	24 (48.0%)	0.550
Hyperlipidemia, n (%)	171 (74.3%)	135 (75.0%)	36 (72.0%)	0.667
Smoking, n (%)	157 (68.3%)	114 (63.3%)	43 (86.0%)	0.002

Values are mean $\pm$ standard deviation (SD) or number (%). P values: Welch's t-test for continuous variables and Pearson chi-square test for categorical variables. BMI: body mass index; CABG: coronary artery bypass grafting; NYHA: New York Heart Association.

Postoperative prolonged mechanical ventilation (PMV): PMV, defined as ventilation exceeding 24 hours, occurred in 29 of 230 records (12.6%). PMV occurred after 26 of 180 on-pump procedures (14.4%) and three of 50 off-pump procedures (6.0%; Pearson $\chi^2 = 2.532$, $P = 0.112$). The absolute risk difference was 8.4 percentage points (95% confidence interval [CI], -2.7 to 15.5), and the risk ratio was 2.41 (95% CI, 0.76 – 7.63). The corresponding group proportions and their 95% CIs are shown in [Figure 1].

Mean ventilation duration was 8.2 ± 8.2 hours after on-pump CABG and 5.9 ± 5.4 hours after off-pump

CABG. The respective medians were 5.0 hours (interquartile range [IQR], 4.0 – 7.0) and 4.0 hours (IQR, 4.0 – 5.0), with a Mann–Whitney U test $P = 0.003$. Ventilation duration is summarized in [Table 2 and Figure 2].

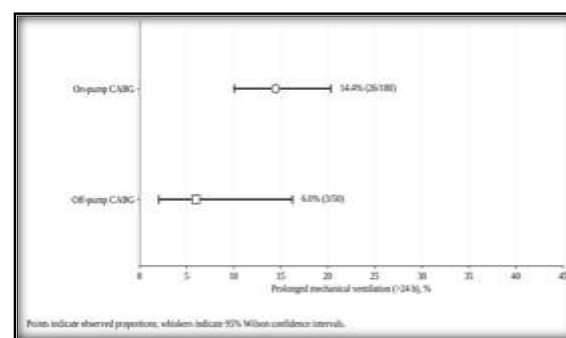


Figure 1: Frequency of prolonged mechanical ventilation after on-pump and off-pump CABG

Table 2: Ventilation outcomes after on-pump and off-pump CABG

Outcome	Overall (n = 230)	On-pump (n = 180)	Off-pump (n = 50)	P value
PMV >24 h, n (%)	29 (12.6%)	26 (14.4%)	3 (6.0%)	0.112
No PMV, n (%)	201 (87.4%)	154 (85.6%)	47 (94.0%)	—
Ventilation duration (h), mean $\pm$ SD	7.7 ± 7.7	8.2 ± 8.2	5.9 ± 5.4	—
Ventilation duration (h), median (IQR)	5.0 (4.0–6.0)	5.0 (4.0–7.0)	4.0 (4.0–5.0)	0.003

Pearson chi-square test for PMV frequency; asymptotic two-sided Mann–Whitney U test (ties accounted for) for ventilation duration.

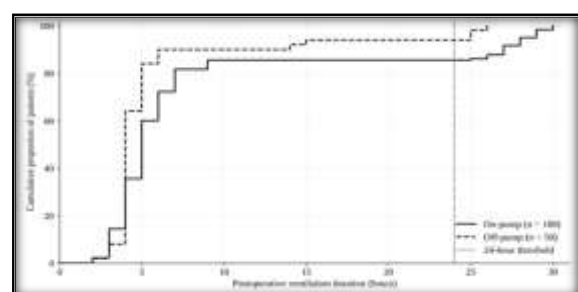


Figure 2: Cumulative distributions of postoperative ventilation duration by surgical technique

Stratified and regression analyses: The comparison of PMV by surgical technique was additionally stratified by age category, sex, BMI category,

hypertension, and hyperlipidemia, as specified in the synopsis. The stratum-specific event counts and P values are presented in Figure 3. Fisher's exact test was used for strata with sparse expected cell counts; in strata containing no PMV events in either group, no inferential comparison was reported.

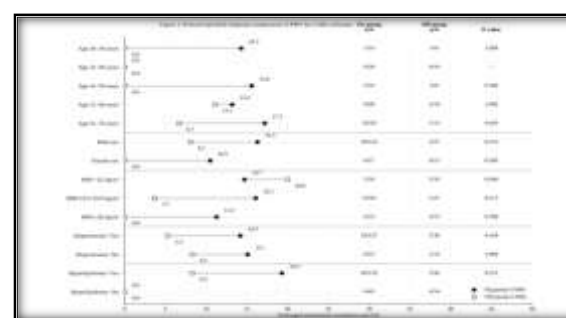


Figure 3: Protocol-specified subgroup comparisons of PMV by CABG technique

In the multivariable logistic model incorporating CABG technique, age, sex, and BMI (230 records; 29 PMV events), the adjusted odds ratio (aOR) for PMV after on-pump versus off-pump CABG was 2.75 (95% CI, 0.79–9.54; $P = 0.112$). Adjusted estimates for age, sex, and BMI and exploratory univariable

associations are presented in Table 4. All 29 patients meeting the duration-based PMV definition had recorded hyperlipidemia; no PMV events occurred among the 59 patients without hyperlipidemia (Fisher's exact $P = 0.000147$). A finite univariable logistic odds ratio was not estimable for this variable.

Table 4: Unadjusted and adjusted associations with duration-defined PMV

Factor	Crude OR (95% CI)	P value	Adjusted OR (95% CI)	P value
On-pump CABG	2.65 (0.77–9.13)	0.124	2.75 (0.79–9.54)	0.112
Age (per 10 years)	1.23 (0.85–1.78)	0.272	1.26 (0.86–1.83)	0.234
Female sex	0.56 (0.22–1.44)	0.227	0.52 (0.20–1.35)	0.180
BMI (per 5 kg/m ²)	1.03 (0.73–1.44)	0.875	1.06 (0.74–1.52)	0.732
NYHA III–IV	2.12 (0.78–5.78)	0.141	—	—
Hypertension	0.86 (0.37–2.00)	0.723	—	—
Diabetes mellitus	1.62 (0.73–3.60)	0.237	—	—
Hyperlipidemia	Not estimable	0.000147*	—	—
Smoking	2.45 (0.90–6.72)	0.081	—	—

Logistic regression used two-sided Wald P values and confidence intervals. The adjusted model included CABG technique, age (per 10 years), female sex, and BMI (per 5 kg/m²). *Fisher's exact P value for hyperlipidemia due to complete separation (29/29 PMV cases were hyperlipidemia-positive). Crude screening is exploratory; dashes mean not included in the adjusted model. BMI: body mass index; CI: confidence interval; NYHA: New York Heart Association; OR: odds ratio.

A separately recorded PMV indicator identified 30 events, including one record with a ventilation duration of nine hours. When this original indicator was used as a sensitivity outcome, PMV was recorded after 27 on-pump procedures (15.0%) and three off-pump procedures (6.0%; Pearson χ^2 $P = 0.095$); the corresponding adjusted on-pump aOR was 2.88 (95% CI, 0.83–9.99; $P = 0.095$).

DISCUSSION

In this comparative observational study from a tertiary cardiac center in Lahore, prolonged PMV, defined as ventilation exceeding 24 hours, was more frequent after on-pump than off-pump CABG. However, neither the prespecified comparison of PMV frequencies nor the model adjusted for age, sex, and body mass index demonstrated a statistically significant between-technique association. Ventilation duration was longer in the on-pump group on an exploratory distributional comparison, but this finding concerns a different outcome from the prespecified binary PMV endpoint. The study addresses a specific gap in Pakistani evidence by examining the same >24-hour definition in both operative groups; its principal contribution is an estimate of the local event burden and the precision of the observed between-group difference, rather than evidence that pump use independently causes delayed extubation.^[1,3]

Several reports are compatible with the direction of the present findings. A Pakistani study of 243 high-risk patients by Nawaz et al. documented reintubation in 9.3% of on-pump and 2.2% of off-pump

recipients ($P = 0.020$).^[11] In a 2025 meta-analysis restricted to total arterial grafting, Comanici et al. reported shorter intubation duration after off-pump procedures.^[12] In the Pakistani series of Aasim et al., the mean ventilation time was 10.43 ± 15.65 hours among CABG patients with left ventricular dysfunction, further documenting the variability of postoperative respiratory support in a clinically different population.^[13] In a cardiac-surgery cohort comprising predominantly CABG cases, Sharifzadeh Kermani et al. reported PMV >24 hours in 13.1% of patients, close to the 12.6% observed here.^[4] Evidence that operative and clinical conditions may both influence ventilation comes from Möller et al., who found independent associations with bypass duration (odds ratio [OR] 1.01 per unit reported), postoperative peak lactate (OR 1.35), and preoperative EuroSCORE (OR 1.23), and from Wise et al., who evaluated preoperative predictors of PMV in a 738-patient CABG cohort.^[2,17] A review by Sahar et al. described generally more favorable pulmonary recovery with off-pump techniques, whereas a 2026 meta-analysis of 1,071 patients with chronic obstructive pulmonary disease reported less mechanical ventilatory support with off-pump CABG (pooled mean difference, -4.73 ; 95% confidence interval [CI], -6.17 to -3.29). The latter estimate pertains to a selected pulmonary-risk population and should not be transferred directly to unselected elective patients.^[18,19]

Other evidence cautions against treating off-pump surgery as consistently protective against delayed ventilation. In a propensity-matched fast-track study of 926 patients per group, Grützner et al. reported median ventilation times of 75 versus 80 minutes after on-pump and off-pump CABG, respectively ($P = 0.973$), with no statistically significant difference. These much shorter durations reflect an early-extubation pathway and are not directly comparable with the present 24-hour threshold⁷. The systematic review by Shahsanaei et al. estimated a pooled PMV frequency of 6.5% (95% CI, 4.1%–10.2%) in studies using a >24-hour threshold, lower than the 12.6% recorded here, whereas Möller et al. reported PMV in

17.4% of 339 isolated-CABG patients; considerable between-study heterogeneity and differences in clinical case-mix limit comparison of these proportions.^[1,2] Similarly, the scoping review by Kumalasari et al. found that PMV cutoffs ranged from >12 to >48 hours, while Daza-Arana et al. evaluated a >48-hour endpoint and identified renal, pulmonary, and postoperative complications rather than operative technique alone as relevant correlates.^[3,5] Ventilator practice itself may contribute to between-center variation: Dollin et al. reported shorter ventilation duration after an intensivist-directed management intervention²⁰. Surgical selection is another consideration. A 2024 Pakistani series documented conversion from off-pump to on-pump CABG in 27 of 714 patients (3.78%), whereas converted patients were excluded by the present protocol²¹. The PROVECS randomized trial found no statistically significant reduction in postoperative pulmonary complications with an open-lung versus conventional ventilatory strategy during on-pump cardiac surgery (54.7% versus 59.2%; $P = 0.320$).^[22] Finally, five-year follow-up from the ROOBY randomized trial identified higher all-cause mortality after off-pump surgery (15.2% versus 11.9%); this long-term endpoint cannot adjudicate the present short-term respiratory question but illustrates why pulmonary recovery should not be considered in isolation from other surgical outcomes.^[23]

The study's strengths include consecutive recruitment at a single institution, a uniform operational definition of PMV, individual ventilation-duration data for all 230 records, and direct comparison of both CABG techniques. The analysis distinguished the prespecified binary outcome from exploratory ventilation-duration comparisons, reported risk estimates with confidence intervals, and retained the original outcome flag for sensitivity assessment. Age, sex, BMI, hypertension, and dyslipidemia were examined as planned subgroups rather than introduced solely after inspecting the outcomes. These features permit a transparent appraisal of the local findings and their statistical uncertainty.

However, several limitations restrict inference. The study was nonrandomized, with 180 on-pump and only 50 off-pump patients; only three off-pump participants experienced PMV. The adjusted OR of 2.75 consequently had a wide 95% CI (0.79-9.54), which is compatible with several clinically different effects. The groups also differed in smoking prevalence, and smoking, diabetes, hypertension, pulmonary disease, renal function, cardiac function, operative urgency, bypass and cross-clamp duration, transfusion, sedation, and postoperative complications were not comprehensively incorporated into the prespecified adjusted model. A 2025 isolated-CABG prediction study identified age, acid-base status, temperature, and chronic obstructive pulmonary disease as relevant to ventilation beyond six hours, illustrating the information unavailable here and the importance of

endpoint consistency.^[24] Finally, the single-center findings may not generalize to other surgical teams or extubation practices.

Future multicenter studies should use a prospective, explicitly documented extubation protocol; validate pulmonary and cardiac comorbidities; record bypass and aortic cross-clamp times, procedural conversions, perioperative transfusion, ventilation settings, and postoperative complications; and retain exact ventilation hours alongside the >24-hour PMV endpoint. Risk-adjusted comparisons should be planned around an adequate number of PMV events, with prespecified assessment of treatment-selection bias and interaction rather than reliance on multiple sparse subgroup tests. Locally published reviews of respiratory rehabilitation and contemporary enhanced-recovery recommendations provide a basis for evaluating whether standardized perioperative respiratory care can reduce avoidable ventilation delays across both surgical approaches.

CONCLUSION

In this single-center cohort, prolonged postoperative mechanical ventilation was more frequent after on-pump than off-pump coronary artery bypass grafting (CABG), although the difference was not statistically significant. No statistically significant association between surgical technique and prolonged ventilation was detected after adjustment for age, sex, and body mass index. Ventilation duration was longer in the on-pump group in an exploratory analysis, but this finding should be distinguished from the prespecified outcome of ventilation exceeding 24 hours. The study provides local comparative evidence on an important postoperative outcome while highlighting the uncertainty surrounding any independent effect of operative technique.

These findings support an approach to postoperative respiratory care that considers individual patient characteristics and perioperative factors rather than pump status alone. Consistent extubation practices and early recognition of patients at risk of delayed ventilator liberation remain important across both surgical approaches. Larger, adequately powered multicenter studies with standardized definitions and comprehensive risk adjustment are needed to clarify the relationship between CABG technique and prolonged ventilation and inform postoperative critical-care planning.

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