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# COMPARISON OF NEUROLOGICAL OUTCOMES BETWEEN ON-PUMP AND OFF-PUMP CORONARY ARTERY BY-PASS GRAFT SURGERY

**Muhammad Abu Bakar[1*], Waseem Riaz[2], Muhammad Haseeb Mumtaz[3], Muhammad Farhan Qazafi[4]**

[1,4]Post Graduate Resident Cardiac Surgery, Punjab Institute of Cardiology, Lahore, Pakistan
[2]Associate Professor of Cardiac Surgery, Punjab Institute of Cardiology, Lahore, Pakistan
[3]Senior Register Cardiac Surgery, Chaudhary Muhammad Akram Teaching and Research Hospital, Lahore
***Corresponding author:** Muhammad Abu Bakar, Email: - dr.abubakar759@yahoo.com

**ABSTRACT**
**Objective:** The objective of the study was to compare early postoperative neurological complications between on-pump and off-pump coronary artery bypass graft (CABG) surgery and to determine predictors of postoperative neurological complications.
**Methods:** The present study is a comparative observational study which was performed in the Department of Cardiac Surgery, Punjab Institute of Cardiology, Lahore from 13 February 2026 to 13 May 2026. Through non-probability consecutive sampling, a total of 182 adult patients who were undergoing isolated CABG were equally distributed in both groups (on-pump and off-pump). Clinical, operative and postoperative data was taken. The early neurological complications in the hospital environment were evaluated. Data were analyzed by SPSS and multivariable logistic regression was used to determine independent predictors.
**Results:** The mean age was 56.8 ± 8.9 years, and 136 (74.7%) patients were male. Overall, neurological complications occurred in 20 (11.0%) patients. These were significantly more frequent after on-pump CABG than off-pump CABG, 15 (16.5%) versus 5 (5.5%), respectively. On multivariable analysis, age ≥60 years, on-pump CABG, postoperative atrial fibrillation, and mechanical ventilation >12 hours were independent predictors.
**Conclusion:** Early neurological complications were more common after on-pump CABG. Careful patient selection, neurological surveillance, and rhythm monitoring may help reduce postoperative neurological morbidity.

**KEYWORDS:** CABG; Stroke; Neurological complications; Cardiopulmonary bypass; Off-pump surgery

## INTRODUCTION

The prevalence of coronary artery disease is still high, and the number of people suffering from ischemic heart disease is steadily rising, so is the need for the development of safe and effective coronary revascularization strategies [1]. Moderately recent estimates from around the world indicate that cardiovascular diseases are the leading cause of premature mortality and morbidity, and that the control of risk factors and access to advanced cardiac treatments is variable, especially in the low- and middle-income countries [2]. Conditions of acute coronary syndromes and more complex multivessel coronary artery disease are therefore a significant clinical challenge, particularly when the patient has diabetes mellitus, hypertension, smoking history, dyslipidaemia and impaired ventricular function [3]. CABG is a proven revascularization option in patients with complex multivessel coronary artery disease, left main coronary artery disease and certain high-risk anatomical patterns where long-term myocardial revascularization is desired [4]. CABG can be performed with (on-pump) or without (off-pump) the use of CPB (cardiopulmonary bypass). Some of the advantages and disadvantages of these techniques are still controversial because off-pump CABG may have less systemic inflammation and embolic exposure, while on-pump CABG may provide a more stable operative field and a more technically complete revascularization [5].
Neurological complications after CABG are clinically important because stroke, transient ischemic attack, delirium, seizure, and new focal neurological deficit can prolong mechanical ventilation, increase intensive care utilization, delay rehabilitation, and reduce postoperative quality of life [6]. The mechanisms of neurological injury after CABG are multifactorial and may include aortic manipulation, embolization, cerebral hypoperfusion, systemic inflammatory response, perioperative atrial fibrillation, blood transfusion, and patient-related vascular risk factors [7]. Avoidance of cardiopulmonary bypass and reduction in aortic handling during off-pump CABG have therefore been proposed as possible strategies to reduce early neurological injury, although outcomes may depend on surgeon experience, patient selection, coronary anatomy, and completeness of revascularization [5].
This is especially important in Pakistan where cardiovascular disease is an important public-health problem and the number of patients with a high load of metabolic and vascular risk factors is now a large part of cardiac surgical care [8]. National statistics reveal that hypertension, diabetes mellitus and ischemic heart disease are very common among the Pakistani adult population, and thus a significant population is at risk of having complex coronary artery disease and risk of perioperative complications [9]. The prevalence of diabetes mellitus is also high among

the patients undergoing CABG and was similar to the findings in local CABG data, where many of the cardiac centers were reported to have patients undergoing CABG with a high-risk profile [10].
Limited local evidence exists on early neurological outcomes after on-pump versus off-pump CABG in Pakistani patients. Given the high burden of diabetes, hypertension, multivessel coronary artery disease, and delayed presentation in this population, international findings may not fully apply to local practice. This study compared early neurological outcomes between both CABG techniques and identified predictors of postoperative neurological complications to support better perioperative risk stratification and postoperative care.

## METHODOLOGY

The study was an observational study with comparative design performed on 13 February 2026 till 13 May 2026 in the Department of Cardiac Surgery, Punjab Institute of Cardiology Lahore. To compare early postoperative neurological outcomes of on-pump and off-pump coronary artery bypass graft surgery, the study design was developed. In all, 182 patients were involved and split into two groups, 91 in the on-pump CABG group and 91 in the off-pump CABG group.
Isolated coronary artery bypass grafting (CABG) for angiographically confirmed coronary artery disease (CAD) were recruited using non-probability consecutive sampling in the adult population of either sex. Exclusion criteria included patients with a previous major neurological deficit or disabling stroke, patients who were scheduled to undergo redo CABG, patients who had concomitant valve surgery or congenital heart surgery, patients with severe carotid artery disease requiring intervention, patients with chronic neurological disease that precluded evaluation, patients with severe hepatic or renal dysfunction, patients undergoing emergency life-saving surgery, and patients for whom the history was not complete. Informed written consent was taken from all eligible patients.
Demographic and clinical data were obtained using a structured proforma, which included age, gender, BMI, place of residence, smoking status, presence of hypertension, diabetes mellitus, dyslipidemia, previous myocardial infarction, previous stroke or TIA, LV EF and coronary angiographic results. Operative data including number of grafts, cardiopulmonary bypass (CPB) time, aortic cross-clamp (ACC) time, total operative time, blood transfusion, use of an intra-aortic balloon pump (IABP), and off-pump to on-pump conversion were also recorded.
The primary outcome was the development of early postoperative neurologic complications (within the first 60 days after surgery and prior to hospital discharge). Neurological outcomes comprised ischemic stroke, hemorrhagic stroke, transient ischemic attack, postoperative delirium, seizure, new focal neurological deficit and major neurological deterioration. All patients with suspected neurological complication were clinically evaluated, and neurology consultation and brain imaging were carried out as indicated.
IBM SPSS Statistics was used to analyse data. Data for quantitative variables were presented in the form of mean ± standard deviation (SD) and data for categorical variables were presented as frequencies and percentages. The independent samples t-test, Mann–Whitney U test, and the chi-square test or Fisher's exact test were used to analyse the continuous and categorical variables, respectively. The independent predictors of postoperative neurological complications were determined using multivariable logistic regression analysis. P value of $< 0.05$ was regarded as statistically significant.

## RESULTS

The 182 patients who underwent a CABG surgery were classified into 2 groups: on-pump CABG group (91) and off-pump CABG group (91). The average age of the population studied was 56.8 ± 8.9 years. Most patients were male, 136 (74.7%), while 46 (25.3%) were female. 116 (63.7%) patients had diabetes mellitus and 112 (61.5%) had hypertension. Demographic and clinical parameters were similar in both groups, and did not differ statistically significantly in terms of age, gender, residence, cardiovascular risk factors, left ventricular ejection fraction, or the extent of coronary artery disease (Table 1).

**Table 1. Demographic and baseline clinical characteristics of study participants**

| Variable | Overall (n = 182) | On-pump CABG (n = 91) | Off-pump CABG (n = 91) | p-value |
|---|---|---|---|---|
| Age, years, mean ± SD | 56.8 ± 8.9 | 57.3 ± 9.0 | 56.2 ± 8.8 | 0.406 |
| Age group, years | | | | 0.775 |
| ≤50 | 39 (21.4) | 18 (19.8) | 21 (23.1) | |
| 51–60 | 68 (37.4) | 33 (36.3) | 35 (38.5) | |
| 61–70 | 55 (30.2) | 28 (30.8) | 27 (29.7) | |
| >70 | 20 (11.0) | 12 (13.2) | 8 (8.8) | |
| Gender | | | | 0.865 |
| Male | 136 (74.7) | 67 (73.6) | 69 (75.8) | |
| Female | 46 (25.3) | 24 (26.4) | 22 (24.2) | |
| Body mass index, kg/m², mean ± SD | 26.3 ± 3.7 | 26.5 ± 3.8 | 26.1 ± 3.6 | 0.467 |
| Residence | | | | 0.877 |
| Urban | 118 (64.8) | 60 (65.9) | 58 (63.7) | |
| Rural | 64 (35.2) | 31 (34.1) | 33 (36.3) | |

| | | | | |
|---|---|---|---|---|
| Hypertension | 112 (61.5) | 58 (63.7) | 54 (59.3) | 0.648 |
| Diabetes mellitus | 116 (63.7) | 60 (65.9) | 56 (61.5) | 0.644 |
| Current or former smoking | 72 (39.6) | 39 (42.9) | 33 (36.3) | 0.448 |
| Dyslipidemia | 88 (48.4) | 46 (50.5) | 42 (46.2) | 0.656 |
| Family history of ischemic heart disease | 58 (31.9) | 31 (34.1) | 27 (29.7) | 0.633 |
| Previous myocardial infarction | 78 (42.9) | 42 (46.2) | 36 (39.6) | 0.454 |
| Left ventricular ejection fraction, %, mean ± SD | 49.2 ± 7.4 | 48.8 ± 7.6 | 49.6 ± 7.2 | 0.467 |
| Left ventricular ejection fraction <40% | 35 (19.2) | 19 (20.9) | 16 (17.6) | 0.707 |
| Triple-vessel disease | 146 (80.2) | 74 (81.3) | 72 (79.1) | 0.852 |
| Left main coronary artery disease | 38 (20.9) | 20 (22.0) | 18 (19.8) | 0.855 |

The surgical technique was analyzed with respect to the operative characteristics. No statistically significant difference was found between the two groups with regard to the number of grafts, which was 3.06 ± 0.66 in the on-pump group and 2.91 ± 0.72 in the off-pump group. The total operative time was significantly longer in the on-pump group than in the off-pump group. Patients who had on-pump CABG also had more intra-operative blood transfusions. 3 (3.3%) patients required conversion from off pump to on pump surgery (Table 2).

**Table 2. Operative characteristics according to surgical technique**

| Variable | Overall (n = 182) | On-pump CABG (n = 91) | Off-pump CABG (n = 91) | p-value |
|---|---|---|---|---|
| Elective surgery | 150 (82.4) | 74 (81.3) | 76 (83.5) | 0.846 |
| Urgent surgery | 32 (17.6) | 17 (18.7) | 15 (16.5) | |
| Number of grafts, mean ± SD | 2.99 ± 0.69 | 3.06 ± 0.66 | 2.91 ± 0.72 | 0.145 |
| Left internal mammary artery used | 177 (97.3) | 88 (96.7) | 89 (97.8) | 1.000 |
| Cardiopulmonary bypass time, minutes, mean ± SD | — | 89.4 ± 22.6 | — | — |
| Aortic cross-clamp time, minutes, mean ± SD | — | 55.7 ± 15.8 | — | — |
| Total operative time, minutes, mean ± SD | 249.7 ± 45.6 | 262.5 ± 45.7 | 236.9 ± 42.3 | <0.001 |
| Intraoperative blood transfusion | 67 (36.8) | 41 (45.1) | 26 (28.6) | 0.031 |
| Intra-aortic balloon pump use | 11 (6.0) | 7 (7.7) | 4 (4.4) | 0.536 |
| Conversion from off-pump to on-pump | 3 (1.6) | — | 3 (3.3) | — |

Early postoperative period and before discharge, postoperative neurological outcomes were evaluated. There were 20 patients (11.0%) with neurological complications overall. On-pump CABG group had a significantly higher incidence of any neurological complication than did an off-pump CABG group (15 (16.5%) vs. 5 (5.5%)). Ischemic stroke was seen in 8 (4.4%) patients with 6 (6.6%) in the on pump group and 2 (2.2%) in the off pump group. There was a higher incidence of TIA and postoperative delirium in the on-pump group as well; although these isolated neurological outcomes did not achieve statistical significance (Table 3).

**Table 3. Comparison of postoperative neurological outcomes between on-pump and off-pump CABG**

| Neurological outcome | Overall (n = 182) | On-pump CABG (n = 91) | Off-pump CABG (n = 91) | Relative risk (95% CI) | p-value |
|---|---|---|---|---|---|
| Any neurological complication | 20 (11.0) | 15 (16.5) | 5 (5.5) | 3.00 (1.14–7.91) | 0.018 |
| Ischemic stroke | 8 (4.4) | 6 (6.6) | 2 (2.2) | 3.00 (0.62–14.47) | 0.278 |
| Hemorrhagic stroke | 0 (0.0) | 0 (0.0) | 0 (0.0) | — | — |
| Transient ischemic attack | 6 (3.3) | 5 (5.5) | 1 (1.1) | 5.00 (0.60–41.96) | 0.211 |
| Postoperative delirium | 12 (6.6) | 9 (9.9) | 3 (3.3) | 3.00 (0.84–10.72) | 0.133 |
| Seizure | 3 (1.6) | 2 (2.2) | 1 (1.1) | 2.00 (0.18–21.67) | 1.000 |
| New focal neurological deficit | 8 (4.4) | 6 (6.6) | 2 (2.2) | 3.00 (0.62–14.47) | 0.278 |
| NIHSS deterioration ≥2 points | 15 (8.2) | 11 (12.1) | 4 (4.4) | 2.75 (0.91–8.32) | 0.103 |

The clinical outcomes of the postoperative period revealed significantly more mechanical ventilation, ICU and hospital stays and higher postoperative chest drain output for the on-pump CABG group than for the off-pump CABG group. In the postoperative period, there were 43 patients (23.6%) with atrial fibrillation, and this was more common in the on-pump group (not statistically significant). There was no significant difference in in-hospital mortality (3.3% overall, 4 in the on-pump group, 2 in the off-pump group. (Table 4).

**Table 4. Postoperative clinical outcomes according to surgical technique**

| Outcome | Overall (n = 182) | On-pump CABG (n = 91) | Off-pump CABG (n = 91) | p-value |
|---|---|---|---|---|
| Mechanical ventilation, hours, mean ± SD | 12.4 ± 6.7 | 13.8 ± 7.2 | 10.9 ± 5.8 | 0.003 |
| ICU stay, days, mean ± SD | 4.3 ± 1.7 | 4.7 ± 1.8 | 3.9 ± 1.5 | 0.001 |
| Total hospital stay, days, mean ± SD | 7.8 ± 2.5 | 8.2 ± 2.7 | 7.4 ± 2.3 | 0.033 |
| Chest drain output, mL, mean ± SD | 665 ± 250 | 710 ± 260 | 620 ± 230 | 0.014 |
| Postoperative atrial fibrillation | 43 (23.6) | 26 (28.6) | 17 (18.7) | 0.163 |
| Acute kidney injury | 26 (14.3) | 17 (18.7) | 9 (9.9) | 0.138 |
| Re-exploration for bleeding | 7 (3.8) | 5 (5.5) | 2 (2.2) | 0.444 |
| Surgical site infection | 11 (6.0) | 6 (6.6) | 5 (5.5) | 1.000 |
| Perioperative myocardial infarction | 9 (4.9) | 4 (4.4) | 5 (5.5) | 1.000 |
| In-hospital mortality | 6 (3.3) | 4 (4.4) | 2 (2.2) | 0.682 |

Multivariable logistic regression analysis revealed that age ≥60 years, on-pump CABG, postoperative atrial fibrillation and prolonged mechanical ventilation were independent risk factors for postoperative neurological complications. On-pump CABG was found to be significantly associated with increased odds of postoperative neurological complications after adjusting for other age-, gender-, diabetes mellitus-, hypertension-, LVEF- and operative-related variables. (Table 5)

**Table 5. Multivariable logistic regression analysis for predictors of postoperative neurological complications**

| Predictor | Adjusted odds ratio | 95% confidence interval | p-value |
|---|---|---|---|
| Age ≥60 years | 2.54 | 1.01–6.38 | 0.048 |
| Male gender | 1.18 | 0.41–3.39 | 0.758 |
| Diabetes mellitus | 1.87 | 0.72–4.84 | 0.198 |
| Hypertension | 1.66 | 0.64–4.29 | 0.296 |
| Smoking history | 1.31 | 0.51–3.38 | 0.572 |
| Left ventricular ejection fraction <40% | 1.79 | 0.63–5.08 | 0.274 |
| On-pump CABG | 3.10 | 1.09–8.84 | 0.034 |
| Intraoperative blood transfusion | 1.92 | 0.76–4.85 | 0.168 |
| Postoperative atrial fibrillation | 2.96 | 1.07–8.21 | 0.037 |
| Mechanical ventilation >12 hours | 2.49 | 1.01–6.15 | 0.047 |

## DISCUSSION

An early postoperative neurological complication was seen in 11.0% of patients who had undergone CABG, being significantly higher in the on-pump group compared to the off-pump group in the present study. The risk of any neurological complication was three times higher following on pump CABG and this risk was independent of other demographic, clinical and operative factors. This discovery is supportive of the theory that avoidance of CPB may minimize early Neurologic morbidity in certain patients. He et al. also found that the off-pump CABG procedure was linked to reduced short-term stroke risk, but they noted that long-term outcomes and reintervention risk should be taken into account when choosing the surgical method [5].

The incidence of ischemic stroke was higher in the on-pump group than the off-pump group, but not statistically different. This is probably due to the small population size of the current cohort with stroke events. However, in a Veterans Affairs randomized cohort, Qin et al. observed no long-term benefit of off-pump CABG, indicating a potential loss of long-term benefit may be observed in early neurological outcomes [11]. Taggart et al. also demonstrated long-term results of on-pump and off-pump CABG may be broadly similar when performed in highly experienced centers [12]. Thus, our results must be viewed as proof of a neurological signal in the early postoperative period and not as an evidence of superiority of one procedure. Some of the reasons for higher incidence of neurological complications in the on-pump group may be attributed to mechanisms associated with cardiopulmonary bypass such as embolization, non-pulsatile flow, systemic inflammation, and aortic cross-clamping. When comparing OPCAB and OPCBG, Zhou et al. emphasized that graft-related outcomes and technical adequacy are still relevant, and should not be judged in isolation of the completeness and durability of revascularization [13].

In the present study, although there was a slight difference in the number of grafts between the two groups, the difference was not statistically significant, indicating that the difference in neurological outcome was probably not directly attributable to graft number. Clinically the high prevalence of diabetes mellitus in the cohort (63.7%) is important. Rena et al. reported that diabetic patients are a high-risk subgroup where the issue of balancing perioperative safety and long-term revascularization durability is particularly important [14]. Xu et al. also noted that diabetic patients' clinical outcomes after CABG may be influenced by their diabetes status and this suggests that a careful selection of patients is needed and should not be done according to a preference for either surgical approach [15].

The results of this study are very significant for Pakistan, where diabetes is prevalent among CABG patients. Delirium was more common following on-pump CABG, but not significantly. The authors of Greaves et al. found that these factors were age and perioperative vulnerability to delirium and cognitive decline following CABG [16]. Li et al. also found that elderly CABG patients are at a high risk of postoperative delirium, in accord with our regression result that age ≥60 years was an independent predictor of neurological complications [17].

The postoperative delirium frequency was also higher in the on-pump group, and Tutuš et al. hypothesized that this is due to the presence of gaseous microemboli [18]. Another independent predictor of neurologic complications in our analysis was postoperative atrial fibrillation. Benedetto et al. showed that patients who develop postoperative atrial fibrillation (POAF) following isolated CABG have a higher long-term risk of stroke [19]. In addition, Rasmussen et al. found an association with stroke subtypes after new onset postoperative atrial fibrillation (AF) after coronary bypass surgery [20].

The results confirm a policy of robust prevention, timely detection and treatment of post-CABG AF. On-pump group also required more mechanical ventilation, ICU, hospital stays and intraoperative transfusion, chest drain output and had more frequent chest drain use. The higher transfusion rates seen in our on-pump group also support its clinical relevance as seen in the early outcomes of CABG patients reported by Koster et al. [21]. Rustenbach et al. demonstrated that the pump strategy used can have differential effects on the perioperative outcome of high-risk cardiac surgical sub-groups, favoring the selection of a technique that is tailored to individual patients [22].

Thus, our results indicate that off-pump CABG could be beneficial in decreasing early neurologic morbidity in adequately selected Pakistani patients, however, surgical experience, coronary anatomy, extent of revascularization, and postoperative rhythm monitoring must still be a major point of consideration.

## CONCLUSION

The incidence of early postoperative neurologic complication was less with off-pump CABG than with on-pump CABG. Important predictors of neurological morbidity were older age, on-pump surgery, postoperative atrial fibrillation and prolonged mechanical ventilation. The results suggest that the surgical selection must be made with care, early nervous evaluation is required, and intensive monitoring of the postoperative rhythm is needed in CABG patients.

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