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Assessment Of Risk Factors for Postoperative Cognitive Dysfunction After Coronary Artery Bypass Surgery

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Abstract

Background: Coronary artery bypass graft (CABG) surgery is a widely performed procedure and the gold standard for treating advanced coronary artery disease. Despite advances reducing mortality, postoperative complications remain a concern, especially in aging patients with comorbidities. Postoperative cognitive dysfunction (POCD) is a common complication characterized by impairments in memory, attention, and executive function. POCD can significantly impact patients' quality of life and functional independence long after surgery.

Aim and Objective: To assess the prevalence of postoperative cognitive dysfunction (POCD) in coronary artery bypass grafting patients.

Material and Methods: A cross-sectional study was

conducted at Khyber Teaching Hospital Peshawar with 180 participants predominantly male (93.9%) and aged over 50 years (74.4%). Data on demographic characteristics, health status, anesthesia duration, and postoperative complications were collected and analyzed. The Montreal Cognitive Assessment (MOCA) was used to evaluate cognitive function post-surgery.

Result: A total of 180 participants, mostly males (93.9%) aged over 50 years (74.4%), were included. Half reported diabetes (50%) and smoking (50%), with 62.2% experiencing anesthesia longer than three hours. Postoperative complications included prolonged hospitalization (37.8%) and reintubation (37.2%). Montreal Cognitive Assessment showed significant impairment in memory recall and attention, with longer anesthesia duration strongly associated with decreased cognitive performance ($p < 0.001$).

Conclusion: Postoperative cognitive dysfunction is a common complication following coronary artery bypass graft surgery, particularly among older male patients with comorbidities such as diabetes and history of smoking. Prolonged anesthesia significantly correlates with impairments in memory recall and attention. Early identification and management of risk factors may help reduce the incidence and impact of cognitive decline after surgery, improving patient outcomes and quality of life.

INTRODUCTION

Coronary artery bypass grafting (CABG) remains one of the most commonly performed cardiac surgical procedures worldwide and is considered the gold standard for revascularization in patients with advanced coronary artery disease (2). Advances in surgical techniques, perioperative management, and cardiopulmonary bypass technology have significantly reduced mortality rates over the past decades (1). However, increasing attention has shifted toward postoperative complications that affect patients' quality of life and functional independence. Among these, postoperative cognitive dysfunction (POCD) is an important complication characterized by impairments in memory, attention, executive function, and processing speed following surgery (2).

The reported incidence of POCD after CABG varies widely, ranging from 20% to 50% in the early postoperative period and persisting in approximately 10%–30% of patients within three to six months after surgery (3). Persistent cognitive impairment has been associated with prolonged hospitalization, reduced quality of life, and increased long-term mortality (6). Even mild cognitive deficits may affect patients' ability to follow medication regimens and rehabilitation programs, thereby influencing cardiovascular outcomes and healthcare costs (7).

The pathogenesis of POCD is multifactorial and involves a combination of patient-related vulnerabilities, surgical factors, anesthetic effects, and systemic inflammatory responses (17). During cardiopulmonary bypass, microemboli composed of air, lipids, or platelet aggregates may enter the cerebral circulation and cause microinfarcts and white matter injury (8). In addition, systemic inflammatory responses triggered by cardiopulmonary bypass can lead to cytokine release, endothelial dysfunction, and disruption of the blood–brain barrier, contributing to neuroinflammation and neuronal injury (14, 9).

Several demographic and clinical characteristics have been identified as risk factors for POCD after CABG. Advanced age is considered one of the strongest predictors, with patients older than 65 years having a significantly higher risk of postoperative cognitive decline (11, 15). Lower educational level, reflecting reduced cognitive reserve, has also been associated with greater vulnerability to cognitive impairment (12). Furthermore, comorbidities such as diabetes mellitus, hypertension, and cerebrovascular disease may increase susceptibility to perioperative cerebral ischemia and cognitive decline (13). Surgical factors including prolonged cardiopulmonary bypass time and aortic cross-

clamp duration have also been associated with increased risk of POCD due to prolonged exposure to inflammatory and embolic events (17).

Neuroinflammation is increasingly recognized as a key mechanism in POCD. Elevated perioperative levels of inflammatory cytokines, particularly interleukin-6 and tumor necrosis factor-alpha, have been associated with postoperative cognitive decline (22). Biomarkers such as S100B and neuron-specific enolase have also been suggested as indicators of neuronal injury and blood–brain barrier disruption (23). Despite extensive research, the precise contribution of these factors remains incompletely understood, and no universally accepted risk prediction model for POCD currently exists (26).

Despite increasing research on postoperative cognitive dysfunction, there is still no standardized diagnostic approach, and the role of systemic inflammation in its development remains unclear. Most studies have focused on long-term outcomes, while fewer studies have evaluated early postoperative cognitive changes. Postoperative cognitive dysfunction is a common complication that can affect memory, attention, and recovery after surgery (5), yet the combined impact of multiple risk factors is still not fully understood.

This study is significant because it aims to evaluate cognitive outcomes after CABG using standardized neuropsychological assessment and to examine the influence of patient-related and perioperative factors on postoperative cognitive dysfunction. Identifying these factors may help clinicians recognize high-risk patients, improve perioperative management, and enhance patient counseling, ultimately reducing long-term morbidity following CABG surgery.

The objective of this study is to assess postoperative cognitive dysfunction and its associated risk factors among patients undergoing coronary artery bypass grafting.

Age refers to the patient's age measured in completed years. Educational level refers to the level of formal education and is categorized as low (<12 years) or high (≥12 years). Preoperative comorbidity refers to the presence of medical conditions such as hypertension, diabetes, or cerebrovascular disease recorded from the patient's medical history as Yes or No. Anesthesia duration refers to the total time a patient remains under anesthesia during surgery measured in minutes. Surgical duration refers to the total length of the surgical procedure measured in hours.

METHODOLOGY:

This cross-sectional study was conducted in the Cardiothoracic Surgery Department and Cardiovascular Intensive Care Unit (CVICU) of Khyber Teaching Hospital, Peshawar. The study included patients undergoing elective Coronary Artery Bypass Grafting (CABG) surgery and assessed early postoperative cognitive outcomes within 1–4 weeks after surgery.

Patients undergoing elective CABG surgery who were able to provide informed consent and had no history of neurological disorders such as stroke or dementia were included in the study. Patients undergoing emergency CABG surgery, those who refused consent, or those undergoing other cardiac surgeries were excluded.

A total of 180 patients were included using a convenience sampling technique. The sample size was calculated assuming a 13.5% prevalence of postoperative cognitive dysfunction (POCD), with a 95% confidence level and a 5% margin of error. The study was conducted over a period of four months.

Data were collected using structured questionnaires, patient medical records, and standardized neuropsychological tests including the Montreal Cognitive Assessment (MOCA) and Trail Making Test (Part A and B). After obtaining written informed consent, demographic and clinical information such as age, gender, comorbidities, and baseline cognitive status were recorded. Cognitive function was assessed using MOCA before surgery and on the 7th postoperative day. Postoperative clinical data including surgical details, ICU stay, duration of mechanical ventilation, complications, and medication use were also documented.

Data were analyzed using SPSS version 27. Descriptive statistics including frequencies, percentages, means, and standard deviations were used to summarize the demographic and clinical characteristics of the participants. Chi-square tests were applied to determine the association between potential risk factors and the occurrence of postoperative cognitive dysfunction. A p-value of less than 0.05 was considered statistically significant.

RESULT

In our study, a total of 180 participants were included. The majority were male, comprising 93.9% (n = 169) of the sample, while females accounted for 6.1% (n = 11). This indicates that the study population was predominantly male. (Figure 4.1)

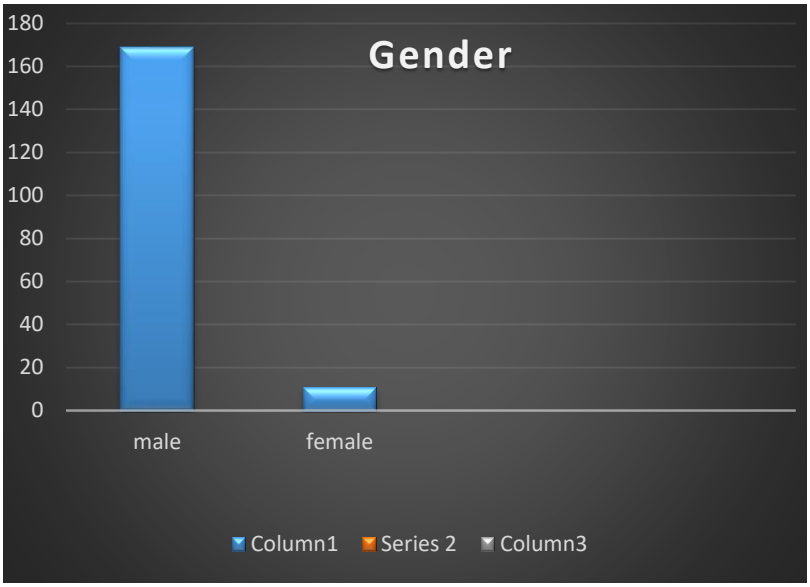


Figure 1 show gender of participants

The age distribution of participants showed that the majority were older than 50 years, representing 74.4% (n = 134) of the total sample. Participants aged between 41 and 50 years accounted for 25.6% (n = 46). This indicates that most of the study population consisted of individuals over 50 years of age. (Figure 4.2).

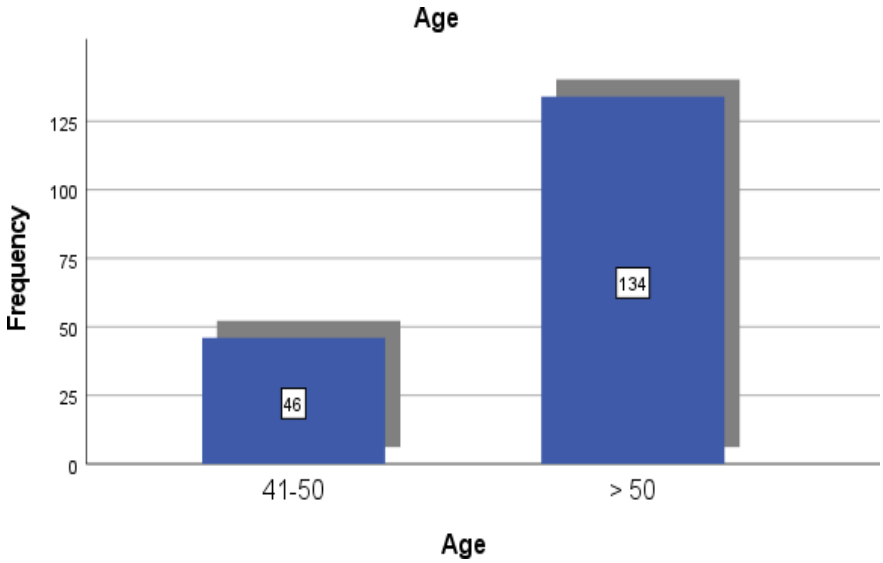


Figure 2 show age of Participants

In our study, educational background varied among participants. Nearly half of the respondents (48.9%, n = 88) had received primary education, while 25.6% (n = 46) reported having no formal education. Secondary education and higher secondary education were reported by 12.8% (n = 23) of participants each. These findings suggest that a significant portion of the study population had either no education or only primary-level education.

Table 4.1: Educational Status of Participants (N = 180)

Education Level	Frequency	Percent (%)
No Education	46	**25.6**
Primary Education	88	**48.9**
Secondary Education	23	**12.8**
Higher Secondary Education	23	**12.8**
Total	180	100.0

In this study, half of the participants (50.0%, n = 90) reported having diabetes, while 12.2% (n = 22) had a history of stroke, and the same percentage (12.2%) reported dementia. Additionally, 25.6% (n = 46) of the participants experienced depression or anxiety. Regarding smoking habits, exactly half of the participants (50.0%, n = 90) identified as smokers. When asked about engagement in regular physical activity, a majority (74.4%, n = 134) reported that they do participate in regular exercise, whereas 25.6% (n = 46) did not. These findings highlight the prevalence of chronic health conditions and lifestyle factors among the study population. (Table 4.2)

Table 4.2: Health-Related Characteristics of Participants

Variable	Category	Frequency	Percent (%)
Pre-Existing Conditions	Diabetes	90	**50.0**
	Stroke	22	**12.2**
	Dementia	22	**12.2**
	Depression or Anxiety	46	**25.6**

Smoking Status	Yes	90	**50.0**
	No	90	**50.0**
Regular Physical Activity	Yes	134	**74.4**
	No	**46**	**25.6**

Participants identified several possible causes of postoperative cognitive dysfunction (POCD). The most reported factor was a long duration of anesthesia exceeding three hours, noted by 62.2% (n= 112) of the participants. Pre-existing cognitive impairment was present in 25.6% (n = 46) cases, while high levels of systemic inflammation were identified as a contributing factor in 12.2% (n =22). these findings suggest that prolonged anesthesia is perceived as the most prominent contributing factor to POCD among the study participants. (Table 4.3)

Table 4.3: Reported Causes of Postoperative Cognitive Dysfunction

Possible Cause of POCD	Frequency	Percent (%)
Pre-existing Cognitive Impairment	46	**25.6**
Long Duration of Anesthesia (>3 hours)	112	**62.2**
High Levels of Systemic Inflammation	22	**12.2**
Total	**180**	**100.0**

The majority of participants (62.8%, n = 113) underwent anesthesia for 201 to 300 minutes, while 37.2% (n = 67) received anesthesia for 120 to 200 minutes. Regarding the duration of surgery, most procedures lasted between 3 to 5 hours, reported in 75.6% (n = 136) of cases. A smaller proportion (24.4%, n = 44) underwent surgeries lasting 1 to 3 hours. These findings indicate that both anesthesia and surgical procedures were of relatively long duration for most patients in the study. (Table 4.4)

Table 4.4: Duration of Anesthesia and Surgery

Variable	Category	Frequency	Percent (%)
Duration of Anesthesia	120–200 minutes	67	**37.2**

	201–300 minutes	113	**62.8**
Duration of Surgery	1–3 hours	44	**24.4**
	3–5 hours	**136**	**75.6**

Among the participants, various postoperative complications were reported. Prolonged hospitalization was the most frequently observed complication, affecting 37.8% (n = 68) of the patients, followed closely by reintubation in 37.2% (n = 67) of cases. Delirium was experienced by 12.8% (n = 23), while 12.2% (n = 22) reported postoperative infections. These results suggest that extended hospital stays, and respiratory-related issues were the most common postoperative concerns in the study population. (Table 4.5)

Table 4.5: Postoperative Complications Experienced by Participants

Postoperative Complication	Frequency	Percent (%)
Delirium	23	**12.8**
Prolonged Hospitalization	68	**37.8**
Infection	22	**12.2**
Reintubation	67	**37.2**
Total	180	100.0

MONTREAL COGNITIVE ASSESSMENT:

The results of the Montreal Cognitive Assessment revealed varied performance across different cognitive domains. Regarding memory recall, 37.2% of participants were able to recall all three words correctly, while 25.6% could not recall any words, indicating notable difficulties in short- term memory among a significant portion of the sample. Orientation to time was well preserved, with 92.8% of participants correctly identifying today's date. Similarly, spatial orientation was intact for most individuals, as 89.4% correctly identified the city they were in. Attention and concentration, assessed by the Serial 7s test, showed more variability: only 25.6% of participants answered all serial subtractions correctly, while nearly half (49.4%) demonstrated partial accuracy. These findings suggest that while orientation remains relatively intact, memory recall and sustained attention may be areas of cognitive challenge within this group. The results of the Clock Drawing Test indicated a broad range of performance in visuospatial and executive functioning among the participants. A total of 40.0% of individuals

completed the task accurately, reflecting intact cognitive processing in these domains. In contrast, 37.5% of participants performed incorrectly, suggesting significant impairments in planning, abstraction, and spatial organization. Additionally, 22.5% of the sample demonstrated partial correctness, indicative of mild to moderate difficulties in task execution. Based on these components, approximately 62% of patients were classified as having POCD. The rest (about 38%) had normal cognition postoperatively. These results highlight that while a portion of participants retained adequate visuospatial and executive abilities, a considerable segment exhibited varying levels of impairment, pointing to potential cognitive decline affecting these areas. (Table 4.6)

Table 4.6 Montreal Cognitive Assessment Results Summary

Subtest	Categories	Frequency	Percent(%)	Valid Percent (%)	Cumulative Percent (%)
Word Recall (3 words)	No words recall	46	25.6	25.6	**25.6**
	One word recall	23	12.8	12.8	**38.3**
	Two words recall	44	24.4	24.4	**62.8**
	All three words recall	67	37.2	37.2	**100.0**
What is today's date?	Correct	167	92.8	92.8	**92.8**
	Incorrect	13	7.2	7.2	**100.0**
What city are we in?	Correct	161	89.4	89.4	**89.4**
	Incorrect	19	10.6	10.6	**100.0**
Attention and Concentration (Serial 7s Test)	Incorrect	45	25.0	25.0	**25.0**
	Partially correct	89	49.4	49.4	**74.4**
	Correct	46	25.6	25.6	**100.0**

Clock drawing test	**Incorrect**	**30**	**37.5**	**37.5**	**37.5**
	Partially correct	**18**	**22.5**	**22.5**	**60**
	Correct	**32**	**40**	**40**	**100**

Association between Duration of Anesthesia and Montreal Cognitive Assessment: A cross-tabulation between duration of anesthesia and performance on the Montreal Cognitive Assessment (MOCA) word recall subtest revealed a statistically significant association. Among those who underwent shorter anesthesia durations (120–200 minutes), the majority (65.7%) were able to recall all three words, while none recalled only one or two words. Conversely, patients exposed to longer durations of anesthesia (201–300 minutes) showed a more distributed performance, with fewer individuals (20.4%) recalling all three words, and higher frequencies of one-word (20.4%) and two-word (38.9%) recall.

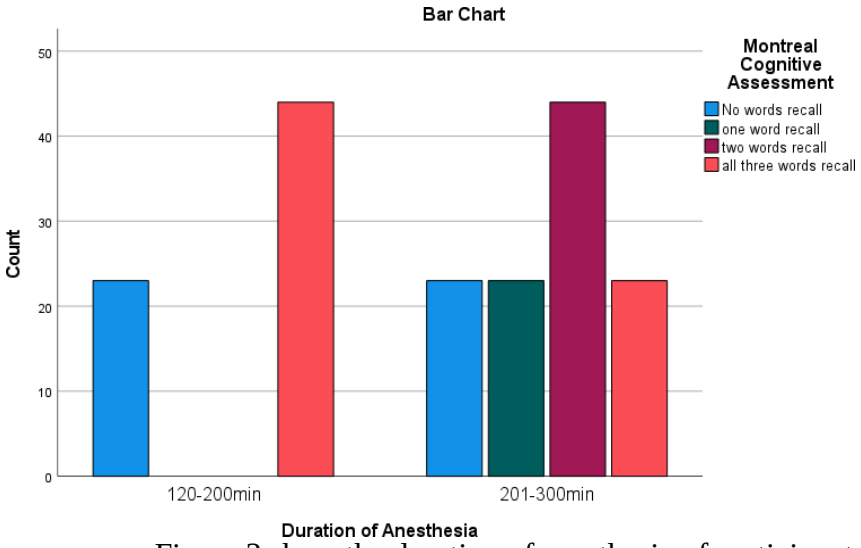


Figure 3 show the duration of anesthesia of participants

The Chi-square test confirmed this association to be statistically significant (Pearson Chi-Square= 66.146, DF = 3, $p < 0.001$), indicating that longer durations of anesthesia may be linked to reduced memory recall. The linear-by-linear association ($p = 0.043$) further supports a trend of decreasing cognitive performance with increasing anesthesia duration. These findings suggest that prolonged exposure to anesthesia may have a negative impact on short-term memory recall. (Table 4.7)

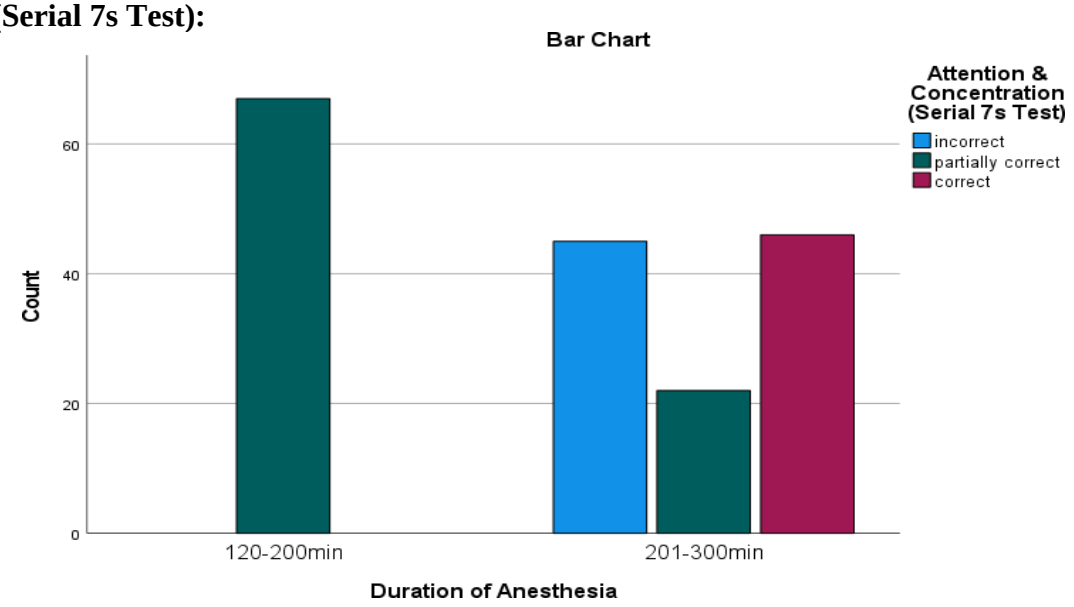
Table 4.7: Association between Duration of Anesthesia and Montreal Cognitive Assessment Word Recall Performance

Duration of anesthesia	No word recall	One word recall	Two word recall	All three word recall	Total p-value

120-200 min	**23**	**0**	**0**	**44**	**67**
201-300 min	**23**	**23**	**44**	**23**	**113**
Total	**46**	**23**	**44**	**67**	**180**

The relationship between duration of anesthesia and performance on the Attention and Concentration subtest (Serial 7s test) of the Montreal Cognitive Assessment was statistically significant. Participants who experienced shorter anesthesia duration (120–200 minutes) all scored as partially correct, with none answering fully correct or incorrect. In contrast, those with longer anesthesia duration (201–300 minutes) showed a more varied distribution: 39.8% answered correctly, 19.5% partially correct, and 39.8% incorrect.

Association between Duration of Anesthesia and Attention & Concentration (Serial 7s Test):



The Pearson Chi-square test confirmed a strong association between anesthesia duration and attention performance ($\chi^2 = 109.124$, df = 2, $p < 0.001$). However, the linear-by-linear association was not significant (p = 0.936), indicating no clear linear trend between increasing anesthesia duration and performance categories. These findings suggest that prolonged anesthesia is associated with greater variability and impairment in attention and concentration. (Table 4.8)

Table: Association between Duration of Anesthesia and Attention & Concentration (Serial 7s Test) Performance

Duration of Anesthesia	Incorrect	Partially Correct	Correct	Total p-value
120–200 min	0	67	0	**67**
201–300 min	45	22	46	**113**

Total	**45**	**89**	**46**	180 < 0.001

Association between Pre-existing Conditions and Montreal Cognitive Assessment: The analysis revealed a highly significant association between pre-existing medical conditions and performance on the word recall subtest of the Montreal Cognitive Assessment ($\chi^2 = 255.266$, df = 9, $p < 0.001$). Participants with diabetes showed a mixed pattern, with 25.6% recalling no words and nearly half recalling all three words. Those with stroke predominantly recalled only one word, while participants with dementia mostly recalled two words. Interestingly, individuals with depression or anxiety either recalled no words or all three, with no intermediate recall observed.

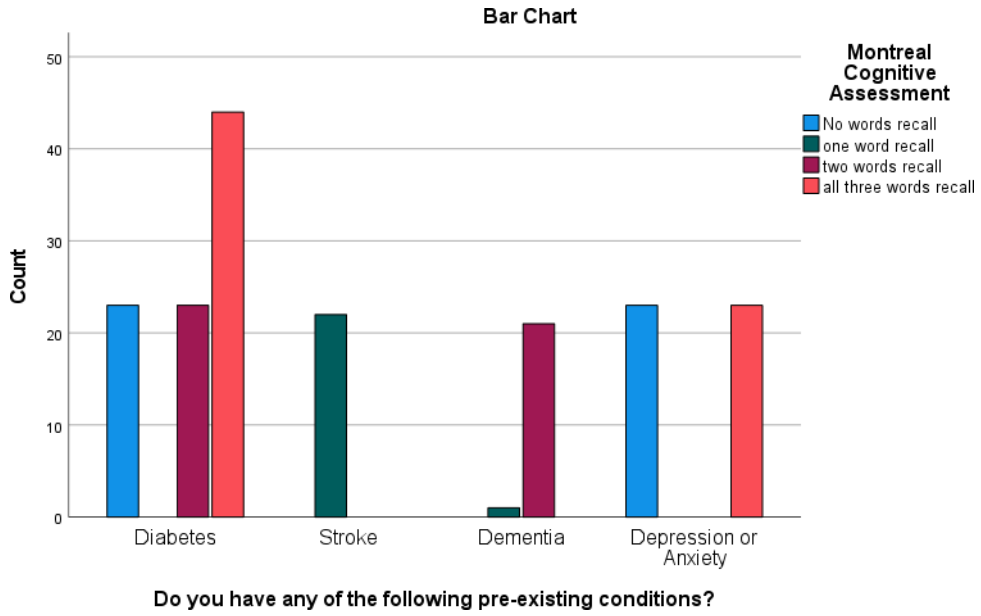


Figure 4 have any following ore-existing condition of participants

The linear-by-linear association was not statistically significant (p = 0.062), suggesting the relationship is not strictly linear. These results indicate that different pre-existing conditions may distinctly impact short-term memory recall performance.

Table 4.9: Association between Pre-existing Conditions and Montreal Cognitive Assessment (Word Recall) Performance

Pre-existing Condition	No Words Recall	One Word Recall	Two Words Recall	All Three Words Recall	Total	p-value
Diabetes	23	0	23	44	90	
Stroke	0	22	0	0	22	
Dementia	0	1	21	0	22	
Depression or Anxiety	23	0	0	23	46	

Total	**46**	**23**	**44**	**67**	180	< 0.001

DISCUSSION

This study investigated the risk factors associated with postoperative cognitive dysfunction (POCD) in patients undergoing coronary artery bypass graft (CABG) surgery, focusing on demographic characteristics, pre-existing conditions, duration of anesthesia and surgery, postoperative complications, and cognitive outcomes assessed by the Montreal Cognitive Assessment (MOCA).

The study sample was predominantly male (93.9%) and mostly comprised older adults, with 74.4% aged above 50 years. This demographic reflects the known epidemiology of coronary artery disease and CABG patients, as cardiovascular risk and surgical interventions increase with age and are more prevalent in males (Roger et al., 2012). Aging is a critical risk factor for POCD because of physiological changes in the brain, such as reduced synaptic density, micro vascular disease, and diminished neuroplasticity (Monk et al., 2008). These changes reduce cognitive reserve, making the elderly more susceptible to perioperative insults like hypoxia, inflammation, and anesthesia- related neurotoxicity, which can impair memory, attention, and executive function (4).

The study revealed a significant portion of participants had low educational attainment, with nearly 75% having only primary education or no formal education. Education is a well-established proxy for cognitive reserve — the brain's resilience to neuropathological damage (Stern, 2009). Lower educational levels may contribute to greater vulnerability to POCD, as individuals with limited cognitive reserves have fewer neural resources to compensate for perioperative stressors. This highlights the importance of considering baseline cognitive capacity and educational background in assessing POCD risk (6).

Half of the patients reported diabetes mellitus, and a notable percentage had histories of stroke (12.2%), dementia (12.2%), or depression/anxiety (25.6%). These conditions are known contributors to cognitive impairment and likely amplify susceptibility to POCD. Diabetes promotes micro vascular damage and chronic inflammation, which affects cerebral perfusion and neurodegeneration (Biessels & Reagan, 2015). Stroke patients often have localized brain damage impairing cognitive domains, explaining their poorer recall performance in this study. Dementia reflects pre-existing neurodegeneration, inherently increasing POCD risk due to reduced baseline cognitive function (7, 13).

Interestingly, participants with depression or anxiety exhibited a bimodal pattern in memory recall either recalling no words or all three. Mood disorders can affect cognitive processes through mechanisms such as hippocampal atrophy and altered neurotransmitter systems (Rock et al., 2014). This variability suggests mood disorders may compound cognitive deficits or, conversely, in some cases, may not have a uniform effect on POCD risk (5).

A key finding was the strong association between longer anesthesia duration (> 3 hours) and decreased cognitive performance, particularly in short-term memory recall and attention. Patients anesthetized for 201–300 minutes had significantly lower rates of recalling all three words and greater variability in attention task performance compared to those with shorter anesthesia exposure (120–200 minutes). These results support previous studies linking prolonged anesthesia and surgery duration with neurocognitive dysfunction (9).

Several pathophysiological mechanisms may explain this. Prolonged anesthesia may increase neuroinflammation, disrupt the blood-brain barrier, and induce neuroapoptosis. Cardiopulmonary bypass and long surgical times can lead to cerebral hypo perfusion and micro emboli formation, further damaging vulnerable brain areas

(Evered et al., 2018). This underscores the need for anesthetic management strategies that minimize anesthesia duration without compromising surgical outcomes (10).
The study identified postoperative complications such as prolonged hospitalization (37.8%) and reintubation (37.2%) as common in this cohort, with delirium present in 12.8% and infection in 12.2%. These complications contribute to systemic inflammation and physiological stress, both recognized contributors to POCD pathogenesis (12).
Delirium, often an acute manifestation of brain dysfunction, is strongly predictive of subsequent cognitive decline. It may exacerbate underlying neuronal injury or reflect early signs of neuroinflammatory processes triggered by surgery (Rasmussen et al., 2016). Prolonged hospitalization and reintubation likely prolong exposure to ICU-related stressors, immobility, and hypoxia, all of which can worsen cognitive outcomes (13).
The MoCA results showed that while orientation to time and place was largely preserved (> 89% accuracy), memory recall and attention were impaired in a substantial proportion of patients. Only 37.2% could recall all three words, and about 25.6% could recall none, indicating considerable Deficits in verbal memory. Similarly, attention measured by the Serial 7s subtraction task was correct in only 25.6%, with many participants showing partial or incorrect performance (13).
These findings highlight that POCD after CABG surgery most prominently affects memory encoding and sustained attention, consistent with the literature (Newman et al., 2001). These cognitive domains are essential for everyday functioning and quality of life, indicating that POCD can have profound long-term consequences (12, 3).

LIMITATIONS

This study had several limitations. First, the sample size was relatively small and predominantly male, which may limit the generalizability of the findings to a broader and more balanced population. The cross-sectional design restricts the ability to establish causal relationships between risk factors and postoperative cognitive dysfunction (POCD). Additionally, cognitive assessment was only performed at a single postoperative time point, which may not capture long-term cognitive changes. Self-reported data on some variables, such as physical activity and smoking status, may be subject to bias. The study did not control for all potential confounding factors such as medication use or intraoperative variables beyond anesthesia duration. Finally, the use of the Montreal Cognitive Assessment alone may not fully represent all cognitive domains affected by POCD. Future studies with larger, more diverse populations and longitudinal follow-up are recommended.

CONCLUSION

Postoperative cognitive dysfunction is a significant complication following coronary artery bypass graft surgery, particularly affecting memory and attention domains. Older age, lower educational levels, and pre-existing conditions like diabetes, stroke, and dementia increase the risk of POCD. Longer durations of anesthesia and surgery are strongly associated with worse cognitive outcomes. Postoperative complications such as delirium and prolonged hospitalization further exacerbate cognitive decline. Early identification of high-risk patients through comprehensive preoperative assessment is essential. Optimizing medical comorbidities and minimizing anesthesia duration may reduce POCD incidence. Attention to postoperative care and rehabilitation can improve cognitive recovery. Incorporating cognitive screening into routine surgical practice is recommended. Future research should focus on preventive strategies and long-term cognitive monitoring. Overall, improving perioperative management could enhance quality of life for CABG patients.

RECOMMENDATIONS

Based on the study findings, it is recommended to perform routine preoperative cognitive assessments for patients undergoing coronary artery bypass surgery, especially those with pre- existing conditions like diabetes, stroke, or dementia. Efforts should be made to manage these conditions effectively before surgery. Reducing the duration of anesthesia and surgery where possible may help minimize the risk of postoperative cognitive dysfunction (POCD). Healthcare providers should closely monitor cognitive function after surgery to detect early signs of POCD and intervene promptly. Patients should be encouraged to maintain a healthy lifestyle, including regular physical activity and smoking cessation, to support cognitive health. Training healthcare staff to recognize and manage POCD is essential for improving patient outcomes. Educating patients and their families about POCD risks and symptoms can aid in timely identification and care. Lastly, further research is needed to develop targeted prevention and treatment strategies for POCD in this patient population.

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