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Optic nerve sheath diameter and postoperative cognitive dysfunction after cardiac surgery: a prospective observational study

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ABSTRACT

Aims: This study aims to investigate the association between perioperative optic nerve sheath diameter (ONSD), a noninvasive marker of intracranial pressure, and the incidence of postoperative cognitive dysfunction (POCD) on postoperative days 8 and 30 in patients undergoing elective open-heart surgery with cardiopulmonary bypass.

Methods: It was designed as a prospective, observational, single-institution study conducted at a tertiary care hospital. Seventy-nine adult patients scheduled for elective open-heart surgery using cardiopulmonary bypass were included. Perioperative ONSD measurements were obtained at five predefined time points during the perioperative period. Cognitive function was assessed using the Mini-Mental State Examination (MMSE) preoperatively and on the 8^{th} and 30^{th} postoperative days. POCD was defined as a clinically significant decline in MMSE score based on the Reliable Change Index (RCI), using a test-retest reliability coefficient of 0.95. An RCI <−1.96 indicated POCD.

Results: On postoperative day-8, 44 patients (55.7%) developed POCD, and these patients had a significantly higher median age compared to those without POCD (70.0 vs. 66.0 years, p=0.002). By day-30, POCD persisted in only seven patients (8.9%). Lower preoperative cognitive reserve was also significantly associated with the development of POCD (p<0.05). No significant association was found between perioperative ONSD values and POCD on either postoperative day (p>0.05).

Conclusion: Perioperative ONSD was not significantly associated with the development of POCD on postoperative days 8 or 30 in patients undergoing elective open-heart surgery. Instead, preoperative cognitive reserve and older age emerged as stronger predictors of POCD, underscoring the importance of baseline cognitive assessment and patient characteristics in evaluating perioperative risk.

Keywords: Cardiac surgery, Mini-Mental State Examination, optic nerve sheath, postoperative cognitive dysfunction

INTRODUCTION

Decreased memory and impaired complex cognitive functions, including attention and decision-making, characterize postoperative cognitive dysfunction (POCD) following major surgical interventions performed under general anesthesia.[1,2] POCD remains a crucial clinical concern, particularly in high-risk surgical populations, as it delays recovery, prolongs hospitalization, and impairs long-term quality of life. Reported incidence and definitions of POCD vary significantly across studies, reflecting diagnostic heterogeneity and differences in neurocognitive assessment methods, underscoring the need for population-specific investigations. POCD is particularly prevalent following major cardiovascular surgery, where the brain is highly susceptible to ischemic injury and cerebral edema during cardiopulmonary bypass (CPB) and extracorporeal circulation.[2-6]

Surgical procedures, particularly laparoscopic and cranial operations, adversely affect cardiovascular hemodynamics, respiratory mechanics, and cerebrovascular perfusion,[1,7-10] leading to increased intracranial pressure (ICP) and intraocular pressure (IOP), contributing to POCD.[8-11] Accordingly, the potential relationship between ICP fluctuations and POCD has received increasing attention, emphasizing the need for perioperative cerebral monitoring.

Optic nerve sheath diameter (ONSD), measured using ocular ultrasonography (USG), is a recognized, noninvasive marker of ICP changes during surgical procedures.[1,7-9,12,13] Previous studies demonstrate strong correlation between USG-measured ONSD and direct ICP measures, including intraventricular and intraparenchymal pressures.[14] Notably, ONSD increase has been regarded as a surrogate of elevated ICP in elderly patients.[7,9] Since ICP fluctuations may

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compromise cerebral perfusion and oxygenation, thereby impairing cognitive processes, ONSD might serve as an indirect marker linking perioperative cerebral physiology with postoperative cognitive outcomes.[6]

Significant perioperative ONSD increases have been reported alongside higher POCD incidence after laparoscopic abdominal surgery.[1,7,8] In contrast, Zhang et al.[15] reported higher POCD incidence in patients with postoperative ONSD decrease following carotid endarterectomy, questioning its predictive value for POCD. These conflicting findings indicate the complexity of the relationship between ONSD dynamics and cognitive outcomes, particularly across different surgical populations.

Despite these findings, research on the use of ocular USG in cardiac surgery patients remains limited,[12,13,16] and its role in predicting POCD is poorly understood. As cardiac surgery is associated with postoperative cognitive decline, evaluating ONSD in this high-risk population may clarify whether ICP-related changes contribute independently to POCD development.

In this context, we evaluated the association between perioperative ONSD changes and POCD incidence in patients undergoing elective open-heart surgery using CPB on postoperative days -8 or -30, hypothesizing that perioperative ONSD alterations, as a noninvasive marker of ICP fluctuations, would predict POCD occurrence after cardiac surgery in this high-risk surgical population.

METHODS

Ethics

This prospective observational study was conducted in the cardiovascular surgery and anesthesiology departments of a university hospital between September 2024 and March 2025. The study protocol has been approved by the Pamukkale University Non-interventional Clinical Researches Ethics Committee (Date: 06.08.2024, Decision No: 14) and conducted in accordance with the ethical principles outlined in the Declaration of Helsinki. Written informed consent was taken from all patients included in the study.

Population and Sample

The study population involves adult patients aged 18 to 80 who underwent elective open-heart surgery using CPB. Patients' medical histories were obtained during the preoperative anesthesia consultation. In addition, face-to-face interviews were held with the patients and their families to obtain information about the patients' previous psychiatric consultations, current psychotropic medication use, and existing psychiatric complaints. Accordingly, acute cardiac surgery, eye surgery history, known eye disease, visual impairment, a history of stroke or transient ischemic attack, mental/psychiatric disorders, drug addiction, and any comorbidity that precludes neuropsychological testing were the exclusion criteria.[7,17] Patients' cognitive statuses were preliminarily evaluated during the initial interview, and those suspected of having POCD underwent a formal cognitive assessment before being included in the study. Subsequently, they were categorized based on whether they had developed POCD on the 8th and 30th postoperative days. Accordingly, the patients were divided into two groups at each time point, on postoperative day-8 and day-30: those who developed POCD [POCD (+)] and those who did not [POCD (-)].

Surgical Technique

A standardized anesthesia protocol was applied to all patients. Anesthesia induction was achieved using lidocaine HCl (1 mg/kg), fentanyl (5–15 µg/kg), midazolam (0.03–0.06 mg/kg), and propofol (0.5 mg/kg). Rocuronium (1 mg/kg) was administered as a muscle relaxant. Anesthesia was maintained with continuous infusions of rocuronium (5 µg/kg/min), remifentanil (0.05–0.2 µg/kg/min), and propofol (3–8 mg/kg/h). Hemodynamic stability was ensured by titrating dobutamine, dopamine, and norepinephrine infusions to maintain a target mean arterial pressure of 60–70 mmHg. Intraoperative hypertension and tachycardia were managed with glyceryl trinitrate (2–10 µg/kg/min) and esmolol (50–200 µg/kg/min) as needed.[6]

All patients underwent median sternotomy followed by standard CPB using a roller pump (Jostra Maquet HL20 Heart and Lung machine, HL20-486, Lund, Sweden) and a membrane oxygenator (Medtronic Affinity, Medtronic Inc., Minneapolis, USA). The CPB circuit perfusion flow was maintained at 50–80 ml/kg/min, with continuous monitoring of arterial blood gases, maintaining a pH range of 7.35–7.45 and an arterial oxygen saturation >95%. Myocardial protection was achieved with cold cardioplegia solution (Cardipassive cardioplegic solution for cardiac perfusion, Polifarma, Tekirdağ, Turkiye) administered via both antegrade and retrograde infusion, supplemented with local hypothermia. An initial dose of 200 ml cardioplegia solution was mixed with 800 ml of patient blood obtained from the pump. Two ampoules of potassium and one ampoule of sodium were added. This mixture was repeated every 20 minutes. The subsequent doses were a 500 cc solution consisting of 100 cc cardioplegia solution and 400 cc blood, with one ampule of potassium and one ampule of sodium. Continuous ultrafiltration was routinely employed. CPB was discontinued once stable circulation was achieved, and patients were weaned off bypass under hemodynamic guidance.[2]

Sample Size Analysis

Sample size calculation was performed using G*power 3.1.9.7 (Heinrich-Heine-Universität Düsseldorf, Germany). Based on the previously reported ONSD measurement in similar patient populations,[15] where significant differences in coronal ONSD changes were observed between patients with and without POCD (effect size d=0.625), we adopted a conservative approach for the cardiac surgery population. Considering the potential physiological differences between carotid endarterectomy and cardiac surgery with CPB, the effect size was maintained at d=0.625 for our power calculation. Using a one-tailed t-test for independent means comparison with 80% power (1-β=0.80), 5% type I error (α=0.05), and an allocation ratio of 1.25 based on expected group distributions, the minimum required sample size was determined to be 66 patients (29 patients without POCD, 37 patients with POCD).

To account for potential dropouts and ensure methodological robustness, 79 patients were included in the final analysis, providing adequate statistical power (actual power=0.80) for detecting clinically significant differences in perioperative ONSD measurements.

Post-hoc power analysis confirmed adequate statistical power (>80%) to detect clinically meaningful effect sizes (Cohen's d≥0.60). The consistently small observed effect sizes for ONSD differences (d=0.09-0.22) suggest limited clinical relevance, regardless of sample size considerations.

Data Collection

Patients' demographic (age and gender), anthropometric [body-mass index (BMI)], clinical (comorbidities), surgical (type of cardiac surgery), and perioperative (duration of surgery and aortic cross-clamping time) characteristics were prospectively recorded.

Cognitive and Pain Assessment

Patients' cognitive functions and pain levels were assessed by an experienced nurse using the MMSE and the numeric rating scale (NRS), respectively.[1] Pain severity was measured using the 11-point NRS, where 0 indicated "no pain" and 10 indicated "worst severe pain." Assessments were conducted at two time points: the 8th and 30th postoperative days. The MMSE, which assesses five domains (orientation, registration, memory, attention and calculation, recall, and language) was administered at three different time points: preoperatively on the day before surgery and the 8th and 30th postoperative days. The highest score that can be obtained from the 11-item MMSE is 30.[4,9] Validity studies of the Turkish version of the MMSE test were performed by Kucukdeveci et al.[18]

Ultrasonographic ONSD Assessment

At the operating room, standard perioperative monitoring, including electrocardiography, pulse oximetry, and noninvasive arterial blood pressure monitoring was used. ONSD measurements were performed by an anesthesiologist, with over ten years of clinical experience in USG, using a 10–5 MHz linear ultrasound probe (GE Healthcare Logiq e Series). To this end, a water-soluble sterile gel was applied over the closed upper eyelid with minimal pressure, and then ONSD was measured in the transverse and sagittal planes, 3 mm behind the optic disc, twice for each eye. The average of eight ONSD measurements was noted as the ONSD value.[7,15]

ONSD measurements were performed at the following time points:

- T0: Just before the anesthesia induction
- T1: 15 minutes after tracheal intubation
- T2: 5 minutes after initiation of CPB
- T3: During the hypothermic period during CPB
- T4: 30 minutes after CPB termination

Reliable Change Index (RCI) Calculation in Assessing Cognitive Decline

The RCI represents the standard error of the difference between two test scores and defines a confidence interval (CI) around the observed change in scores. The RCI values were calculated using a test-retest reliability coefficient of 0.95, along with an MMSE score, to determine clinically significant cognitive decline in patients. Accordingly, patients with an RCI value <-1.96, indicating a clinically significant cognitive decline that was shown by a decrease in MMSE score beyond the 95% CI for normal test-retest variation, were considered to have developed POCD.[19-22]

The following formula was used to calculate the RCI values:

- $RCI=(X_2 - X_1)/SE_{diff}$

X_2 represents the postoperative MMSE score, X_1 represents the preoperative MMSE score, and SE_{diff} represents the standard error of difference. The SE_{diff} was calculated using the following formula:

- $SE_{diff}=SD_1\times\sqrt{2}\times\sqrt{(1-r)}$

SD_1 is the standard deviation of preoperative MMSE scores, and r is the test-retest reliability coefficient (0.95).

Example RCI calculation: for a patient with a preoperative MMSE score of 27 and a postoperative day-8 score of 24, using the observed preoperative standard deviation (SD_1=4.62), the calculation proceeded as follows:

- $SE\_diff=SD_1\times\sqrt{2}\times\sqrt{(1-r)}$
- SE_diff=4.62×1.414×0.224
- SE_diff=1.46
- $RCI=(X_2-X_1)/SE\_diff$
- RCI=(24-27)/1.46
- RCI=-2.05

Since this RCI value of -2.05 is less than -1.96, the patient was classified as having developed POCD, as the cognitive decline exceeded the 95% CI for normal test-retest variation. Conversely, an RCI value greater than -1.96 would indicate no clinically meaningful cognitive change.

Statistical Analysis

The study's primary outcome was the POCD incidence on the 8th and 30th postoperative days, and the secondary outcomes were the relationships between ONSD values and the POCD development at these two points. Comparisons of perioperative ONSD changes over time were conducted separately for each postoperative day between patients who did and did not develop POCD to explore potential predictive thresholds and capture both early and evolving cognitive changes after cardiac surgery without assuming longitudinal continuity or mutual exclusivity between early and late POCD events. Subgroup analyses were planned to assess the influence of surgical duration and CPB parameters on ONSD trajectories.

Statistical analyses were performed using Jamovi project 2.3.28 (Jamovi, version 2.3.28.0, 2023, retrieved from https://www.jamovi.org) and JASP 0.19.2 (Jeffreys' Amazing Statistics Program, version 0.19.2, 2024, retrieved from https://jasp-stats.org) software packages. The normal distribution of the continuous variables was assessed using the Shapiro-Wilk test. The normally distributed continuous variables were expressed using mean±standard deviation and compared using an independent samples t-test. In contrast, the non-normally distributed continuous variables were expressed using median (minimum–maximum) and compared using the Mann-Whitney U test. Categorical variables were expressed using frequencies (n) and percentages (%) and compared using the chi-square or Fisher's exact test as appropriate. To address potential concerns regarding multiple comparisons, a post-hoc Bonferroni correction was applied to the primary analytic outcomes (k=5 comparisons: age difference, preoperative MMSE difference, postoperative day-8 MMSE difference, postoperative day-30 MMSE difference, and surgical procedure type distribution between POCD groups), with an adjusted significance threshold of α=0.01. Probability (p) statistics of ≤0.05 were deemed to indicate statistical significance.

RESULTS

Of the 79 patients in the sample, 44 (55.7%) developed POCD by the 8th postoperative day, and 7 (8.9%) developed POCD by the 30th postoperative day. On postoperative day-8, patients with POCD were significantly older than those without (70.0 vs. 66.0 years, p<0.01). Additionally, patients who underwent concurrent mitral and aortic valve replacement surgery had a significantly lower rate of POCD on the postoperative 8th day than those who did not (p<0.05). There was no difference between the groups in other demographic, anthropometric, clinical, or surgical characteristics, including the distribution of other types of cardiac surgeries (p>0.05) (**Table 1**).

There was also no difference between the groups in perioperative characteristics, including the duration of surgery and aortic cross-clamping time (p>0.05) (**Table 2**). Perioperative ONSD trajectories are illustrated in **Figure**. Visual inspection confirmed the absence of clinically meaningful differences in ONSD values measured at five different perioperative time points between POCD groups, with overlapping distributions and interquartile ranges at all measurement points (**Table 2, Figure**).

There was no difference in the distribution NRS pain scores' distribution measured on the 8th and 30th postoperative days between patients who developed POCD and those who did not (p>0.05) (**Table 3**). Contrarily, the median MMSE scores were significantly lower preoperatively and, on the 8th and 30th postoperative days in patients who developed POCD compared to those who did not (p=0.02, p<0.01, and p<0.01, respectively) (**Table 3**).

Bonferroni-corrected analysis (adjusted α=0.01, k=5 primary comparisons: age, preoperative MMSE, postoperative day-8 MMSE, postoperative day-30 MMSE, and surgical procedure type) confirmed the statistical robustness of age differences

Table 1. Demographic and clinical characteristics of patients stratified by postoperative cognitive dysfunction status

	Postoperative day-8			Postoperative day-30		
Variables	**POCD (+) (n=44)**	**POCD (-) (n=35)**	**p**	**POCD (+) (n=7)**	**POCD (-) (n=72)**	**p**
Age years §	70.0 (50.0–79.0)	66.0 (45.0–78.0)	<0.01*	69.0 (65.0–77.0)	69.0 (45.0–79.0)	0.428*
Sex ‡						
Female	14 (31.8)	16 (45.7)	0.303**	4 (57.1)	26 (36.1)	0.417**
Male	30 (68.2)	19 (54.3)		3 (42.9)	46 (63.9)	
Body-mass index kg/m² §	28.8 (19.5–45.4)	29.1 (19.7–36.3)	0.560*	29.0 (25.0–33.5)	28.8 (19.5–45.4)	0.836*
Comorbidities ‡	41 (93.2)	32 (91.4)	0.999**	6 (85.7)	67 (93.1)	0.438**
Specific comorbidities ‡						
Hypertension	27 (61.4)	20 (57.1)	0.882**	4 (57.1)	43 (59.7)	0.999**
Diabetes mellitus	5 (11.4)	10 (28.6)	0.099**	0 (0.0)	15 (20.8)	0.336**
Chronic obstructive pulmonary disease	10 (22.7)	13 (37.1)	0.249**	3 (42.9)	20 (27.8)	0.409**
Hyperlipidemia	7 (15.9)	3 (8.6)	0.499**	0 (0.0)	10 (13.9)	0.586**
Cardiac surgical procedures ‡						
Coronary artery bypass grafting	33 (75.0)[a]	20 (57.1)[a]	<0.05**	5 (71.4)	48 (66.7)	0.432**
Mitral valve replacement	5 (11.4)[a]	2 (5.7)[a]		1 (14.3)	6 (8.3)	
Mitral+aortic valve replacement	2 (4.5)[a]	10 (28.6)[b]		0 (0.0)	12 (16.7)	
Replacement of the ascending aorta	2 (4.5)[a]	0 (0.0)[a]		0 (0.0)	2 (2.8)	
Tricuspid annuloplasty+mitral valve replacement	0 (0.0)[a]	2 (5.7)[a]		0 (0.0)	2 (2.8)	
Coronary artery bypass grafting+mitral valve replacement	2 (4.5)[a]	1 (2.9)[a]		1 (14.3)	2 (2.8)	

‡: n (%), categorical variables presented as frequency and percentage §: Median (minimum–maximum), continuous variables presented as median and range *: Mann-Whitney U test applied for non-parametric continuous variables **: Pearson Chi-Square test or Fisher's Exact/Fisher-Freeman-Halton test applied for categorical variables [a-b]: Different superscript letters within the same row indicate statistically significant differences between groups Bold p-values indicate statistical significance (p≤0.05). Abbreviations: POCD: Postoperative cognitive dysfunction

Table 2. Perioperative characteristics and optic nerve sheath diameter measurements

Variables §	Postoperative day-8			Postoperative day-30		
	POCD (+) (n=44)	**POCD (-) (n=35)**	**p**	**POCD (+) (n=7)**	**POCD (-) (n=72)**	**p**
Operative duration minutes	130.0 (66.0-313.0)	148.0 (84.0-310.0)	0.13	127.0 (99.0-212.0)	140.0 (66.0-313.0)	0.40
Aortic cross-clamping time minutes	77.5 (44.0-192.0)	83.0 (52.0-192.0)	0.18	74.0 (60.0-131.0)	82.0 (44.0-192.0)	0.66
Optic nerve sheath diameter cm						
Pre-induction (T0)	0.51 (0.36-0.58)	0.53 (0.44-0.59)	0.26	0.52 (0.36-0.59)	0.55 (0.50-0.55)	0.43
Post-intubation 15th minute (T1)	0.57 (0.40-0.70)	0.59 (0.46-0.70)	0.21	0.59 (0.40-0.70)	0.59 (0.55-0.63)	0.76
Cardiopulmonary bypass initiation 5th minute (T2)	0.56 (0.38-0.69)	0.59 (0.46-0.70)	0.09	0.58 (0.38-0.70)	0.58 (0.53-0.63)	0.85
Hypothermic cardiopulmonary bypass period (T3)	0.55 (0.36-0.65)	0.58 (0.45-0.65)	0.12	0.56 (0.36-0.65)	0.56 (0.52-0.60)	0.80
Post-cardiopulmonary bypass 30th minute (T4)	0.56 (0.42-0.66)	0.58 (0.46-0.66)	0.11	0.57 (0.42-0.66)	0.56 (0.53-0.62)	0.92

§: Median (minimum-maximum), continuous variables presented as median and range *: Mann-Whitney U test applied for non-parametric continuous variables T0-T4: Perioperative measurement time points for optic nerve sheath diameter assessment. Bold p-values indicate statistical significance (p≤0.05). Abbreviations: POCD: Postoperative cognitive dysfunction, T0: Pre-anesthetic induction, T1: 15 minutes post-intubation, T2: 5 minutes after cardiopulmonary bypass initiation, T3: Hypothermic period during cardiopulmonary bypass, T4: 30 minutes post-cardiopulmonary bypass

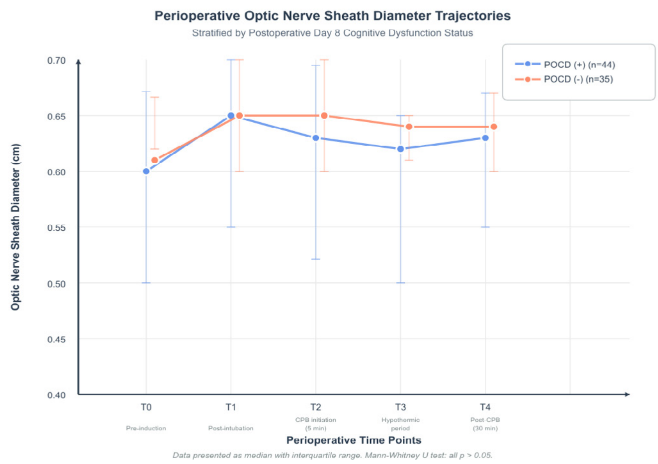

Figure. Perioperative trajectories of optic nerve sheath diameter across measurement time points, stratified by postoperative day-8 cognitive dysfunction status. Data presented as median with interquartile range (error bars). T0: pre-anesthetic induction; T1: 15 minutes post-intubation; T2: 5 minutes after cardiopulmonary bypass (CPB) initiation; T3: hypothermic period during CPB; T4: 30 minutes post-CPB termination. Blue circles represent patients who developed postoperative cognitive dysfunction (POCD+, n=44); orange circles represent patients without POCD (POCD-, n=35). Mann-Whitney U test revealed no statistically significant differences between groups at any time point (all p>0.05).
POCD: Postoperative cognitive dysfunction

between POCD groups (p=0.002) and postoperative MMSE score differences at both time points (p<0.01). The preoperative MMSE association (p=0.02) approached but did not reach adjusted significance, though the observed effect size (d=0.857) remained consistent with established cognitive reserve literature. The surgical procedure type distribution (p<0.05) also did not reach the adjusted significance threshold.

Post-hoc power analysis confirmed that our study achieved 96.2% statistical power (1-β=0.962) for detecting cognitive differences based on the observed preoperative MMSE score variations (effect size, d=0.857).

DISCUSSION

Our findings suggested that POCD development following cardiac surgery was not associated with perioperative ONSD. POCD after cardiac surgery was transient, with incidence decreasing over follow-up. Although heterogeneity in patient and surgical characteristics may have limited detection of associations, the absence of link between ONSD and POCD suggests that other factors, such as preoperative cognitive status and systemic inflammatory responses, rather than

Table 3. Clinical outcomes and cognitive assessment results

Variables	Postoperative day-8			Postoperative day-30		
	POCD (+) (n=44)	**POCD (-) (n=35)**	**p**	**POCD (+) (n=7)**	**POCD (-) (n=72)**	**p**
Postoperative day-8 pain score NRS ‡						
0	38 (86.4)	33 (94.3)		6 (85.7)	65 (90.3)	
3	3 (6.8)	1 (2.9)	0.63**	0 (0.0)	4 (5.6)	0.55**
4	3 (6.8)	1 (2.9)		1 (14.3)	3 (4.2)	
Postoperative day-30 pain score NRS ‡						
0	43 (97.7)	34 (97.1)		7 (100.0)	70 (97.2)	
3	0 (0.0)	1 (2.9)	0.69**	0 (0.0)	1 (1.4)	0.99**
4	1 (2.3)	0 (0.0)		0 (0.0)	1 (1.4)	
Cognitive assessment scores MMSE§						
Preoperative	25.0 (16.0-30.0)	28.0 (16.0-30.0)	<0.01*	24.0 (16.0-28.0)	26.0 (16.0-30.0)	0.29*
Postoperative day-8	21.0 (12.0-27.0)	26.0 (14.0-30.0)	<0.01*	20.0 (12.0-24.0)	22.0 (13.0-30.0)	0.19*
Postoperative day-30	23.0 (13.0-29.0)	28.0 (14.0-30.0)	<0.01*	21.0 (13.0-25.0)	25.0 (14.0-30.0)	0.07*

‡: n (%), categorical variables presented as frequency and percentage §: Median (minimum-maximum), continuous variables presented as median and range *: Mann-Whitney U test applied for non-parametric continuous variables **: Pearson Chi-square test or Fisher's Exact/Fisher-Freeman-Halton test applied for categorical variables Bold p-values indicate statistical significance (p≤0.05). Abbreviations: POCD: Postoperative cognitive dysfunction, NRS: Numeric rating scale (0-10), MMSE: Mini-Mental State Examination (0-30 points)

ONSD, may have played a more critical role in POCD. Thus, perioperative ONSD alterations alone may not fully capture the complex cerebral physiological changes occurring during and after cardiac surgery.

Studies have reported inconsistent POCD incidence after cardiac surgery. Rahman et al.[23] reported no POCD after elective coronary artery bypass graft surgery, whereas others found around 25% POCD after major cardiac surgery. Moreover, most studies overlook PCOD's persistence or progression in the subacute postoperative phase which is crucial to obtain a more comprehensive understanding of the disease. For instance, one report shows 20.2% POCD incidence at discharge decreases to 6.9% six-weeks after cardiac bypass surgery.[24] Similarly, Zhao et al.[2] reported 5.17% and 27.27% POCD incidence in patients undergoing cardiac surgery, at the 24th and 72nd postoperative-hours, respectively, depending on the type of anesthesia. Discrepancies between POCD incidence studies following cardiac surgery have been attributed to differences in diagnostic criteria, neurocognitive assessment methodologies, and postoperative follow-up periods.[4,19,25] Our findings, showing a decline from 55.7% on day 8 to 8.9% on day 30, emphasize the transient nature of POCD and suggest reversible neuronal dysfunction as a predominant mechanism.[9] This temporal pattern also implies that early postoperative cognitive impairment may be more closely related to transient perioperative physiological disturbances rather than sustained elevations in ICP.

Zhang et al.[15] reported a significant correlation between decreased coronal ONSD and increased POCD risk in patients undergoing carotid endarterectomy, suggesting that hyperperfusion-induced POCD may be involved. However, they found no difference in sagittal ONSD between patients with and without POCD. On the contrary, here, where we measured ONSD in both transverse and sagittal planes and reported a single averaged-value, we did not find a correlation between ONSD and POCD. This may reflect that CPB triggers mechanisms (ie. microembolization, global perfusion alterations, temperature shifts, systemic inflammation) affect neurocognition independently of ICP. Microembolic load and hypoperfusion can cause subtle ischemic injury without elevating ICP, limiting the predictive utility of ONSD.

Several studies have used predetermined ONSD cut-off values for patient categorization. Song et al.[9] used >5.00 mm and ≤4.00 mm in older adults undergoing rectal cancer surgery, reporting lower MMSE scores in patients with increased ONSD. However, despite substantial cerebral perfusion changes during CPB, we did not observe any significant changes in the perioperative ONSD of patients undergoing cardiac surgery, supporting the notion that POCD may be driven predominantly by non-ICP mechanisms. Limitations of ONSD measurements, including timing, anesthesia effects, and transient fluctuations, further reduce its predictive ability.[26,27]

In a rare study on cardiac surgery, Mermer et al.[12] reported that ONSD correlated with extracorporeal support, cross-clamping, and surgery duration in newborns, suggesting it may predict extracorporeal life support duration. Similarly, Rivas-Rangel et al.[28] found a significant positive correlation between the duration of extracorporeal life support and ONSD in children undergoing cardiac surgery, with values returned to normal 24 hours after surgery. Nevertheless, perioperative measurement is challenging due to sterility, positioning, and intraoperative fluctuations, highlighting the limited practical utility of ONSD monitoring in adult cardiac surgery.

A study comparing baseline and 72nd postoperative hour values associated ONSD changes after cardiac surgery with variations in volume status. Additionally, Wakimoto et al.[13] found that Fontan patients were more likely to have increased ONSD values, suggesting that prolongation of surgery may increase ICP by placing additional stress on cerebral circulation, which in turn may cause higher ONSD values. However, these associations may not reflect neurocognitive outcomes, underscoring the multifactorial and dynamic nature of POCD pathophysiology in cardiac surgery. Further research is needed to clarify the clinical utility of ONSD in predicting neurocognitive outcomes in patients undergoing cardiac surgery.

We found advanced age and lower preoperative cognitive function as significant risk factors for POCD, consistent with literature indicating that baseline cognitive reserve is crucial to postoperative cognitive resilience.[23,24] Several studies reported that elderly patients with pre-existing cognitive limitations are particularly vulnerable to the neurological stressors of cardiac surgery, including microembolization, hypoperfusion, and inflammatory cascades.[19,21-23] Taken together, these findings suggest that ONSD alone cannot capture the multifactorial etiology of POCD. Clinically, our results underscore that early POCD remains frequent after cardiac surgery, even when ONSD changes are absent, highlighting the importance of preoperative cognitive screening in identify high-risk patients. Implementing targeted neuroprotective strategies, optimizing perioperative management, and providing early cognitive support may therefore be more relevant for patient outcomes than relying solely on ONSD monitoring. Future studies should use multimodal neuromonitoring in larger cohorts with multicenter design and longer follow-up to better understand POCD mechanisms and predictors.

There is a notable variation in POCD incidence between postoperative days -8 and -30, which may be explained by several factors. First, our homogenous study population introduces a substantial variability in surgical complexity and duration which may have led to differences in perioperative physiological stress and recovery trajectories, influencing the timing and extent of cognitive changes. Second, the observed reduction in POCD rates at day-30 may reflect a learning effect due to repeated neurocognitive testing, as patients may perform better on the second assessment regardless of proper cognitive recovery. Finally, although we used validated cognitive assessment tools, test–retest reliability and methodological factors, including patient fatigue, perioperative fluctuations, or attrition of cognitively vulnerable patients between assessments, may have also affected the observed incidence. These factors should be considered when interpreting the temporal changes in POCD prevalence. Nevertheless, the observed high POCD incidence in the early period and its subsequent rapid resolution highlight a clinically relevant phenomenon that warrants further investigation. Future prospective studies with standardized neurocognitive assessments and detailed perioperative data would clarify the underlying mechanisms and clinical significance of these temporal patterns.

Limitations

Several limitations should be considered when interpreting current findings. Its single-center design and modest sample size, particularly the small POCD subgroup at day-30, reduce statistical power. Our POCD assessment, which relied exclusively on the MMSE as a validated and widely used tool for efficient assessment of global cognitive function in the perioperative setting, may lack sensitivity for detecting subtle, domain-specific deficits such as executive dysfunction, which are often affected after cardiac surgery. A comprehensive neuropsychological test battery or additional tools such as the Montreal Cognitive Assessment (MoCA) may have provided a more nuanced evaluation of domain-specific cognitive impairments. However, the robustness of our findings is strengthened applying RCI method, which detects meaningful intra-individual change while accounting for measurement error, practice effects, and regression to the mean. By adopting a 95% CI threshold (±1.96), we focused on changes unlikely to occur by chance. This method, validated in population-based studies,[29] has shown that small changes in MMSE scores—often within 2–3 points—are common in cognitively normal individuals and should not be automatically interpreted as a clinically meaningful decline. Therefore, our statistically grounded definition of POCD enhances the reliability of outcome classification and facilitates comparison with studies using similar statistical frameworks. Nevertheless, future studies should incorporate broader cognitive assessment tools to capture subtle and multidimensional postoperative cognitive changes better without restrictions to detect domain-specific cognitive impairments and to provide a more detailed characterization of POCD. Although ONSD measurement by USG is a recognized noninvasive method for estimating ICP, the fact that its accuracy depends on factors like the operator's skill, the timing of measurements, and patient positioning constitutes another limitation. Despite using a standardized protocol, our fixed perioperative intervals may have missed transient ICP changes relevant to POCD. Moreover, while statistically rigorous, defining POCD via RCI with 95% CI may have identified changes of limited clinical relevance. Furthermore, our study lacks data on patients' educational levels, a known determinant of cognitive reserve, which may have influenced the interpretation of our findings, as higher educational attainment is often associated with greater resilience to postoperative cognitive decline. Since this variable could have confounded the observed associations between ONSD and POCD, future studies should incorporate detailed educational and cognitive baseline assessments to better account for this important factor. Our follow-up period constitutes another limitation, as other studies have shown that longer follow-up may reveal different patterns of cognitive recovery or decline. Additionally, we did not assess inflammatory biomarkers such as CRP or cytokines, which could have provided insight into perioperative inflammatory cascades linked to cognitive outcomes. This was due to the practical challenges of repeated sampling at all predefined perioperative time points (T0–T4), and a single preoperative or intraoperative measurements would not have accurately captured the dynamic inflammatory response. Finally, although we controlled for key factors, other factors such as age, differences in the types of surgeries patients had undergone, their pre-existing cerebrovascular diseases, genetic predispositions, or perioperative physiological fluctuations may have confounded our findings. Notably, the inclusion of heterogeneous cardiac surgical procedures (CABG, valve replacements, and combined procedures) rather than focusing on a single procedure type, such as isolated CABG, may have introduced variability in our results. However, this approach was intentional as we hypothesized that CPB-related perfusion changes would be the primary determinant of cognitive outcomes.

CONCLUSION

As a result, our findings suggest that perioperative ONSD was not significantly associated with the development of POCD in patients undergoing cardiac surgery, highlighting that ONSD is not a reliable predictor of POCD in this setting. Routine preoperative cognitive assessment should therefore be prioritized to identify patients at higher risk. The high prevalence of POCD in the early postoperative period emphasizes the need for vigilant monitoring and potential interventions during this critical phase, even though most cases resolve over time. This transient but significant cognitive dysfunction may have substantial implications for early postoperative care, rehabilitation planning, and patient education. Further research is needed to explore additional predictive markers and develop targeted interventions to mitigate cognitive decline in this patient population.

ETHICAL DECLARATIONS

Ethics Committee Approval

The study protocol has been approved by the Pamukkale University Non-interventional Clinical Researches Ethics Committee (Date: 06.08.2024, Decision No: 14).

Informed Consent

All patients signed and free and informed consent form.

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Financial Disclosure

The authors declared that this study has received no financial support.

Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

REFERENCES

1. Karaca U, Onur T, Okmen K, Terkanlloglu S, Çevik G, Ata F. Effect of various modes of mechanical ventilation in laparoscopic cholecystectomies on optic nerve sheath diameter and cognitive functions. *J Laparoendosc Adv Surg Tech A*. 2021;31(7):808-813. doi:10.1089/LAP.2020.0866
2. Zhao N, Qin R, Liu B, Zhang D. Sevoflurane versus propofol on immediate postoperative cognitive dysfunction in patients undergoing cardiac surgery under cardiopulmonary bypass: a comparative analysis. *J Cardiothorac Surg*. 2025;20(1):54. doi:10.1186/S13019-024-03327-0
3. Zhao A, Peng Y, Lin L, Chen L, Lin Y. Predictive value of preoperative hypersensitive C-reactive protein in the incidence of postoperative cognitive impairment in valvular disease patients: a retrospective study. *J Inflamm Res*. 2024;17:11729-11739. doi:10.2147/JIR.S499836
4. Borulu F, Erkut B. Comparison of the effect of pump flow type (pulsatile or non-pulsatile) on postoperative neurocognitive functions in coronary artery surgery. *Braz J Cardiovasc Surg*. 2024;39(5):e20230345. doi:10.21470/1678-9741-2023-0345
5. Hu YN, Hsieh TH, Tsai MT, et al. Cognitive function deterioration after cardiopulmonary bypass: can intraoperative optimal cerebral regional tissue oxygen saturation predict postoperative cognitive function? *J Cardiothorac Vasc Anesth*. 2023;37(5):715-723. doi:10.1053/J.JVCA.2023.01.025
6. Kaynar A, Kömürcü Ö, Bahşi E, et al. Optic nerve sheath diameter is associated with postoperative delirium in patients undergoing open heart surgery. *BMC Anesthesiol*. 2025;25(1):309. doi:10.1186/S12871-025-03194-9
7. Chen K, Wang L, Wang Q, et al. Effects of pneumoperitoneum and steep Trendelenburg position on cerebral hemodynamics during robotic-assisted laparoscopic radical prostatectomy: a randomized controlled study. *Medicine (United States)*. 2019;98(21):e15794. doi:10.1097/MD.0000000000015794
8. Bang YJ, Jeong H, Heo BY, et al. Effects of increased optic nerve sheath diameter on inadequate emergence from anesthesia in patients undergoing robot-assisted laparoscopic prostatectomy: a prospective observational study. *Diagnostics*. 2021;11(12):2260. doi:10.3390/DIAGNOSTICS11122260
9. Song B, Li LP, Wang XL, Guo Y, Li J. Relationship between intracranial pressure and neurocognitive function among older adults after radical resection of rectal cancer. *World J Gastrointest Surg*. 2024;16(10):3261-3268. doi:10.4240/WJGS.V16.I10.3261
10. Yang B, Li M, Liang J, Tang X, Chen Q. Effect of internal jugular vein catheterization on intracranial pressure and postoperative cognitive function in patients undergoing robot-assisted laparoscopic surgery. *Front Med (Lausanne)*. 2023;10:1199931. doi:10.3389/FMED.2023.1199931
11. Awad H, Bai M, Ramadan ME, et al. The effect of increased intraocular pressure during steep Trendelenburg positioning in robotic prostatectomy and hysterectomy on structural and functional ocular parameters. *Anesth Analg*. 2020;130(4):975-982. doi:10.1213/ANE.0000000000004547
12. Mermer A, Aydoğan E, Celep A, et al. Evaluation of the association between the optic nerve sheath diameter and extracorporeal life support time during cardiac surgery in newborns. *Eur Rev Med Pharmacol Sci*. 2023;27(15):7058-7064. doi:10.26355/EURREV_202308_33278
13. Wakimoto M, Patrick J, Yamaguchi Y, Roth C, Corridore M, Tobias J. Optic nerve ultrasound and cardiopulmonary bypass: a pilot study. *Saudi J Anaesth*. 2022;16(2):188-193. doi:10.4103/SJA.SJA_14_22
14. Zhang X, Medow JE, Iskandar BJ, et al. Invasive and noninvasive means of measuring intracranial pressure: a review. *Physiol Meas*. 2017;38(8):R143-R182. doi:10.1088/1361-6579/AA7256
15. Zhang LM, Li Y, Zhang YT, Zhang BX, Wang JZ, Zhang DX. Decrease of coronal optic nerve sheath diameter is associated with postoperative cognitive decline in patients undergoing carotid endarterectomy. *J Cardiothorac Vasc Anesth*. 2021;35(8):2355-2362. doi:10.1053/J.JVCA.2020.11.006
16. Chen H, Wang XT, Ding X, et al. The correlation between optic nerve sheath diameter and volume status in patients after cardiac surgery. *Zhonghua Nei Ke Za Zhi*. 2016;55(10):779-783. doi:10.3760/CMA.J.ISSN.0578-1426.2016.10.011
17. Yang Q, Li C, Ye M, Zhou X, Li W, Li F. Effect of central sensitization on postoperative cognitive dysfunction in total knee arthroplasty patients: a retrospective study. *Front Neurol*. 2025;15:1509197. doi:10.3389/FNEUR.2024.1509197
18. Kücükdeveci AA, Kutlay S, Elhan AH, Tennant A. Preliminary study to evaluate the validity of the mini-mental state examination in a normal population in Turkey. *Int J Rehabil Res*. 2005;28(1):77-79. doi:10.1097/00004356-200503000-00011
19. Sauër AC, Veldhuijzen DS, Ottens TH, Slooter AJC, Kalkman CJ, Van Dijk D. Association between delirium and cognitive change after cardiac surgery. *Br J Anaesth*. 2017;119(2):308-315. doi:10.1093/BJA/AEX053
20. Van Sinderen K, Schwarte LA, Schober P. Diagnostic criteria of postoperative cognitive dysfunction: a focused systematic review. *Anesthesiol Res Pract*. 2020;2020:7384394. doi:10.1155/2020/7384394
21. Zhao Q, Wan H, Pan H, Xu Y. Postoperative cognitive dysfunction—current research progress. *Front Behav Neurosci*. 2024;18:1328790. doi:10.3389/FNBEH.2024.1328790/PDF
22. Frerichs RJ, Tuokko HA. A comparison of methods for measuring cognitive change in older adults. *Arch Clin Neuropsychol*. 2005;20(3):321-333. doi:10.1016/J.ACN.2004.08.002
23. Rahman SH, Mazlan M, Suhaimi A, Hashim NHM. Identifying postoperative cognitive dysfunction after elective coronary artery bypass graft surgery in a tertiary centre in Malaysia. *Med J Malaysia*. 2024;79(4):483-486.
24. Abu Yazit NA, Juliana N, Hafidz KM, et al. Exploring cognitive changes in high-risk cardiac patients receiving dexmedetomidine and evaluating the correlation between different cognitive tools: a cohort study. *Rev Cardiovasc Med*. 2024;25(8):273. doi:10.31083/J.RCM2508273
25. Othman SMA, Aziz MAA, Sriwayyapram C, Xu Q. Systematic literature review on early detection of postoperative delirium in adult patients after cardiac surgery. *J Cardiothorac Surg*. 2024;19(1):1-10. doi:10.1186/S13019-024-03173-0/TABLES/4
26. Stevens RRF, Gommer ED, Aries MJH, et al. Optic nerve sheath diameter assessment by neurosonology: a review of methodologic discrepancies. *J Neuroimag*. 2021;31(5):814-825. doi:10.1111/JON.12906
27. Schroeder C, Katsanos AH, Richter D, Tsivgoulis G, Gold R, Krogias C. Quantification of optic nerve and sheath diameter by transorbital sonography: a systematic review and metanalysis. *J Neuroimag*. 2020;30(2):165-174. doi:10.1111/JON.12691
28. Rivas-Rangel J, García-Arellano M, Marquez-Romero JM. Correlation between optic nerve sheath diameter and extracorporeal life support time. *An Pediatr (Engl Ed)*. 2022;96(2):91-96. doi:10.1016/J.ANPEDE.2021.02.002
29. Hensel A, Angermeyer MC, Riedel-Heller SG. Measuring cognitive change in older adults: reliable change indices for the Mini-Mental State Examination. *J Neurol Neurosurg Psychiatry*. 2007;78(12):1298-1303. doi:10.1136/JNNP.2006.109074