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ORIGINAL ARTICLE

Correlation of Postoperative Cerebral Oxygen Saturation and Duration of Intensive Care Unit Stay Following Heart Valve Surgery

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Abstract

Background: Postoperative neurological complications and prolonged recovery are key concerns in heart valve surgery, and monitoring regional cerebral oxygen saturation ($rScO_2$) using Near–Infrared Spectroscopy (NIRS) offers a non–invasive way to assess cerebral oxygenation. This study aimed to evaluate the relationship between perioperative $rScO_2$ and ICU length of stay and its potential clinical significance.

Methods: A cross–sectional, observational, analytic study was conducted in 48 patients undergoing heart valve surgery at Haji Adam Malik General Hospital, Medan. Regional cerebral oxygen saturation was measured at three time points: preoperative (T0), immediately postoperative (T1), and 8 hours post–extubation (T2).

Results: Spearman correlation analysis revealed a significant negative relationship between right $rScO_2$ at T1 and ICU length of stay ($r=-0.406$; $p=0.034$), and similarly, left $rScO_2$ at T1 ($r=-0.343$; $p=0.017$), indicating that lower postoperative cerebral oxygenation correlates with longer ICU stays, emphasizing its potential clinical relevance.

Discussion: These findings suggest that the immediate postoperative period may represent a critical window in which cerebral oxygenation reflects hemodynamic stability and early recovery trajectory. However, interpretation should be cautious due to the cross–sectional design, small sample size, and lack of adjustment for potential confounders, limiting causal inference.

Conclusion: Lower immediate postoperative $rScO_2$ is associated with prolonged ICU length of stay, suggesting its potential role as an early indicator of recovery trajectory, although causal interpretation remains limited.

Keywords: Cerebral oxygen saturation; heart valve surgery; ICU length of stay; near-infrared spectroscopy

Introduction

Heart valve surgery is associated with significant hemodynamic changes that increase the risk of central nervous system complications, ranging from cerebral infarction to cognitive dysfunction. These neurological injuries are known to increase mortality and prolong the length of stay in the Intensive Care Unit (ICU).[1,2] The brain is highly sensitive to hypoxia; therefore, maintaining adequate oxygenation is essential for optimal recovery. Notably, the incidence of cerebral injury is reported to be higher in valve surgery compared to coronary artery bypass grafting, necessitating more stringent postoperative

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monitoring.[3,4]

Near–Infrared spectroscopy (NIRS) has been widely used as a non–invasive method to monitor regional cerebral oxygen saturation ($rScO_2$). Unlike systemic parameters, NIRS provides real–time information on cerebral tissue oxygenation and may serve as an early indicator of hemodynamic instability.[5] Although the role of intraoperative NIRS monitoring has been extensively studied, its clinical significance in the postoperative period remains less clearly defined. Limited evidence exists regarding whether early postoperative cerebral oxygen desaturation is associated with clinically relevant outcomes, such as ICU length of stay.

This knowledge gap is important, as the immediate postoperative period represents a critical phase of physiological transition, during which undetectedad cerebral hypoxia may contribute to delayed recovery. However, most existing studies have focused primarily on intraoperative monitoring, with relatively few addressing the prognostic value of postoperative $rScO_2$ measurements for ICU–related outcomes. Recent evidence suggests that decreased $rScO_2$ is associated with adverse outcomes, including prolonged ICU stay and increased morbidity, yet data specifically evaluating early postoperative measurements remain limited and inconsistent.[6]

Therefore, this study aims to evaluate the relationship between postoperative cerebral oxygen saturation measured by NIRS ($rScO_2$) and ICU length of stay in patients undergoing heart valve surgery. Identifying this association may help improve risk stratification and guide postoperative management strategies.[7]

Subjects and Methods

This study used a cross–sectional, observational design to assess the correlation between perioperative cerebral oxygen saturation ($rScO_2$) and ICU length of stay. The study was conducted at the Intensive Care Unit (ICU) of Haji Adam Malik General Hospital, Medan, Indonesia, from March to April 2024. The protocol was approved by the Health Research Ethics Committee of Universitas Sumatera Utara (No. 160/KEPK/USU/2024). Written informed consent was obtained from all patients or their legal surrogates before enrolment.

The study population consisted of adult patients (aged 18–64 years) undergoing elective heart valve surgery. A total of 48 patients were enrolled by consecutive sampling during the study period at a single tertiary referral centre. Exclusion criteria included patients with a history of neurological disorders (stroke or transient ischemic attack), non–cardiac surgery, severe pulmonary disease, chronic heart failure, liver failure, history of thromboembolism, myocardial infarction, endocarditis, and alcohol abuse. Patients with a baseline cerebral oxygen saturation (StO_2) of <60% were also excluded to rule out pre–existing cerebral desaturation.

Demographic and clinical data, including age, sex, body mass index (BMI), heart rate, and mean arterial pressure (MAP), were extracted from medical records. Cerebral oxygen saturation ($rScO_2$) was monitored non–invasively using Near–Infrared Spectroscopy (NIRS). Cerebral oxygen saturation ($rScO_2$) was monitored non–invasively using a commercially available Near–Infrared Spectroscopy (NIRS) device (manufacturer and model). The device was applied and calibrated according to the manufacturer's instructions before measurement to ensure signal accuracy and consistency. Bilateral cerebral sensors were applied to the patient's forehead. Measurements were recorded at three specific time points:

T0 (Preoperative): baseline measurement before the induction of anesthesia.
T1 (Immediate Postoperative): measurement taken immediately upon admission to the ICU after surgery. T2 (Post–extubation): Measurement taken 8 hours after the patient was extubated.

The timing of extubation was determined based on standard ICU clinical criteria, including hemodynamic stability, adequate oxygenation, and sufficient level of

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consciousness, as assessed by the attending intensivist.
The primary outcome was ICU length of stay, defined as the number of days from ICU admission to ward discharge. Perioperative management, including anesthesia technique and cardiopulmonary bypass (CPB), was conducted according to institutional standard protocols. However, specific intraoperative variables such as anesthetic agents, CPB duration, temperature management, and perfusion strategies were not standardized or analyzed in this study.

Data were coded, tabulated, and analysed using SPSS software version 22.0 (IBM Corp., Armonk, NY, USA). The normality of the data distribution was assessed using the Shapiro–Wilk test. Continuous variables were presented as mean, standard deviation or median (interquartile range), as appropriate. Due to non–normal distribution, Spearman's rank correlation was used to assess the relationship between $rScO_2$ and ICU length of stay. No a priori sample size calculation or statistical power analysis was performed. In addition, the analysis was limited to bivariate correlation without adjustment for potential confounders such as age, comorbidities, surgical complexity, or cardiopulmonary bypass duration. Therefore, the findings should be interpreted with caution, and no causal or prognostic inference can be definitively established. A p–value of <0.05 was considered statistically significant.

Results

A total of 48 patients who underwent heart valve surgery at Haji Adam Malik General Hospital were included in this study.

Table 1 Characteristics of the Study Participants

Characteristics	Data
Age (years)	
Mean±SD	46.48±14.84
Median	51
Min-max	18–64
Sex	
Male	28 (58.3%)
Female	20 (41.7%)
Height (cm)	
Mean±SD	157.85±5.34
Median	158
Min-max	143–167
Weight (kg)	
Mean±SD	54.54±7.08
Median	53
Min-max	45–71
BMI	
Mean±SD	21.94±3.07
Median	21.63
Min-max	16.9–29.17

Note: Height=body height; Weight=body weight; BMI=body mass index

Table 2 Hemodynamic Data

Hemodynamic Parameters	Data	p-value[a]
HR		
T0	78.88±14.96	
T1	74.15±13.05	<0.001
T2	75.21±13.77	
TDS		
T0	123.04±12.89	
T1	119.15±16.12	0.119
T2	116.52±18.04	
TDD		
T0	79.33±8.61	
T1	75.98±11.83	0.085
T2	75.25±8.62	
RR		
T0	19.33±2.08	
T1	19.56±2.18	0.305
T2	19.42±1.29	
SpO_2		
T0	96.77±1.39	
T1	96.77±1.22	0.268
T2	97.17±1.14	

Note: [a]Friedman test. HR=heart rate; SBP=systolic blood pressure; DBP=diastolic blood pressure; RR=respiratory rate T0=preoperative; T1=postoperative; T2=8 hours after extubation

The baseline characteristics of the study participants are presented in Table 1. The mean age was 46.48±14.84 years, with a predominance of male patients (58.3%). The mean body mass index (BMI) was 21.94±3.07 kg/m^2.

Hemodynamic parameters were assessed at three time points: preoperative (T0), immediately postoperative (T1), and 8 hours post–extubation (T2). As shown in Table 2, the Friedman test demonstrated a significant difference in heart rate across the measurement times ($p<0.001$).

In contrast, no significant differences were observed in systolic blood pressure, diastolic blood pressure, respiratory rate, or peripheral oxygen saturation (SpO_2) ($p>0.05$).The length of ICU stay was recorded for all patients. The mean ICU length of stay was 5.41±4.50 days, ranging from 1 to 19 days.

Regional cerebral oxygen saturation ($rScO_2$) was measured bilaterally. As shown in Table 3, the descriptive statistics indicate that mean $rScO_2$ values in both hemispheres increased from the preoperative period (T0) to 8 hours post-extubation (T2).

The primary objective of this study was to assess the relationship between regional cerebral oxygen saturation ($rScO_2$) and ICU length of stay. Because the length-of-stay data were not normally distributed, a Spearman rank correlation analysis was performed. As shown in Table 4, a significant negative correlation was observed between

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Table 3 Analysis of Right and Left Cerebral Oxygen Saturation

Cerebral Oxygen Saturation	Mean±SD	Min-Max
$rScO_2$		
T0	54.75±14.80	15–92
T1	59.47±13.39	15–92
T2	65.08±11.59	31–92
$tScO_2$		
T0	56.97±14.12	15–89
T1	59.47±12.68	15–89
T2	67.04±11.15	38–89

Note: $rScO_2$=right cerebral oxygen saturation; $tScO_2$=left cerebral oxygen saturation; T0=preoperative; T1=postoperative; T2=8 hours after extubation

postoperative (T1) $rScO_2$ and ICU length of stay for both the right hemisphere (r=–0.406, p=0.034) and the left hemisphere (r=–0.343, p=0.017). This finding indicates that lower cerebral oxygen saturation immediately after surgery is associated with a longer ICU stay. In contrast, no significant correlations were identified at T0 or T2.

Additionally, the relationship between right and left regional cerebral oxygen saturation ($rScO_2$) was analyzed to assess measurement consistency. As shown in Table 5, a very strong positive correlation was observed between right and left $rScO_2$ values at all time points (T0, T1, and T2) (p<0.001), indicating good agreement between hemispheric measurements.

Discussion

The main finding of this study demonstrates a significant negative correlation between postoperative regional cerebral oxygen saturation ($rScO_2$) at T1 and ICU length of stay in patients undergoing heart valve surgery. Patients with lower $rScO_2$ levels immediately after surgery tended to have a longer ICU stay. This association may reflect the occurrence of

Table 4 Correlation Between Cerebral Oxygen Saturation and Length of ICU Stay

Cerebral Oxygen Saturation		ICU Length of Stay	r	p-value [b]
$rScO_2$				
T0	54.75±14.8	5.42±4.59	0.056	0.703
T1	59.98±12.78		–0.406	0.034
T2	65.08±11.59		–0.037	0.804
$tScO_2$				
T0	56.98±14.12		–0.059	0.693
T1	61.81±12.18		–0.343	0.017
T2	67.04±11.15		0.028	0.853

Note: [b]Correlation test; $rScO_2$=right cerebral oxygen saturation; $tScO_2$=left cerebral oxygen saturation; T0=preoperative; T1=postoperative; T2=8 hours after extubation

Table 5 Correlation Between Right and Left Cerebral Oxygen Saturation

$rScO_2$	$tScO_2$	r	p-value[b]
T0	T0	0.856	0.001
T1	T1	0.851	0.001
T2	T2	0.777	0.001

Note: [b]Spearman correlation test; $rScO_2$=right cerebral oxygen saturation; $tScO_2$=left cerebral oxygen saturation; T0=preoperative; T1=postoperative; T2=8 hours after extubation

impaired cerebral oxygen delivery secondary to hemodynamic instability condition, reduced cardiac output, or microcirculatory dysfunction during the immediate postoperative period. As the brain is highly sensitive to hypoxia, even subclinical cerebral desaturation may indicate global tissue hypoperfusion and contribute to delayed recovery.

In contrast, there was no significant differences in peripheral oxygen saturation level (SpO_2) observed across measurement time points (T0, T1, and T2), suggesting that systemic oxygenation alone may not adequately reflect regional cerebral perfusion. This supports the concept that $rScO_2$ provides additional physiological information beyond conventional systemic parameters. While previous studies have reported inconsistent findings regarding perioperative oxygen saturation, these discrepancies may be related to differences in patient populations, intraoperative management, and monitoring protocols.[8,9]

Regarding cerebral oxygenation, the correlation with ICU length of stay was significant only at T1 (immediately postoperative), but not at T0 (preoperative) or T2 (8 hours post-extubation). This suggests that the timing of cerebral oxygen measurement may be an important factor. While some studies have reported no significant association between NIRS-derived parameters and ICU length of stay,[10] our findings indicate that early postoperative measurements may be more clinically relevant. Other studies have similarly reported non-significant correlations at different time points, although clinical differences may still be observed despite a lack of statistical significance.[11,12]

Our findings are in line with previous studies indicating that early perioperative monitoring, particularly at T0 and T1, may facilitate earlier detection of physiological disturbances and potentially support improved recovery trajectories.[13] Furthermore, monitoring during the immediate postoperative period (T1) may allow closer observation during the critical transition to ICU care, whereas later measurements (T2) may have less clinical relevance for early outcomes.[13]

Despite these findings, several limitations should be acknowledged from this study. First, the sample size was relatively small. Second, this study did not control for multiple potential confounders, including age, comorbidities, type of surgery, hemodynamic status, and cardiopulmonary bypass duration. In addition, other factors influencing ICU length of stay, such as intraoperative complications, perioperative events, and complications during ICU care, were not evaluated. Therefore, although a significant association was observed at T1, a causal relationship cannot be established. Additionally, neurocognitive assessments were not performed to evaluate the relationship between cerebral desaturation and functional neurological outcomes.

Conclusion

Lower cerebral oxygen saturation measured immediately after surgery (T1) is associated with a prolonged length of stay in the Intensive Care Unit among patients undergoing heart valve surgery. These findings should be interpreted as exploratory, suggesting that the immediate postoperative period represents a critical window for hemodynamic monitoring

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and may serve as an early indicator of delayed recovery. However, due to the lack of control for potential confounding factors, a causal relationship cannot be established. Future prospective studies with larger sample sizes and multivariable analyses are warranted to validate the prognostic value of postoperative cerebral oxygen saturation.

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