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Role of Near Infrared Spectroscopy Monitoring in Intra-Operative Period for Neurological Outcomes in Complex Aortic Surgeries- A study of 50 Adult Cases

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ABSTRACT

Introduction: Complex aortic surgeries are associated with a considerable risk of perioperative neurological complications, mainly due to cerebral hypoperfusion, ischemia, or embolic events. Early recognition of cerebral oxygen imbalance during surgery may help in reducing postoperative neurological morbidity. Near-infrared spectroscopy (NIRS) offers a non-invasive method for continuous monitoring of regional cerebral oxygen saturation (rSO_2).

Methods: This observational study included 50 adult patients undergoing complex aortic surgery. Baseline cerebral rSO_2 values were recorded using NIRS before induction and monitored throughout the intraoperative period. Cognitive function was assessed using the Standard Mini-Mental State Examination (SMMSE) before surgery and again in the postoperative period. Intraoperative changes in NIRS values were compared with postoperative SMMSE scores to evaluate cognitive decline and delirium. Additional clinical outcomes, including duration of mechanical ventilation and length of intensive care unit stay, were also analyzed.

Results: A fall in intraoperative cerebral rSO_2 was associated with a reduction in postoperative SMMSE scores, indicating postoperative cognitive decline in a subset of patients. Patients with lower intraoperative NIRS values also showed a tendency toward prolonged ventilation and longer intensive care unit (ICU) stay. Postoperative cognitive dysfunction was observed in approximately 10% of the study population.

Conclusion: Intraoperative NIRS monitoring may be a useful adjunct in complex aortic surgeries for detecting cerebral desaturation and identifying patients at risk of postoperative cognitive dysfunction. Reduced rSO_2 values were associated with poorer neurological recovery, prolonged ventilation, and increased ICU stay.

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Introduction

Complex aortic surgery is associated with a considerable risk of neurological injury, particularly because cerebral perfusion may be interrupted or altered during key stages of the operation. Stroke, transient neurological dysfunction, embolic events, and postoperative cognitive decline remain important concerns after repair of complex aortic disease (1).

Acute aortic dissection is one of the most severe presentations of aortic pathology. It occurs when an intimal tear allows blood to enter the medial layer of the aortic wall, creating a false lumen. Stanford type A dissection, which involves the ascending aorta, generally requires urgent surgical treatment because delayed management is associated with high mortality and serious complications (2–6). During surgical repair, techniques such as cardiopulmonary bypass, hypothermia, circulatory arrest, and selective cerebral perfusion may influence cerebral oxygen delivery and increase the risk of neurological complications (7).

Monitoring cerebral status during these procedures is therefore an important part of perioperative care. Different methods, including electroencephalography, bispectral index monitoring, jugular venous oxygen saturation, and near-infrared spectroscopy, have been used for this purpose (7–16). However, some of these techniques are invasive, technically demanding, or provide only indirect information about cerebral oxygen balance.

Near-infrared spectroscopy offers a non-invasive and continuous method for measuring regional cerebral oxygen saturation. Because it provides real-time information, it may allow earlier recognition of cerebral desaturation during periods of hemodynamic instability, circulatory arrest, or cerebral perfusion changes (15–18). Several studies in cardiac surgery have linked intraoperative cerebral desaturation with postoperative neurological dysfunction, cognitive impairment, prolonged ventilation, and longer hospital or intensive care unit stay (19-27).

Nevertheless, the role of near-infrared spectroscopy (NIRS) in complex aortic surgery is still not clearly defined. Available studies vary in patient population, surgical technique, desaturation thresholds, and outcome definitions, which may explain the inconsistency in reported findings (25–28). Therefore, this study aimed to evaluate whether intraoperative NIRS-derived regional cerebral oxygen saturation was associated with postoperative neurological outcomes in adult patients undergoing complex aortic surgery. Secondary objectives included assessment of its relationship with postoperative cognitive function, duration of mechanical ventilation, and length of intensive care unit stay.

Methods

The approval was obtained from the Institutional Ethics Committee after due scrutiny and review, with the document number (EC/Approval/C.ANESTHE/05/2021/17/03/2021). Well-structured written and informed consent was obtained from the patients regarding the conduct of anesthesia, surgical and cardiopulmonary bypass, the risks associated and their willingness to participate in the study. A prospective, observational trial was conducted on a total of 50 patients posted for complex aortic surgeries under general anesthesia.

Inclusion Criteria

Age> 18 years, ASA grade II, III & IV, LV ejection fraction > 30% and Complex aortic surgery.

Exclusion Criteria

LV Ejection fraction<30%, patients requiring ECMO, Emergency surgeries, Re-do surgeries, Pre-existing neurological deficits with a baseline standard mini-mental state examination (SMMSE) scores of < 23 and patients with carotid artery diseases.

Technique of anesthesia and surgical procedure performed and conduct of CPB

In the pre-operative holding area, the cerebral oximetry electrodes (Somanetics INVOS Oximeter, Covidien, LLC) were applied to the forehead bilaterally and the baseline regional cerebral oxygen saturation (rSO2) values on left and right side were measured. Upon wheeling into the operating room, Standard ASA monitors Pulse oximeter, 5 lead electrocardiogram , temperature, capnography was connected. Large bore 16-gauge intravenous access and a radial arterial cannula was secured under local anesthesia, and connected to the invasive arterial blood pressure monitor. A base line arterial blood gas (ABG) sample was obtained.

After pre-oxygenation with 10 litres of oxygen for 3 to 5 minutes, patients received Injection (Inj) midazolam 0.1-0.2 mg/kg body weight, Inj. Fentanyl 5-10 mcg/kg bodyweight and Inj. Vecuronium 0.08-0.12 mg/kg body weight during induction of anesthesia. Intubation was done with an appropriately-sized endotracheal tube and anesthesia was maintained with boluses of Inj fentanyl, Inj Vecuronium and sevoflurane with oxygen and air mixture. Mean arterial pressure was maintained above 60 mm of Hg except during deep hypothermic circulatory arrest. Rewarmed to normothermia while weaning off cardiopulmonary bypass (CPB). NIRS values and vital parameters were recorded at important time frames.

Statistical Analysis

The collected data were analyzed with IBM SPSS Statistics for Windows, Version 29.0. (Armonk, NY: IBM Corp). To describe the data, descriptive statistics frequency analysis and percentage analysis were used for categorical variables and the mean & standard deviation were used for continuous variables. To find the significant difference in the multivariate variables and for repeated measures, the repeated measures of ANOVA was used with Bonferroni correction to control the type I error on multiple comparison. To assess the relationship between the variables Pearson's Correlation was used. In all the above statistical tools the probability value 0.05 is considered as significant level.

Results

The study included a total of 50 adult patients who underwent complex aortic surgery. There were 39 males (78%) and 11 females (22%), with ages ranging between 20 and 75 years. The demographic details and baseline characteristics are summarized in Table 1. We recorded rSO_2 using NIRS before the operation and then took serial measurements at set time points during and after surgery. Huynh–Feldt analysis comparing right and left cerebral rSO_2 values showed no statistically significant difference between the two sides (Table 2).

Mean SMMSE scores were 27.9 before surgery, 26.9 at 8 hours after extubation, and 27.0 at 12 hours post-extubation. There was a significant change in SMMSE scores over time according to Huynh–Feldt analysis (Type III Sum of Squares = 28.093, p = 0.024). Pairwise comparison showed a notable drop specifically between the preoperative score and the 8-hour post-extubation score (mean difference = 0.980, p = 0.036) (Table 3).

Table 1. Standard mini-mental state examination (SMMSE) analysis.

Source SMMSE	Type III Sum of Squares	Df	Mean Square	F	p-value
Huynh-Feldt	28.093	1.219	23.041	4.930	0.024

Table 2. rSO2 at various intervals.

	Left rSO2	Right rSO2
Pre-op	66.5	67.3
Induction	66.6	67.4
After Sternotomy	66.3	67.2
Before Cross Clamping	65.9	67.3
After Cross Clamping	65.9	67.0
After Cross Clamp off	66.0	66.7
After Protamine	66.0	67.2
At ICU Admission	65.8	66.1
2 Hours after Extubation	65.6	66.3
8 Hours after Extubation	65.7	66.5
12 Hours after Extubation	65.9	66.7

In correlation analysis, we found significant links between preoperative NIRS readings and cognitive scores. Preoperative left and right rSO_2 values were strongly correlated with each other (p = 0.0005). Both also showed significant positive correlations with preoperative SMMSE scores (left: p = 0.001; right: p = 0.006) (Table 4). After Bonferroni adjustment, multivariate analysis confirmed a significant reduction in SMMSE scores at 8 hours post-extubation compared to baseline (p = 0.036) (Table 5).

We also observed meaningful associations between cerebral oxygen saturation and recovery parameters. Both left and right NIRS values correlated significantly with total ventilation time and intensive care unit (ICU) stay. Not surprisingly, ventilation time itself was closely linked with the length of ICU stay (Table 6).

Looking at the operative variables, mean CPB time was 72 minutes (range 31–147 minutes), while mean aortic cross-clamp time was 51 minutes (range 21–105). Twelve patients (24%) needed total circulatory arrest (TCA), lasting a mean of 14.2 minutes. The average core temperature was 30.5°C, and total surgery time averaged 234.4 minutes. Mean haemoglobin was 13.7 g/dL and mean arterial pressure was 64 mmHg (Table 7).

Table 3. SMMSE mean and standard deviation.

	Mean	SD	N
Pre-op SMMSE	27.9	1.5	50
SMMSE 8 hours post extubation	26.9	3.5	50
SMMSE 12 hours post extubation	27.0	3.7	50

Table 4. NIRS rSO2 and SMMSE correlation.

		NIRS Pre-op Right rSO2	Pre-op SMMSE
NIRS Pre-op Left rSO2	**r-value**	0.708**	0.468**
	p-value	**0.0005**	**0.001**
	N	50	50
NIRS Pre-op Right rSO2	**r-value**		0.383**
	p-value		**0.006**
	N		50

**. Correlation is significant at the 0.01 level (2-tailed).

Table 5. SMMSE at various intervals.

SMMSE		Mean Difference	Std.Error	Sig^b	Interval for Difference	
					Lower Bound	Upper Bound
Pre-op	**8 hours PE**	0.980*	0.376	0.036	0.047	1.913
	12 hours PE	0.840	0.420	0.154	-0.202	1.882
8 hours PE	**12 hours PE**	-0.140	0.154	1.000	-0.521	0.241

Based on estimated marginal means
*. The mean difference is significant at the .05 level.
b. Adjustment for multiple comparisons: Bonferroni.

Table 6. NIRS rSO2, total ventilation time and total ICU stay correlation.

		NIRS Right rSO2	Total ventilation time	Total ICU stay
NIRS Left rSO2	**r-value**	0.823**	-0.516**	-0.509**
	p-value	**0.0005**	**0.0005**	**0.0005**
	N	50	50	50
NIRS Right rSO2	**r-value**	1	-0.482**	-0.427**
	p-value		**0.0005**	**0.002**
	N		50	50
Total Ventilation time	**r-value**		1	0.921**
	p-value			**0.0005**
	N			50

** Correlation is significant at the 0.01 level (2-tailed).

Postoperative cognitive dysfunction (POCD) developed in 5 out of 50 patients (10%). These patients had noticeably lower baseline NIRS values (left rSO_2: 58.1; right rSO_2: 58.9) compared to the overall average (left: 60.02; right: 60.9). Their SMMSE scores dropped sharply— from 25.6 preoperatively to 18.0 at 8 hours and 17.2 at 12 hours after extubation.

On the other hand, patients without POCD had fairly stable scores: 28.11 preoperatively, 27.86 at 8 hours, and 28.11 at 12 hours. Those who developed POCD also had slower recovery, with mean ventilation time of 34 hours (versus 16.11 hours in non-POCD patients) and mean ICU stay of 57.2 hours (versus 29.53 hours).

Table 7. CPB and vitals chart.

	N	Minimum	Maximum	Mean	SD
CPB Time	50	31.0	147.0	72.0	23.3
Cross clamp Time	50	21.0	105.0	51.0	20.5
TCA Time	12	1.0	51.0	14.2	13.4
Least Core Temp	50	20.0	33.0	30.5	3.1
Surgery Total Time	50	145.0	400.0	232.4	52.1
Hb	50	10.0	17.0	13.7	1.5
MAP	50	64.0	92.0	78.0	6.5

Table 8. SMMSE in POCD subjects.

SMMSE in POCD	
Pre-op	25.6
8 hours post extubation	18.0
12 hours post extubation	17.2

Discussion

This study looked at how well NIRS monitoring during the operation helps predict neurological outcomes in patients going through complex aortic surgery. Basically, we saw that when cerebral oxygen saturation dropped, it was often linked to postoperative cognitive decline and slower overall recovery.

Neurological complications are still a serious issue in these big aortic cases because of the risks from cerebral hypoperfusion, ischemia, or emboli. That's why keeping a continuous watch on cerebral oxygenation makes sense it gives the team real-time feedback on how the brain is handling things during the toughest parts of the surgery. In our patients, the ones who developed postoperative cognitive dysfunction had noticeably lower cerebral oxygen saturation values. This points to a possible link between those desaturations and worse neurologicalrecovery.

Our results line up well with what Slater et al. (26) reported earlier. They showed that intraoperative cerebral oxygen desaturation was tied to postoperative cognitive decline and longer hospital stays after cardiac surgery. We also saw similar patterns as Olsson and Thelin (20), who found that reduced regional cerebral oxygen saturation during aortic surgery raised the chances of postoperative neurological complications. All this backs up NIRS as a handy non-invasive way to catch cerebral hypoxia in these complex cardiac procedures.

On top of the cognitive problems, we noticed that lower cerebral oxygen levels were also connected to longer mechanical ventilation times and extended ICU stays. It looks like not getting enough oxygen to the brain during surgery can really drag down postoperative recovery. Spotting and fixing these drops early might therefore make a meaningful difference.

NIRS has some real strengths — it gives continuous real-time data, it's completely non-invasive, and it can flag oxygen imbalance before any clear neurological damage shows up. Earlier work has already highlighted how useful it is for spotting cerebral hypoperfusion and helping the team make quick adjustments to improve brain perfusion (16, 23).

Even so, it's still not completely clear if using NIRS to actively guide interventions actually improves long-term neurological outcomes. Some studies, like the one by Slater (26), have suggested benefits for neurocognitive results, but others (27) didn't find any big drop in postoperative neurological complications. We definitely need more solid data before we can say for sure how valuable NIRS-guided management really is in everyday practice.

This study isn't without limitations. It was done at a single center with a fairly small number of patients. Plus, we only looked at NIRS and didn't combine it with other neuromonitoring tools like electroencephalography (EEG), bispectral index (BIS), entropy monitoring, or jugular venous oxygen saturation. Larger multicenter trials will be important to confirm what we found and to set clear, clinically useful thresholds for when desaturation becomes a problem.

In the end, intraoperative NIRS monitoring looks like it could be a helpful extra tool during complex aortic surgery. It may help pick out patients who are at greater risk of postoperative cognitive dysfunction and delayed recovery. Making cerebral oximetry part of routine practice could allow earlier detection of hypoperfusion and support steps that lead to better neurological outcomes.

Limitation

A significant limitation was that it was a single-center study involving a small cohort of patients. Only NIRS monitoring was utilized in the intraoperative period; other modalities like EEG, BIS, Entropy and jugular venous oxygen saturation monitoring would have given additional and more comprehensive perspectives on the neurological status. Furthermore, NIRS electrodes were attached to the foreheads of patients, which will give the saturation of the frontal cortex, and the representation of other areas was unaccounted for in the interpretation of results.

Conclusion

This study was targeted at observing post-operative neurological cognitive decline and delirium in patients who underwent, complex aortic surgeries, by monitoring their NIRS rSO2 values in the intra-operative period and their neurological state was assessed by employing Standard mini-mental state examination scores. Our research found out a strong correlation between decreased intra-operative NIRS rSO2 values, begetting a decline in post-operative SMMSE scores, suggesting that, post-operative cognitive decline is evident in this subset of patients and the correlation between decline in NIRS rSO2 values, translating into prolonged ventilation time and prolonged ICU stay.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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