Journal of Cardiology and Cardiovascular Sciences

Review Article Open Access

Prediction of Mortality after Cardiac and Noncardiac Surgery Using Cerebral Near-Infrared Spectroscopy: A Narrative Review

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Article Info

Article Notes
Received: December 22nd, 2025
Accepted: January 20th, 2026

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Keywords
Cardiac Surgery
Cerebral Oxygen Saturation
Mixed Venous Oxygen Saturation
Mortality Prediction
Near-Infrared Spectroscopy
Oxygen Supply-Demand Balance

Abstract

Background: Cerebral tissue oxygen saturation monitoring using near-infrared spectroscopy (NIRS) is widely employed during cardiac surgery. Although NIRS devices are approved for monitoring cerebral oxygenation, they are not licensed for prognostic purposes. Nevertheless, multiple studies have demonstrated significant associations between baseline cerebral NIRS values measured before anesthesia induction and postoperative mortality after cardiac and noncardiac surgery in adults, suggesting a potential role for baseline NIRS values in mortality risk prediction. This narrative review summarizes current evidence regarding the association between baseline cerebral NIRS values and postoperative mortality, focusing primarily on adult cardiac and noncardiac surgery and exclusively on mortality rather than composite morbidity endpoints.

Methods: A comprehensive PubMed search was conducted to identify studies investigating the relationship between cerebral NIRS values and postoperative mortality in adult surgical patients.

Results: Six studies evaluating adult cardiac surgery patients and three studies involving adult noncardiac surgery patients were identified. All studies but one demonstrated a significant association between low baseline cerebral NIRS values recorded before anesthesia induction and increased postoperative mortality. These findings suggest that baseline NIRS values reflect underlying cardiac functional reserve and systemic oxygen delivery capacity. Emerging evidence also suggests potential inter-device differences in mortality prediction performance among commonly used NIRS technologies.

Conclusions: Baseline cerebral NIRS values may serve as convenient, useful predictors of postoperative mortality. This review highlights the mechanistic basis of this association and discusses potential differences in prognostic performance among NIRS devices, underscoring the need for further large-scale comparative studies.

Introduction

Cerebral tissue oxygen saturation monitoring using near-infrared spectroscopy (NIRS) is widely employed during cardiac surgery.[1,2] Although NIRS oximetry devices are not approved for prognostic purposes, Heringlake et al. first demonstrated that baseline cerebral NIRS values measured before anesthesia induction were significantly associated with postoperative mortality after adult cardiac surgery, suggesting potential utility for perioperative risk prediction.[3] Through a comprehensive PubMed search, we identified nine studies in adult cardiac and noncardiac surgery patients examining associations between cerebral NIRS values and postoperative mortality, most of which reported significant associations.

This review summarizes the reported associations between baseline cerebral NIRS values and postoperative mortality in adults, discusses potential mechanisms underlying these associations, and addresses inter-device differences in mortality prediction. To facilitate interpretation, this review focuses exclusively on postoperative mortality rather than composite endpoints that include major postoperative complications.

Search Strategy for Study Identification

PubMed was searched for studies published between 2000 and 2025 examining associations between perioperative NIRS values and postoperative mortality in adults using the terms "near-infrared spectroscopy" AND "postoperative mortality" and "cerebral oxygen saturation" AND "postoperative mortality." After removal of 52 duplicates from 247 retrieved records, 195 unique articles were screened. We excluded 57 pediatric studies, 20 reviews, four case series or reports, eight protocols, two animal studies, and two conference abstracts. Of the remaining 102 original articles, 62 were excluded because they did not assess associations between perioperative NIRS values and postoperative outcomes. The remaining 40 articles were reviewed in full, of which nine reported associations between perioperative NIRS values and postoperative mortality in adults.

Association between Baseline Cerebral NIRS Values and Mortality after Cardiac and Noncardiac Surgery in Adults

The reported associations between cerebral NIRS values and postoperative mortality are summarized in Table 1.

Table 1. Reported associations between baseline near-infrared spectroscopy (NIRS) values measured before anesthesia and postoperative mortality in adults.

Article	Study design	NIRS device	Subjects	Surgery	Endpoint	Mortality	Statistical analysis	Result	*p*-value
Heringlake et al. (2011) [3]	Prospective observational	INVOS 5100C (rSO_2)	Consecutive patients **(n = 1,178)**	On-pump cardiac surgery	30-day mortality	41 (3.5%)	Non-survivors (n =41) vs. survivors (n = 1,137)	Baseline rSO_2 (%), 58 (47-64) vs. 64 (59-69)	< 0.001
							ROC curve analysis	AUC (95%CI), 0.71 (0.68-0.73); Cutoff value, 51%	< 0.001
Sun et al. (2013) [4]	Retrospective observational	INVOS 5100C (rSO_2)	Consecutive white patients **(n = 2,097)**	On-pump or off-pump cardiac surgery	30-day mortality	82 (3.9%)	Baseline rSO_2, < 60% (n = 601) vs. ≥ 60% (n = 1,496)	Mortality, 43 (7.2%) vs. 39 (2.6%)	< 0.001
							Univariate logistic regression	OR (95%CI), 0.95 (0.94-0.97)	< 0.001
							ROC curve analysis	AUC, 0.7018	< 0.001
Mukaida et al. (2017) [5]	Retrospective observational	INVOS 5100C (rSO_2)	Consecutive patients **(n = 575)**	On-pump or off-pump cardiac surgery	Hospital mortality	12 (2.1%)	Baseline rSO_2, ≤ 50% (n = 45) vs. > 50% (n = 528)	Mortality, 5 (11.1%) vs. 7 (1.3%)	< 0.01
							Univariate logistic regression	Not shown	0.0031
							ROC curve analysis	AUC (95%CI), 0.715 (0.508-0.859); Cutoff value, 50.5%	0.0024
Ghosal et al. (2018) [6]	Retrospective observational	INVOS 5100C (rSO_2)	Consecutive patients **(n = 210)**	Left ventricular assist device surgery	30-day mortality	11 (5.2%)	Multivariable logistic regression (adjusted for four additional predictors)	OR (95%CI), 0.940 (0.888-0.995)	0.032
							ROC curve analysis	AUC with four predictors, 0.7373; AUC with four predictors plus baseline rSO_2, 0.8086	Not shown
Bennett et al. (2021) [7]	Retrospective observational	INVOS 5100 (rSO_2)	Consecutive patients **(n = 166)**	On-pump cardiac surgery	Hospital mortality	7 (4.2%)	Non-survivors (n =7) vs. survivors (n = 159)	Baseline rSO_2 (%), 49.2 ± 4.2 (SEM) vs. 56.8 ± 0.7 (SEM)	0.003
							Competing risk model	sHR, 1.034	< 0.01

Clemmesen et al. (2018)[8]	Prospective observational	INVOS 5100 (rSO_2)	Consecutive elderly patients (> 65 years) **(n = 40)**	Surgery for hip fracture	30-day mortality	4 (10%)	Non-survivors (n =4) vs. survivors (n = 36)	Baseline rSO_2 (%), 57.0 (51.5-60.0) vs. 66.0 (58.0-70.0)	0.042
							Baseline rSO_2 ≤ 55% (n = 15) vs. > 55% (n = 25)	Mortality, 4/15 (26.7%) vs. 0/25 (0%)	0.015
Baehner et al. (2023)[9]	Prospective observational	INVOS 5100 (rSO_2)	Consecutive patients aged between 18 and 89 years **(n = 126)**	High-risk noncardiac surgery	30-day mortality	6 (4.8%)	Non-survivors (n = 6) vs. survivors (n = 120)	Baseline rSO_2 (%), 56.9 ± 8.2 vs. 58.2 ± 7.2	0.682
					30-day morbidity	32 (25.4%)	Patients with morbidity (n = 32) vs. without morbidity (n = 96)	Baseline rSO2 (%), 55.8 ± 7.2 vs. 58.9 ± 7.1	0.035
					30-day mortality and morbidity	38 (30.2%)	ROC curve analysis for baseline rSO_2	AUC (95% CI), 0.616 (0.508–0.723)	0.051
							ROC curve analysis for baseline rSO_2 under 2L/min oxygen	AUC (95% CI), 0.618 (0.509–0.726)	0.047
Thedim et al. (2025)[10]	Prospective observational	INVOS 5100C (rSO_2)	Consecutive elderly patients (> 65 years) **(n = 254)**	Elective noncardiac surgery	30-day mortality	5 (2.0%)	Non-survivors (n = 5) vs. survivors (n = 249)	Baseline rSO_2 (%), 51 ± 15 vs. 64 ± 8	< 0.001
							ROC curve analysis for baseline rSO_2	AUC, 0.801	0.021
Kakemizu-Watanabe et al. (2025)*[11]	Retrospective observational	INVOS 5100C (rSO_2)	Consecutive non-dialysis patients **(n = 510)**	On-pump or off-pump cardiac surgery	Hospital mortality	6 (1.2%)	Univariate logistic regression	OR (95%CI), 0.841 (0.763-0.928)	0.00052
		NIRO-200NX (TOI)	Non-dialysis patients **(n = 468)**	On-pump or off-pump cardiac surgery	Hospital mortality	8 (1.7%)	Univariate logistic regression	OR (95%CI), 0.862 (0.789-0.943)	0.00111
		FORESIGHT Elite (StO_2)	Non-dialysis patients **(n = 510)**	On-pump or off-pump cardiac surgery	Hospital mortality	12 (2.4%)	Univariate logistic regression	OR (95%CI), 0.850 (0.749-0.964)	0.01122

Data are presented as mean ± SD, mean ± SEM, median (interquartile range), or number (%), as appropriate. Group comparisons were performed using the unpaired *t* test, Mann–Whitney *U* test, chi-square test, or Fisher's exact test, as appropriate. Associations between baseline near-infrared spectroscopy (NIRS) values and mortality, morbidity, or their composite outcome were evaluated using receiver operating characteristic (ROC) curve analysis, logistic regression analysis, or a competing-risk model. Results are reported as the area under the ROC curve (AUC) with 95% confidence interval (95% CI), odds ratio (OR) with 95% CI, or subdistribution hazard ratio (sHR), as available. *P* values are reported where available.
*The results of newly performed ROC analyses are shown in *Figure 1*.

Such associations after adult cardiac surgery was first documented by Heringlake et al. in 2011.[3] In a prospective cohort of 1,178 consecutive patients undergoing cardiac surgery, baseline cerebral regional oxygen saturation (rSO_2), measured before anesthesia induction using the INVOS 5100C (Medtronic, Minneapolis, MN, USA), correlated with EuroSCORE (p < 0.001) and was significantly associated with 30-day mortality (p < 0.001). Receiver operating characteristic (ROC) curve analysis demonstrated an area under the curve (AUC) of 0.71 (p < 0.001) for 30-day mortality.[3]

Sun et al. retrospectively analyzed 2,097 consecutive patients undergoing cardiac surgery and demonstrated that baseline rSO_2 was significantly associated with 30-day mortality (p < 0.001).[4] ROC analysis showed that rSO_2 was slightly less accurate than the Society of Thoracic Surgeons (STS) Mortality Risk Score (AUC 0.71 vs. 0.85), but was nonetheless clinically informative given the simplicity of measurement.[4]

In a retrospective cohort of 573 consecutive patients undergoing cardiac surgery, Mukaida et al. reported that hospital mortality was significantly associated with EuroSCORE (p < 0.001), baseline rSO_2 (p = 0.003), and the lowest intraoperative rSO_2 (p = 0.018), whereas the

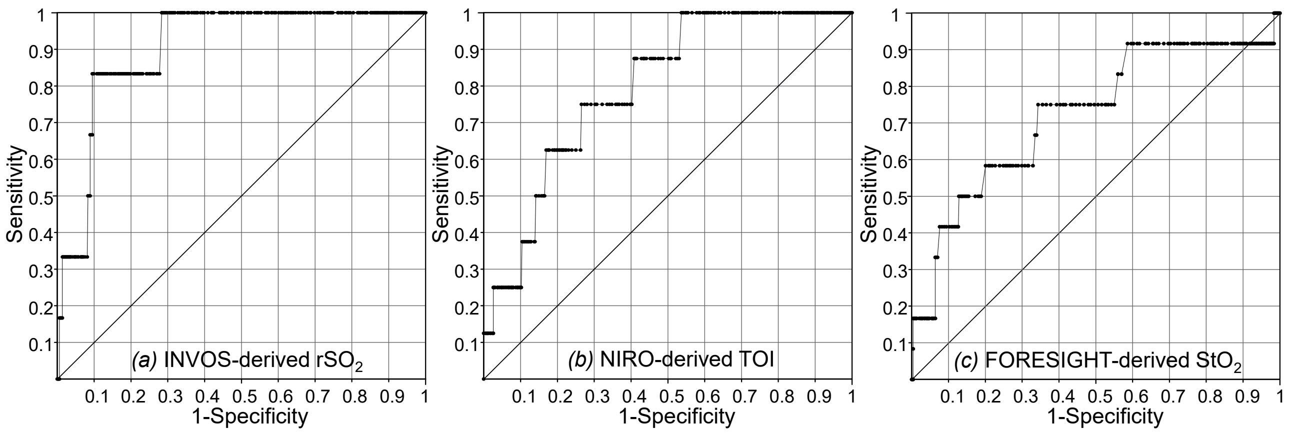

Figure 1. Receiver operating characteristic (ROC) curves for predicting postoperative mortality based on baseline cerebral near-infrared spectroscopy (NIRS) values measured using three devices.
Areas under the ROC curves (AUCs; 95% confidence intervals), newly calculated from data reported in Reference 11, were 0.905 (0.831–0.980) for INVOS-derived rSO_2 (a), 0.795 (0.672–0.918) for NIRO-derived tissue oxygenation index (TOI) (b), and 0.723 (0.560–0.887) for FORESIGHT-derived StO_2 (c). Pairwise comparisons of AUCs using the Hanley–McNeil method showed that the AUC for INVOS-derived rSO_2 was significantly higher than that for FORESIGHT-derived StO_2 ($p = 0.047$), whereas no significant differences were observed between INVOS-derived rSO_2 and NIRO-derived TOI or between NIRO-derived TOI and FORESIGHT-derived StO_2.
Baseline cerebral NIRS values in non-dialysis cardiac surgery patients with comparable clinical characteristics, expressed as medians (interquartile ranges), were 65.2% (59.4–71.2%) for INVOS-derived rSO_2, 67.1% (63.3–72.2%) for NIRO-derived TOI, and 69.2% (66.2–72.3%) for FORESIGHT-derived StO_2, with statistically significant differences observed among the groups.[11]
The optimal cutoff values for mortality prediction, determined using the maximized Youden index, were 54.4% for INVOS-derived rSO_2 (sensitivity 0.833, specificity 0.905), 63.6% for NIRO-derived TOI (0.750, 0.735), and 67.8% for FORESIGHT-derived StO_2 (0.750, 0.657).

maximal intraoperative decrease in rSO_2 was not ($p = 0.893$).[5] ROC analysis demonstrated an AUC of 0.715 ($p = 0.002$) for baseline rSO_2, underscoring the dominant prognostic relevance of baseline values.[5]

Ghosal et al. retrospectively examined 210 patients undergoing left ventricular assist device implantation and found that baseline rSO_2 was independently associated with 30-day mortality ($p = 0.032$) after adjusting for other risk predictors, whereas rSO_2 recorded at the end of surgery was not ($p = 0.236$), again underscoring the prognostic relevance of baseline values.[6]

Bennett et al. retrospectively analyzed 166 patients undergoing cardiac surgery and demonstrated that baseline rSO_2 was significantly associated with hospital mortality ($p = 0.027$).[7] Collectively, these studies suggest that low baseline cerebral NIRS values are predictive of increased mortality after adult cardiac surgery.

Clemmesen et al. extended these findings to noncardiac surgery by reporting that in a prospective cohort of 40 consecutive elderly patients (> 65 years) undergoing hip fracture surgery, baseline rSO_2 was significantly associated with 30-day mortality ($p < 0.05$).[8]

In contrast, Baehner et al. found no significant association between baseline rSO_2 and 30-day mortality in a prospective cohort of 126 patients undergoing high-risk noncardiac surgery ($p > 0.05$), although a marginal association was observed with a composite endpoint of 30-day mortality and morbidity ($p = 0.05$).[9] Notably, the inclusion of patients across a wide age range (18–89 years) and the heterogeneity of surgical procedures may have attenuated the observed associations.[9]

When the analysis was again restricted to elderly patients (> 65 years), Thedim et al. reported in a prospective cohort of 254 patients undergoing elective noncardiac surgery that baseline cerebral rSO_2 was significantly associated with 30-day mortality ($p < 0.001$).[10]

Importantly, all abovementioned studies relied exclusively on INVOS-derived rSO_2 (Table 1).[3–10] Until recently, it was unclear whether other NIRS indicators were similarly associated with mortality. In 2025, Kakemizu-Watanabe et al. retrospectively studied approximately 500 non-dialysis cardiac surgery patients per device group with comparable perioperative clinical characteristics, in whom cerebral oxygenation was assessed using rSO_2 (INVOS 5100C), tissue oxygenation index (TOI; NIRO-200NX, Hamamatsu Photonics, Hamamatsu, Japan), and tissue oxygen saturation (StO_2; FORESIGHT Elite, Edwards Lifesciences, Irvine, CA, USA).[11] All baseline cerebral oxygenation indices—INVOS-derived rSO_2, NIRO-derived TOI, and FORESIGHT-derived StO_2—were strongly correlated with EuroSCORE (all $p < 0.001$) and significantly associated with hospital mortality (p, < 0.001, 0.001, and 0.011, respectively; Table 1).[11] These findings suggest that baseline cerebral NIRS values, irrespective of the device used, may predict postoperative mortality.[11]

Mechanisms Underlying the Association between Baseline Cerebral NIRS Values and Postoperative Mortality

Reductions in cerebral NIRS values during cardiac surgery generally reflect impaired cerebral oxygen delivery due to hypotension, low cardiac output, anemia, hypoxemia, and/or hypocapnia.[12] In a prospective study of 42 patients undergoing off-pump coronary artery bypass grafting (OPCAB), Moerman et al. simultaneously and continuously monitored INVOS-derived rSO_2, FORESIGHT-derived StO_2, and mixed venous oxygen saturation ($SmvO_2$) throughout surgery.[12] During intraoperative hemodynamic fluctuations, NIRS values—reflecting regional cerebral oxygen supply–demand balance—and $SmvO_2$—reflecting global oxygen supply–demand balance—changed in parallel. Scatter plots of repeated measurements at multiple time points across multiple patients revealed strong correlations between $SmvO_2$ and both NIRS indices, as well as between mean arterial pressure and both NIRS indices (all $p < 0.001$).[12]

Using single-time-point measurements in larger cohorts, Kakemizu-Watanabe et al. demonstrated that all baseline cerebral NIRS indices (INVOS-derived rSO_2, NIRO-derived TOI, and FORESIGHT-derived StO_2) measured before anesthesia and $SmvO_2$ measured at pulmonary artery catheter insertion after anesthesia induction shared common characteristics: all of them correlated most strongly with preoperative B-type natriuretic peptide (BNP) and hemoglobin levels—markers of cardiac function and oxygen transport capacity (all $p < 0.00001$).[11] They also demonstrated strong correlations between $SmvO_2$ and NIRS indices measured simultaneously at pulmonary artery catheter insertion in all three NIRS groups (all $p < 0.00001$).[11]

Taken together, these findings suggest that baseline cerebral NIRS values, similar to $SmvO_2$, reflect underlying cardiac functional reserve and systemic oxygen delivery capacity. Consequently, low baseline NIRS values may represent impaired physiological reserve, providing a plausible mechanistic explanation for their associations with postoperative mortality.

Slopes for Relationships between Mixed Venous Oxygen Saturation and NIRS Indices

Although strong correlations have consistently been observed between $SmvO_2$ and various NIRS indices measured simultaneously, the slopes of these relationships differ substantially among devices.[11, 12] In Moerman et al.'s analysis of continuous intraoperative data during OPCAB in 42 patients, the regression slope between INVOS-derived rSO_2 and $SmvO_2$ was 0.62, whereas the slope between FORESIGHT-derived StO_2 and $SmvO_2$ was 0.22, indicating marked inter-device differences within the same patients.[12] In this context, a 1% decrease in $SmvO_2$ corresponded to a 0.62% decrease in rSO_2 but only a 0.22% decrease in StO_2—nearly a threefold difference.[12]

Similarly, Kakemizu-Watanabe et al. reported regression slopes of 0.96, 0.61, and 0.44 for INVOS-derived rSO_2, NIRO-derived TOI, and FORESIGHT-derived StO_2, respectively, plotted against $SmvO_2$.[11] These analyses were based on single-time-point measurements obtained at pulmonary artery catheter insertion in approximately 500 patients per group with comparable clinical backgrounds.[11] Accordingly, for each 1% decrease in $SmvO_2$, rSO_2 decreased by 0.96%, TOI by 0.61%, and StO_2 by 0.44%, again demonstrating more than a twofold difference between INVOS-derived rSO_2 and FORESIGHT-derived StO_2, with NIRO-derived TOI showing intermediate behavior.[11]

Given that $SmvO_2$ reflects purely venous oxygenation, whereas INVOS-derived rSO_2 represents a mixture of arterial and venous components,[1, 2, 12] and considering the effects of cerebral autoregulation, which preserves cerebral perfusion at the expense of peripheral tissues during hypoperfusion,[7, 13] these findings suggest that reductions in INVOS-derived rSO_2 relative to $SmvO_2$ may be disproportionately large. Consequently, INVOS-derived rSO_2 may detect reductions in systemic oxygen delivery more sensitively, or potentially oversensitively, compared with FORESIGHT-derived StO_2, with NIRO-derived TOI demonstrating intermediate behavior.

Potential Factors Underlying Differences in Relationships between $SmvO_2$ and NIRS Indices

Most NIRS systems estimate tissue oxygenation using modified Beer–Lambert (MBL) algorithms.[1, 2] These approaches require multiple wavelengths to differentiate oxyhemoglobin from deoxyhemoglobin; however, when optical pathlength cannot be measured directly—as is the case with conventional two-wavelength MBL—only relative changes in hemoglobin concentrations can be derived, limiting the ability to provide absolute oxygen saturation values.[1]

The INVOS 5100C uses a simplified two-wavelength MBL algorithm to calculate rSO_2, likely assuming a fixed, simulated optical pathlength.[1, 2] Consequently, INVOS-derived rSO_2 should be interpreted primarily as a trend indicator.[1, 12] The NIRO-200NX employs a proprietary MBL algorithm with three wavelengths to track relative changes in oxygenated, deoxygenated, and total hemoglobin, and additionally incorporates spatially resolved spectroscopy (SRS), which theoretically compensates for pathlength variability and allows estimation of absolute TOI values.[2] The FORESIGHT Elite uses five wavelengths to further reduce pathlength-related uncertainty, thereby enabling absolute StO_2 measurements.[2, 12]

A further methodological limitation of MBL-based NIRS is incomplete elimination of extracranial signal contamination. Although multi-distance detector designs aim to remove superficial tissue signals,[1, 2] experimental models of extracranial ischemia demonstrate substantially greater extracranial contamination in INVOS-derived rSO_2 compared with FORE-SIGHT–derived StO_2.[14, 15] Similarly, NIRO-derived TOI appears relatively resistant to extracranial contamination, as shown in a study involving internal and external carotid artery clamping.[16]

Under conditions of reduced cardiac output or hypotension, cerebral autoregulation preferentially preserves cerebral blood flow, whereas perfusion to peripheral tissues is compromised, potentially leading to earlier and more pronounced desaturation in extracranial tissues.[13] Consequently, the greater decreases observed in INVOS-derived rSO_2 compared with FORE-SIGHT–derived StO_2 during reductions in $SmvO_2$ or mean arterial pressure[11, 12] may be attributable, at least in part, to the higher sensitivity of the INVOS system to extracranial tissue desaturation.[14, 15]

Potential Inter-Device Differences in Mortality Prediction after Surgery

FORESIGHT-derived StO_2 is promoted as an absolute-value monitor, whereas INVOS-derived rSO_2 is generally regarded as a relative or trend monitor.[12] NIRO-derived TOI is based on an absolute measurement principle,[2] but is often treated clinically as a relative monitor.[17] Consistent with these characteristics, inter-individual variability in baseline cerebral NIRS values was greatest for INVOS-derived rSO_2, intermediate for NIRO-derived TOI, and smallest for FORESIGHT-derived StO_2,[11, 12, 18] suggesting increasing reliability of absolute values in that order (INVOS rSO_2 < NIRO TOI < FORESIGHT StO_2).

Conversely, baseline cerebral NIRS values correlated more strongly—with the reverse ranking (INVOS rSO_2 > NIRO TOI > FORESIGHT StO_2)—with preoperative blood biomarkers associated with prognosis in cardiac patients, including BNP, hemoglobin, albumin, cholinesterase, creatinine, estimated glomerular filtration rate, and free triiodothyronine.[11]

Likewise, baseline cerebral NIRS values correlate more strongly—in the reverse order (INVOS rSO_2 > NIRO TOI > FORESIGHT StO_2)—with preoperative echocardiographic parameters reflecting cardiac function, including indices of left ventricular (LV) systolic function, such as LV ejection fraction (LVEF); indices of left atrial pressure and/or volume loading, such as left atrial dimension index; and indices of right atrial pressure and/or volume loading (inferior vena cava dimension index).[18] Notably, among LV systolic function parameters,[19] LVEF correlated significantly with INVOS-derived rSO_2 but not with NIRO-derived TOI or FORESIGHT-derived StO_2, whereas LV end-systolic dimension index and systolic mitral annular velocity (s') correlated significantly with INVOS-derived rSO_2 and NIRO-derived TOI, but not with FORESIGHT-derived StO_2.[18]

Furthermore, decreases in NIRS values during reductions in $SmvO_2$ and/or mean arterial pressure are greatest for INVOS-derived rSO_2, intermediate for NIRO-derived TOI, and smallest for FORESIGHT-derived StO_2.[11,12] These findings suggest that baseline INVOS-derived rSO_2 may most sensitively detect underlying cardiac dysfunction.[11,12,18]

Indeed, ROC curve analyses demonstrated that the AUC for mortality prediction was highest for INVOS-derived rSO_2 (0.905), followed by NIRO-derived TOI (0.795) and FORESIGHT-derived StO_2 (0.723), with a statistically significant difference observed between INVOS and FORESIGHT *(Figure 1)*.[11] While all baseline cerebral NIRS indices were significantly associated with postoperative mortality, these findings suggest potential inter-device differences in predictive performance. Specifically, although INVOS-derived rSO_2 may be the least reliable in terms of absolute values, it may offer the highest accuracy for NIRS-based mortality prediction.

Addition of baseline NIRS values to established predictors

Ghosal et al. reported that adding baseline INVOS-derived rSO_2 to a multivariate model including four other predictors increased the AUC from 0.7373 to 0.8086 (Table 1).[6] Mukaida et al. showed that a multivariate model including both EuroSCORE and baseline INVOS-derived rSO_2 identified each as an independent predictor of hospital mortality ($p = 0.0059$ and $p = 0.0417$, respectively), despite a strong correlation between the two predictors ($p < 0.0001$).[5]

Reanalysis of data from Kakemizu-Watanabe et al.[12] demonstrated that models incorporating both EuroSCORE and baseline INVOS-derived rSO_2 identified both as independent predictors ($p = 0.04128$ and $p = 0.00437$, respectively). Similarly, inclusion of both EuroSCORE and baseline NIRO-derived TOI yielded independent predictive value for both variables ($p = 0.00069$ and $p = 0.02660$, respectively), whereas in a model including EuroSCORE and baseline FORESIGHT-derived StO_2, only EuroSCORE remained significant ($p = 0.00004$ and $p = 0.30075$, respectively).

Collectively, these data suggest that the addition of baseline INVOS-derived rSO_2 may provide incremental prognostic value beyond established risk prediction models among currently available devices.

Study Limitations

This review has several limitations. First, the numbers of mortality events were relatively small in many of the included studies (Table 1),[5–11] which may limit the statistical robustness of the reported associations. Second, all studies were conducted at single centers, raising concerns regarding external validity. Indeed, the reported cutoff values of INVOS-derived rSO_2 for mortality prediction varied widely, ranging from 50% to 60% depending on the study population (Table 1),[3-5,8,11] underscoring the absence of universally applicable baseline thresholds and limiting immediate clinical implementation. Third, evidence regarding NIRS indices other than INVOS-derived rSO_2 remains scarce,[11] precluding definitive conclusions about the comparative prognostic performance of different devices. Fourth, we did not address important issues related to the efficacy of NIRS-guided interventions to improve patient outcomes,[20] as this was beyond the scope of the present review.

Conclusions

Current evidence suggests that the prognostic utility of baseline cerebral NIRS values for postoperative mortality prediction is supported primarily by studies using INVOS-derived rSO_2. More recently, baseline cerebral NIRS values measured with other devices, including NIRO-derived TOI and FORESIGHT-derived StO_2, have also been reported to be significantly associated with postoperative mortality following cardiac surgery. Nevertheless, INVOS-derived rSO_2 appears to demonstrate superior predictive performance, and incorporation of baseline rSO_2 into established risk prediction models may improve model discrimination. Further large-scale, prospective, and device-comparative studies are warranted to confirm these findings and to clarify the role of baseline cerebral NIRS monitoring in perioperative risk stratification.

Acknowledgements

The authors thank all the staff associated with cardiac surgery for their assistance in preparing this review.

Funding

The authors declare that no financial support was received for the preparation of this review.

Conflict of interest

The authors declare no competing interests.

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