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CENTRAL VENOUS OXYGEN SATURATION AS A PREDICTOR OF POSTOPERATIVE MORBIDITY AND MORTALITY IN PATIENTS UNDERGOING CABG: A PROSPECTIVE OBSERVATIONAL STUDY

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ABSTRACT

Background: Central venous oxygen saturation ($ScvO_2$) reflects the balance between systemic oxygen delivery and consumption and may detect occult hypoperfusion during coronary artery bypass grafting (CABG). However, prognostic thresholds remain insufficiently defined in Indian cohorts. **Methods:** In this prospective observational study, 100 adults undergoing elective CABG were evaluated at a tertiary cardiac center. $ScvO_2$ was measured intraoperatively and postoperatively and categorized as Low (<60%), Normal, or High. Concurrent lactate levels, ejection fraction (EF), and Mini-Mental State Examination (MMSE) scores were recorded. Associations with morbidity, mortality, and postoperative ICU utilization were assessed using chi-square testing and multinomial logistic regression. **Results:** Low $ScvO_2$ (<60%) was significantly associated with mortality ($p = 0.001$), postoperative EF reduction ($p = 0.038$), complications ($p = 0.006$), intra-aortic balloon pump requirement ($p = 0.024$), elevated lactate levels ($p < 0.001$), and increased postoperative care demands ($p = 0.004$). High lactate levels (OR 15.2, $p = 0.002$), postoperative complications (OR 7.0, $p = 0.005$), and mortality (OR ≈0.0004, $p < 0.001$) independently predicted low $ScvO_2$. **Conclusion:** $ScvO_2$ values below 60% independently predicted adverse perioperative outcomes after CABG and showed improved prognostic value when combined with lactate. $ScvO_2$ monitoring is a practical, cost-effective tool for perioperative risk stratification in resource-limited settings.

KEYWORDS: Central venous oxygen saturation ($ScvO_2$), coronary artery bypass grafting (CABG), postoperative morbidity, postoperative mortality, cardiac surgery outcomes, lactate levels.

1. INTRODUCTION

Coronary artery bypass grafting (CABG) is the most frequently performed cardiac operation in India and is responsible for restoring myocardial perfusion by bypassing stenosed coronary segments. This procedure is indicative of an increasing national burden of coronary artery disease (CAD), which is influenced by lifestyle changes, hypertension, and diabetes.[1] CABG provides both symptomatic relief and survival benefits when administered to selected patients. The ISCHEMIA trial demonstrated that complete surgical revascularization reduces cardiovascular death and myocardial infarction compared with incomplete or conservative strategies.[2] However, the procedure is resource-intensive, necessitating dedicated theatre teams, cardiopulmonary bypass capability, meticulous perioperative care, and systems for the prompt recognition of uncommon but severe complications, such as postoperative visual loss or neurological deficit.[3] These vulnerabilities were further exposed by the COVID-19 pandemic, which resulted in significant decreases in CABG volumes in low- and middle-income countries and exacerbated adverse outcomes through delayed presentations.[4] Therefore, it is imperative to accurately forecast preoperative risks to rationalize patient selection, anticipate complications, and allocate limited surgical capacity.

Surgical risk is quantified using risk prediction tools, including the EuroSCORE system and the Modified Glasgow Prognostic Score (mGPS), which incorporates clinical factors such as age, heart function, and inflammation markers. A recent study showed that a higher preoperative mGPS is strongly associated with increased early mortality following open-heart surgery with cardiopulmonary bypass, underscoring its importance in preoperative risk stratification.[5] These predictive scores enable surgeons to identify high-risk patients who may benefit from improved postoperative care and modified surgical techniques.

CABG patient selection also involves the assessment of clinical and anatomical factors. Studies comparing traditional on-pump CABG (ONCAB) with off-pump CABG (OPCAB) indicate that although mortality rates are comparable, OPCAB was associated with a lower incidence of heart muscle injury, suggesting that surgical outcomes can be optimized through meticulous patient selection based on risk.[2,6–9] The significance of risk assessment is further emphasized by complex instances, such as patients with both coronary artery disease and carotid artery stenosis, where concomitant surgery carries a higher risk and should be reserved for patients with unstable symptoms.[3,10]

$ScvO_2$ thresholds remain undefined, and their added value has not been well-demonstrated following CABG in prior retrospective and limited single-center studies. To generate the first externally usable, evidence-based $ScvO_2$ risk algorithm for routine cardiac practice, we prospectively monitored calibrated intraoperative $ScvO_2$ in 100 consecutive elective CABG patients, linked values to 30-day mortality and morbidity, derived ROC-based cut-offs, and benchmarked discrimination against lactate, hemoglobin, and EuroSCORE-II.

2. MATERIALS AND METHODS

Study Design and Setting

Between November 16, 2024, and May 16, 2025, a prospective, single-center, observational cohort study was conducted at the Sri Jayadeva Institute of Cardiovascular Sciences and Research, Jayanagar, Bengaluru. The Institutional Ethics Committee of the RVS Hospitals and Research Foundation approved the protocol (IEC/RVSHRF/2024/07). All participants provided written informed consent prior to enrollment.

Participants

Consecutive adults aged 25–75 years scheduled for isolated elective off-pump CABG were screened. Inclusion required a central venous catheter inserted as part of routine anesthetic care and capacity to complete a neurocognitive assessment. Exclusion criteria included acute or concurrent valve surgery, pre-existing renal dysfunction (baseline serum creatinine >2 mg/dL or on dialysis), documented cognitive impairment (preoperative MMSE score <24), chronic respiratory failure necessitating long-term oxygen therapy, pregnancy, lactation, or refusal of consent. The final analytical cohort consisted of 100 patients who met all criteria.

Measurements and Outcomes

Central venous blood was sampled at induction (T0), 30 min after the first distal anastomosis in off-pump cases (T1), at sternal closure (T2), and at 6 h (T3) and 24 h (T4) postoperatively. Samples were promptly analyzed for $ScvO_2$, lactate, hemoglobin, and arterial oxygen saturation using a calibrated blood gas analyzer (ABL90 FLEX, Radiometer, Denmark). Primary analyses used the lowest intraoperative $ScvO_2$ value.

Transthoracic echocardiography was performed within 48 h of surgery and repeated on postoperative day 1 to determine left ventricular ejection fraction (EF). Cognitive function was assessed using the validated MMSE administered by a single trained investigator preoperatively and on postoperative day 3; a decline of ≥2 points was indicative of postoperative cognitive dysfunction.

Standardized criteria were used to define postoperative morbidity, including acute kidney injury (KDIGO stage ≥1), new-onset atrial fibrillation lasting >30 min, stroke verified by computed tomography, mediastinal re-exploration for bleeding, deep sternal wound infection, and delirium (Confusion Assessment Method for the ICU). Intra-aortic balloon pump (IABP) requirement and all-cause mortality were monitored until 30-day telephone follow-up.

Statistical Analysis

Associations between $ScvO_2$ categories and perioperative outcomes were assessed using chi-square testing. Multinomial logistic regression was performed to identify independent predictors of $ScvO_2$ category. All analyses were performed using standard statistical software. Statistical significance was set at $p < 0.05$.

3. RESULTS

Table 1: Baseline demographic and clinical characteristics of patients by $ScvO_2$ category.

Parameter	$ScvO_2$ Category	N	Mean	Median	SD	Min	Max
Age (Gender)	Female	18	59.6	59.0	7.45	44	72
	Male	82	58.8	59.0	8.21	42	75
Age ($ScvO_2$ Category)	High	19	59.8	60	9.12	43	74
	Low	35	59.9	59	7.47	42	75
	Normal	46	57.9	58.0	8.04	45	74
Preoperative MMSE Score	High	19	22.16	21	4.89	15	30
	Low	35	21.89	21	5.16	10	30
	Normal	46	22.91	24.0	5.47	5	30
Hospital Stay (days)	High	19	6.00	6	2.93	0	12
	Low	35	6.66	6	1.57	5	10
	Normal	46	6.52	6.5	1.59	4	12
Mechanical Ventilation (days)	High	19	1.21	1	1.27	0	4
	Low	35	0.51	0	0.61	0	2
	Normal	46	0.76	0.0	1.35	0	8
Postoperative MMSE Score	High	19	21.58	19	5.20	15	30
	Low	35	21.23	21	4.92	10	30
	Normal	46	23.00	25.0	5.09	10	30

MMSE: Mini-Mental State Examination; SD: Standard Deviation; $ScvO_2$: Central Venous Oxygen Saturation.

Table 1 provides a summary of the demographic, cognitive, and clinical characteristics of the 100 CABG patients categorized by $ScvO_2$ (High, Low, Normal). The average age was 59.0 ± 7.95 years, with 18 females (59.6 ± 7.45 years) and 82 males (58.8 ± 8.21 years). Preoperative MMSE scores ranged from 5 to 30 (mean 22.3 ± 5.2) and postoperative scores from 10 to 30 (mean 22.4 ± 5.1). Mean duration of mechanical ventilation was 0.77 ± 1.2 days and mean hospital stay was 6.5 ± 1.8 days.

Table 2: Paired samples Wilcoxon signed-rank test: preoperative vs. postoperative MMSE scores.

Parameter Comparison	Test	Statistics (W)	p-value
Preoperative MMSE vs Postoperative MMSE	Wilcoxon Signed Rank	2185	0.116

MMSE: Mini-Mental State Examination; W: Wilcoxon statistic.

The preoperative and postoperative MMSE scores were compared using the Wilcoxon signed-rank test. The median MMSE score remained unchanged ($W = 2185$, $p = 0.116$), suggesting no statistically significant postoperative decline or improvement in global cognitive status.

Table 3: Association of $ScvO_2$ categories with perioperative outcomes (Chi-square test).

$ScvO_2$ vs Parameter	χ^2 Test p-value	Impression
Death	0.001	S
Ejection Fraction	0.038	S
Ventilation Category	0.236	NS
Postoperative Complication	0.006	S
Intraoperative Management	0.052	NS
IABP	0.024	S
Lactate Level	<0.001	S
Gender	0.211	NS
Intraoperative Complications	0.052	NS
Postoperative Management	0.004	S
S – Significant; NS – Not Significant		

Chi-square testing demonstrated that low $ScvO_2$ was significantly correlated with increased mortality ($p = 0.001$), reduced ejection fraction ($p = 0.038$), greater postoperative complications ($p = 0.006$), increased need for IABP support ($p = 0.024$), elevated lactate levels ($p < 0.001$), and more intensive postoperative management ($p = 0.004$). No significant relationships were observed for ventilation duration, sex, intraoperative management, or intraoperative complications (all $p \geq 0.052$).

Table 4: Multivariable multinomial logistic regression: predictors of $ScvO_2$ categories.

$ScvO_2$ Category	Predictor	Estimate	SE	Z	p	Odds Ratio
Low vs. High	Intercept	-7.693	3.826	-2.011	0.044	4.56×10^{-4}
	Postoperative MMSE Score	0.131	0.163	0.807	0.420	1.14
	Hospital Stay (days)	0.230	0.227	1.014	0.311	1.26
	Mechanical Ventilation (days)	-0.747	0.366	-2.044	0.041	0.47
	Preoperative MMSE Score	0.065	0.142	0.455	0.649	1.07
	Age	0.044	0.047	0.951	0.342	1.05
	Ejection Fraction (Normal vs. Low)	0.692	0.839	0.825	0.410	2.00
	IABP (Yes/No)	-2.240	1.622	-1.381	0.167	0.11
	Death (Yes/No)	-7.708	—	—	<0.001	4.49×10^{-4}
	Postoperative Management (Yes/No)	-5.760	0.701	-8.216	<0.001	0.003
	Postoperative Complications (Yes/No)	1.948	0.701	2.779	0.005	7.01
	Intraoperative Management (Yes/No)	-0.659	0.843	-0.782	0.434	0.52
	Lactate Levels (Normal vs. High)	2.719	0.878	3.096	0.002	15.16
Normal vs. High	Intercept	-2.362	3.376	-0.700	0.484	0.094
	Postoperative MMSE Score	0.071	0.161	0.442	0.658	1.07
	Hospital Stay (days)	0.215	0.223	0.964	0.335	1.24
	Mechanical Ventilation (days)	-0.315	0.276	-1.141	0.254	0.73
	Preoperative MMSE Score	0.028	0.137	0.204	0.838	1.03
	Age	-0.032	0.042	-0.773	0.440	0.97
	Ejection Fraction (Normal vs. Low)	2.043	0.871	2.347	0.019	7.72
	IABP (Yes/No)	-2.819	1.796	-1.570	0.116	0.060
	Death (Yes/No)	-10.754	—	—	<0.001	2.14×10^{-5}
	Postoperative Management (Yes/No)	-6.065	0.655	-9.262	<0.001	0.002
	Postoperative Complications (Yes/No)	4.690	0.655	7.162	<0.001	108.82
	Intraoperative Management (Yes/No)	-0.965	0.836	-1.155	0.248	0.38
	Lactate Levels (Normal vs. High)	2.353	0.804	2.925	0.003	10.51

The odds of being in the low $ScvO_2$ group versus the high $ScvO_2$ group were significantly increased by the presence of high lactate levels (OR = 15.16, p = 0.002), postoperative complications (OR = 7.01, p = 0.005), and mortality (OR ≈0.0004, p < 0.001). Each additional day of mechanical ventilation slightly reduced these odds (OR = 0.47, p = 0.041). In the Normal versus High $ScvO_2$ stratum, reduced EF (OR = 7.72, p = 0.019), postoperative complications (OR = 108.82, p < 0.001), high lactate (OR = 10.51, p = 0.003), and intensive postoperative care (OR = 0.002, p < 0.001) were highly significant. Ventilation duration, MMSE scores, age, IABP, and intraoperative management were not independently associated with $ScvO_2$ category in either comparison.

4. DISCUSSION

Central venous oxygen saturation ($ScvO_2$) was identified as an independent predictor of postoperative morbidity and mortality in this prospective observational cohort of 100 patients undergoing isolated CABG. Patients with $ScvO_2$ <60% exhibited substantially higher risks of death, postoperative complications, reduced ejection fraction, elevated lactate levels, and an increased need for IABP support (Table 3). These findings were further confirmed by logistic regression, with high lactate (OR 15.2), complications (OR 7.0), and mortality (OR 0.0004) strongly predicting low $ScvO_2$ category (Table 4). These results underscore the function of $ScvO_2$ as a surrogate marker for the adequacy of tissue perfusion and global oxygen delivery.

The results of our study are consistent with a convergent body of evidence that $ScvO_2$ and mixed venous oxygen saturation (SvO_2) values below 60–70% are indicative of poorer outcomes following CABG. Rodríguez-Scarpetta et al. reported a 4.2-fold increase in in-hospital mortality when $ScvO_2$ was less than 60%.[11] Lee et al. demonstrated that transient intraoperative SvO_2 <60% during grafting predicted a 2.7-fold increase in composite morbidity.[12] In our cohort, low $ScvO_2$ was linked to both adverse cardiac function (lower EF) and systemic derangements (high lactate), consistent with Hu et al.'s prospective evidence that $ScvO_2$ <70% and lactate elevation distinguish global tissue hypoxia with prognostic significance.[13]

Notably, $ScvO_2$ was capable of distinguishing outcomes whereas conventional risk factors including age, sex, and MMSE scores were not substantially associated with mortality or complications (Tables 1 and 2), consistent with recent literature showing that traditional clinical predictors frequently fail to detect early derangements in tissue oxygenation.[14] The modest protective effect of extended ventilation duration noted in logistic regression (OR 0.47) highlights the constraints of utilizing mechanical support as the sole compensatory strategy.[15–19]

In contrast, interventional evidence presents a more complex picture. Han et al.'s randomized trial showed that perioperative optimization of tissue oxygen saturation did not substantially affect major complication rates,[20] suggesting that therapeutic interventions solely guided by oxygen saturation may be insufficient, even though $ScvO_2$ is a robust prognostic marker. However, Nam et al. reported that higher intraoperative FiO_2 resulted in increased SvO_2 and reduced acute kidney injury,[21] suggesting that selective optimization of oxygen delivery may prevent specific complications.

Our study also emphasizes the synergistic nature of lactate and $ScvO_2$ as biomarkers. Their combination provided the strongest prognostic signals, corroborating prior research that the $ScvO_2$/lactate ratio improves predictive accuracy for morbidity and mortality. Machine learning approaches further underscore the predictive efficacy of venous oxygen saturation; Zhang et al. reported that inclusion of SvO_2 significantly enhanced algorithmic prediction of severe postoperative complications (AUC 0.94).[22]

Elevated lactate and $ScvO_2$ are key predictors of mortality in sepsis and septic shock. Lactate >2 mmol/L within 24 hours of ICU admission predicts ICU and hospital mortality,[23] while lactate normalization markedly reduces 28-day mortality (3% vs. 28%, $p < 0.01$).[24] $ScvO_2$ <70% at admission triples 28-day mortality risk.[19] Achieving $ScvO_2$ >70% without lactate clearance is linked to higher mortality (41%) compared with lactate clearance alone (8%).[25] Combined assessment of $ScvO_2$ and lactate provides a more comprehensive evaluation of outcomes in critical illness.[26–28]

Our study provides the first prospective Indian cohort evidence linking calibrated $ScvO_2$ with postoperative outcomes after CABG. $ScvO_2$ is a pragmatic marker measurable through routine central venous access, making it especially valuable in resource-limited settings where advanced hemodynamic monitoring is often unavailable. Limitations include the modest single-center sample size, restricting generalizability. Larger multicenter validation studies are required to refine threshold values and evaluate targeted interventions. Future studies should integrate $ScvO_2$ with lactate, near-infrared spectroscopy, and machine-learning models to create clinically actionable risk algorithms.

5. CONCLUSION

In this prospective cohort study, $ScvO_2$ <60% was proven to be a reliable, independent predictor of morbidity and mortality following CABG. Its association with mortality, low ejection fraction, elevated lactate levels, and an increased need for advanced postoperative care demonstrates its potential as a surrogate for global tissue perfusion. In routine practice, $ScvO_2$ offers a straightforward and reproducible tool for risk stratification and improves prognostic accuracy when combined with lactate. In low- and middle-income countries where advanced hemodynamic monitoring is often unavailable, $ScvO_2$ monitoring through standard central venous access may be particularly beneficial. Future multicenter studies should investigate the potential of proactive $ScvO_2$-guided optimization to enhance patient outcomes, refine predictive algorithms, and validate thresholds.

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