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Original article

The Role of Central Venous Oxygen Saturation as a Predictor of Outcome after Valve Replacement

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Abstract

Background: The nonregenerative valve replacements have been developed to ensure long term functionality upon implantation without possibility of integration, remodeling, or growth. **This study aimed to** assess the role of central venous oxygen saturation ($ScvO_2$) as a predictor of outcome after valve replacement. **Methods:** This prospective cross-sectional study was conducted on 50 patients who underwent valve replacement. All studied cases underwent history taking and demographic data collection, hemodynamic parameters and routine investigations. **Results**: There was a statistically significant negative correlation between $ScvO_2$ level on induction and 48h. postoperative with MV duration, while its level on induction only was negatively correlated with ICU length of stay. There was high sensitivity of ScvO2 level in prediction of unfavorable outcome on induction of anesthesia (84.6%) and 48 hours postoperative (74.4%) at cut off < 75.5 & 73.5 respectively, with significant high-test accuracy of 80% and 70% respectively. **Conclusion:** $ScvO_2$ is a valuable predictor of outcomes in patients undergoing valve replacement surgery. Significant changes in ScvO2 levels over time were strongly associated with ICU length of stay and duration of mechanical ventilation, with lower ScvO2 levels on induction and at 48 hours postoperatively correlating with worse outcomes, such as longer ICU stays and prolonged mechanical ventilation. These findings suggest that monitoring ScvO2 could aid in early identification of patients at risk of complications and unfavorable outcomes, potentially guiding more targeted postoperative care.

Keywords: Central venous Oxygen saturation, Predictor, Outcome, Valve Replacement

Introduction

Aging, rheumatic heart diseases, and the growing prevalence of heart and vascular system conditions increased the incidence of severe valvular dysfunctions that require surgically implanted valve replacements (1). Due to their durability, mechanical valves are the gold standard treatment for patients up to 60 years, even though the life-long anticoagulant treatment required to prevent thrombosis reduces the patient's quality of life (2).

Valvular heart disease (VHD) is an increasing health problem in both developed and developing countries and is associated with aging of the population and congenital malfunction (3). Generally, VHDs are characterized by stenosis and/or regurgitation due to an improper opening and closing mechanism caused by the degeneration and/or calcification of the leaflets (4). In case of severe valvular dysfunction, the replacement of the valve is the most effective solution and is currently performed over 300,000 times each year worldwide (5). In approximately 55% of the cases a mechanical valve is used, and for the remaining 45% a bioprosthetic valve is chosen. Besides the individual advantages and disadvantages of these valve replacements, their major drawback is the lack of regeneration potential (4).

The nonregenerative valve replacements have been developed to ensure long term functionality upon implantation without possibility of integration, remodeling, or growth. Due to this major drawback, in particular young patients have to undergo multiple surgeries and redo interventions to replace the valve substitute over their lifetime, with an increasing risk of morbidity and mortality (6).

Central venous oxygen saturation ($ScvO_2$) is a level of oxygen saturation measured from the superior vena cava. Its value is the balance between oxygen delivery and oxygen consumption (VO_2), indicating how much oxygen remains after delivery to the cells. The physiological value is greater than 70%. This is also the last goal to be achieved according to the early goal-directed therapy. $ScvO_2$ is used to indicate an adequate level of oxygenation at the cellular level (7). Because $ScvO_2$ changes rapidly, frequent measurement of $ScvO_2$ must be used after an intervention is implemented. However, no difference in mortality was found between intermittent and continuous $ScvO_2$ monitoring (8).

The purpose of this study was to assess the role of $ScvO_2$ as a predictor of outcome after valve replacement.

Patients and methods

This prospective cross-sectional study was conducted on 50 patients who underwent valve replacement attending the Cardiothoracic surgery Department at Benha University Hospital from September 2023 to September 2024

An informed written consent was obtained from the patients. Every patient received an explanation of the purpose of the study and had a secret code number. The study was done after being approved by the Research Ethics Committee, Faculty of Medicine, Benha University (**MS 27-9-2023**).

Inclusion criteria were all patients above 18 years old, both sexes, and those undergoing valve replacement.

Exclusion criteria were concomitant coronary artery bypass graft surgery or other cardiac operations, and simultaneous repair of complex congenital heart defects.

All studied cases were subjected to the following: History taking and Demographic data collection including: [Age, gender, and smoking]. **Hemodynamic parameters**: **[**blood pressure, O_2 saturation, pulse, temperature, respiratory rate]. **Anthropometric measures:** [weight, height, and BMI]. Cardiac and abdominal examination, number of patients who received vasopressor drugs, evaluation of acute physiology and chronic health evaluation (APACHE II)**,** Glasco coma scale (GCS) (9) and SOFA (10). **Routine investigations including:** [Complete blood count, C-reactive protein, erythrocyte sedimentation, hematocrit, platelet count, prothrombin time, activated partial thromboplastin time, antithrombin, serum creatinine value, venous blood gas, and lactate level].

Technique:

Venous blood gas samples were obtained from the central venous cannula, respectively, using a pre-heparinized 3-mL BG syringe. Maintenance, calibration, and quality control are performed on a regular basis by the central hospital laboratory. According to the manufacturer, the coefficient of variation for the PO_2 for the range of $PcvO_2$ was 1.66 to 3.31% and the coefficient of variation for Co-oximetry_$ScvO_2$ was 0.2 to 0.6%. The dead-space was 1.9 mL for the venous system.

Outcomes of the study:

The outcome included duration of mechanical ventilation (days), mechanical ventilation parameters as positive end-expiratory pressure; tidal volume: dynamic compliance; arterial pressure/oxygen fraction ratio, duration of ICU stay (days), morbidity (pneumonia, wound infection, renal or hepatic insufficiency), and mortality in ICU.

Statistical analysis

Statistical analysis was done by SPSS v27 (IBM©, Chicago, IL, USA). The Shapiro-Wilks test and histograms were used to evaluate the normality of the distribution of data. Quantitative parametric data were presented as mean and standard deviation (SD) and were analyzed by ANOVA (F) test with post hoc test (Tukey). Quantitative non-parametric data were presented as median and interquartile range (IQR) and were analyzed by Kruskal-Walli's test with Mann Whitney-test to compare each group. Qualitative variables were presented as frequency and percentage (%) and were analyzed utilizing the Chi-square test. A two tailed P value < 0.05 was considered statistically significant.

Results

Table 1 shows the basic demographic data, preoperative vital signs and laboratory investigations. ABGs assessed preoperative among studied group, mean of PH (7.38±0.12), PaCO2 40 ± 5.23, PaO2 78.9± 25.5 and Spo2 95.1± 3. 34. The levels of central venous oxygen assessed on three times, first on anesthesia induction with mean of 82.4%, second 24 hours postoperative with mean of 76.3% and finally 48 hours postoperative with mean of 85.9%.

Table 2 shows vital signs, laboratory investigations, and ABG assessed postoperative among studied groups. ICU length of stay among studied group with mean of 2.47 days ranged from 1 to 4 days, and duration of respiratory support on mechanical ventilation ranged from 6 to 20 hours. Mortality rate was 16%. 11 cases (22%) suffered of postoperative complications, 6 cases had pneumonia, 3 cases had wound infection and renal insufficiency in two cases.

Table 3 shows that patients stayed in ICU for less than for less than 2 days had significant p-value <0.001 and patients stayed for more than 2 days had a non-significant p-value 0.342 indicating more significant change in central venous oxygen saturation in patients with favourable outcome, with significant increase in ScvO2 among them on induction 24 h. and 48 h. postoperative. Patients stayed on mechanical ventilation less than 2 days had significant p-value 0.003 and patients stayed on mechanical ventilation more than 2 days had a non-significant p-value 0.542 indicating more significant change in central venous oxygen saturation in patients with favourable outcome, with significant increase in ScvO2 among them on induction and 48 h. postoperative.

There was a statistically significant negative correlation between ScvO2 level on induction and 48h. postoperative with MV duration, while its level on induction only was negatively correlated with ICU length of stay. **Table 4**

There was high sensitivity of $ScvO_2$ level in prediction of unfavourable outcome on induction of anaesthesia (84.6%) and 48 hours postoperative (74.4%) at cut off < 75.5 & 73.5 respectively, with significant high-test accuracy of 80% and 70% respectively. **Figure 1**

Table 1: Basic demographic data, vital signs, laboratory data, ABG, and central venous oxygen saturation of the studied group

		Group N=50	
		Mean ± SD	
Age (years)		50.2 ± 11.2	
Range		43-75	
Weight (kg)		85.6 ± 11.2	
Range		80-93	
BMI (Kg/m^2)		28.2 ± 2.82	
Range		26-31	
		N	**%**
Gender	**Male**	31	62.0
	Female	19	38.0
Smoking state	**Non smoker**	19	38.0
	Ex-smoker	17	34.0
	Smoker	14	28.0
Vital signs			
Systolic BP (mm\Hg)		120 ± 15.2	
Diastolic BP (mm\Hg)		78 ± 11.8	
RR		30.4 ± 5.37	
Pulse (mins)		92.1 ± 11.9	
Temperature (ºC)		37.3 ± 0.48	
Laboratory data			
Hb (g/dl)		13.6 ± 1.97	
RBCs (million/mm3)		5.28 ± 1.13	
WBCs (mm3)		10.8 ± 4.98	
HCT (L/L)		44.7 ± 7.27	
Platelets (mcL)		285.8 ± 97.1	
Albumin (g/dL)		3.85 ± 0.48	
ALT (U/L)		29.8 ± 40.72	
AST (U/L)		22.4 ± 10.59	
Urea (mmol/L)		71.6 ± 63.8	
Creatinine (µmol/L)		1.16 ± 0.71	
ABG			
PH		7.38 ± 0.12	
$PaCO_2$ (mm\Hg)		40 ± 5.23	
PaO_2 (mm\Hg)		78.9 ± 25.5	
SPo_2 (%)		95.1 ± 3.34	
$ScvO_2$ (%)			
On induction		82.4 ± 3.42	
24 h. postoperative		76.3 ± 3.67	
48 h. postoperative		85.9 ± 4.55	

BMI: body mass index, BP: blood pressure, RR: respiratory rate, Hb: hemoglobin, RBCs: red blood cells, WBCs: white blood cells, HCT: hematocrit, ALT: alanine transaminase, AST: aspartate transaminase, $PaCO_2$: partial pressure of arterial carbon dioxide, PaO_2: partial pressure of oxygen, SPo_2: Oxygen saturation, $ScvO_2$: Central venous oxygen saturation

Table 2: Vital signs assessed, Laboratory data, and ABG postoperative and ICU stay and mechanical ventilation, and outcome among studied group

		Studied group N=50
		Mean ± SD
Systolic BP (mm\Hg)		125 ± 15.2
Diastolic BP (mm\Hg)		80 ± 11.8
RR		21.4 ± 3.37
Pulse (mins)		92.1 ± 11.9
Temperature (ºC)		38.3 ± 0.48
Laboratory data		
Hb (g\dl)		10.2 ± 1.97
RBCs (cells/mcL)		4.28 ± 2.13
WBCs (mm3)		11.8 ± 4.98
HCT (L/L)		41.7 ± 5.27
Platelets (mcL)		285.8 ± 97.1
Albumin (g/dL)		3.65 ± 0.58
ALT (U/L)		26.5 ± 4.52
AST (U/L)		21.4 ± 3.39
Urea (mmol/L)		70.6 ± 3.18
Creatinine (μmol/L)		1.06 ± 0.31
ABG		
PH (mm\Hg)		7.28 ± 0.12
$PaCO_2$ (mm\Hg)		44.2 ± 7.23
PaO_2 (mm\Hg)		76.9 ± 5.35
SPo_2 (%)		92.1 ± 5.34
ICU duration\ days	**Mean ± SD**	2.47 ± 0.81
	Median (Range)	2 (1-4)
MV\ days	**Mean ± SD**	9.55 ± 5.15
	Median (Range	8 (6-20)
Outcome		
Mortality		8 (16%)
Complications		
Yes		11 (22%)
No		39 (78.4%)
Pneumonia		6 (12%)
Wound infection		3 (6%)
Renal insufficiency		2 (4%)

RR: Respiratory rate, BP: Blood pressure, ICU: intensive care unit, MV: mechanical ventilation.

Table 3: Relation between $ScvO_2$ and ICU length of stay, and MV duration, among studied group

	Studied group N=50			P2
	On induction	**24 h. post-operative**	**48 h. postoperative**	
		ICU length of stay		
<2 days N=22	83.5 ± 3.31	77.4 ± 4.25	84.8 ± 4.38	<0.001 HS
>2 days N=28	77.4 ± 2.65	73.8 ± 3.15	74.7 ± 3.96	0.342 NS
P1	<0.001 HS	0.026 S	0.002 S	
		MV duration\ days		
<12 hours (n=20)	83.8 ± 3.11	76.8 ± 4.15	85.8 ± 4.78	0.003 S
>12 hours (n=30)	77.9 ± 3.81	71.1 ± 3.44	73.8 ± 4.29	0.542 NS
P1	0.01 S	0.016 S	0.002 S	

ICU: intensive care unit, MV: mechanical ventilation, S: P-value<0.05 is significant, HS: P-value<0.001 is high significant, NS: P-value>0.05 is not significant, P1: significance between 2 groups (Independent sample t-test), P2: for change over same group (ANOVA test)

Table 4: Correlations between ScvO2 & MV support time & ICU length of stay

	ScvO2 (%)		
	On induction	**24 h. postoperative r (P-value)**	**48 h. postoperative**
ICU length of stay	-0.455 (0.02) *	-0.199 (0.401)	-0.401 (0.07)
MV duration	-0.633 (0.004) *	-0.239 (0.302)	-0.505 (0.02) *

ICU: intensive care unit, MV: mechanical ventilation, r: Pearson`s Correlation test, * statistical significance p-value<0,05

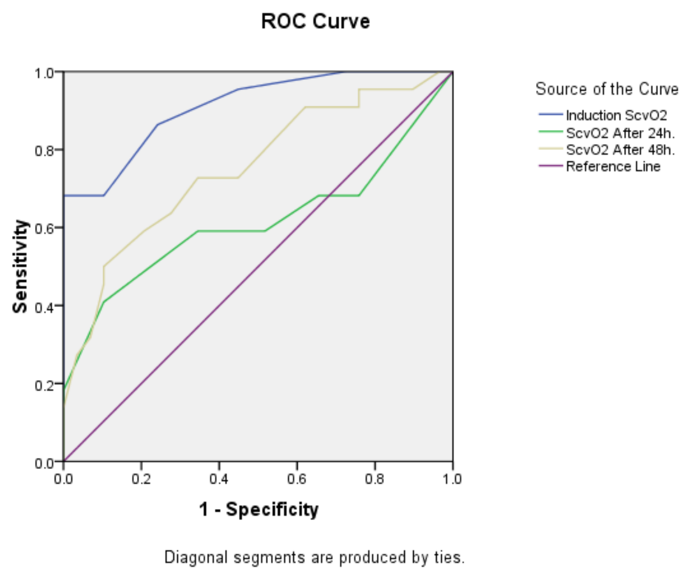

Figure 1: Receiver Operating characteristics (ROC) curve for ScvO2 analysis as a predictor of unfavorable outcome among studied group

Discussion

Our study population consisted of 50 patients with a mean age of 50.2 ± 11.2 years, ranging from 43 to 75 years. The majority (62%) were males, and the mean BMI was 28.2 ± 2.82 Kg/m^2, indicating that most patients were overweight.

These demographic characteristics are similar to those reported in other studies on valve replacement surgery. For instance, a study by Mahrous et al. (11) reported a mean age of 50.39 years and 56% male patients in their open cardiac surgery cohort.

In our study, the smoking status of our patients (28% smokers, 34% ex-smokers, and 38% non-smokers) highlights the importance of considering smoking as a risk factor in cardiac surgery outcomes.

This distribution is comparable to that reported by Agarwal et al. (12), who found that 24% of their valve replacement patients were current smokers.

In our study, the preoperative vital signs and laboratory data were within expected ranges for patients undergoing cardiac surgery. The mean hemoglobin level of 13.6 ± 1.97 mg/dl suggests that most patients were not anemic preoperatively, which is favorable for cardiac surgery outcomes.

This is in line with the findings of Mufti et al. (13), who reported that preoperative anemia was associated with poorer outcomes in cardiac surgery.

In our study, the mean $ScvO_2$ on induction was 82.4 ± 3.42%, which decreased to 76.3 ± 3.67% at 24 hours postoperatively, and then increased to 85.9 ± 4.55% at 48 hours postoperatively. This pattern of change in $ScvO_2$ is interesting and may reflect the physiological stress of surgery followed by recovery.

Our findings are similar to those reported by Pearse et al. (14), who also observed a decrease in $ScvO_2$ in the immediate postoperative period followed by an increase as patients recovered. They suggested that this pattern could be used as an indicator of postoperative recovery in cardiac surgery patients.

In our study, ICU length of stay among studied group with mean of 2.47 days ranged from 1 to 4 days, and duration of respiratory support on mechanical ventilation ranged from 6 to 20 hours.

The mortality rate in our study was 16%, with 22% of patients experiencing postoperative complications. The most common complication was pneumonia (12%), followed by wound infection (6%) and renal insufficiency (4%).

These complication rates are slightly higher than those reported by some other studies. For instance, von Bardeleben et al. (15) reported a mortality rate of 12% and an overall complication rate of 18% in their valve replacement cohort. The higher rates in our study may be due to differences in patient characteristics or perioperative management and warrant further investigation.

One of the key findings of our study is the relationship between $ScvO_2$ levels and patient outcomes. Patients with an ICU stay of less than 6 days showed significant changes in ScvO2 over time ($p<0.001$), while those with longer ICU stays did not ($p=0.342$). Similarly, patients who required mechanical ventilation for less than 2 days showed significant changes in $ScvO_2$ ($p=0.003$), while those with longer ventilation times did not ($p=0.542$). These findings suggest that the pattern of change in $ScvO_2$ may be a useful predictor of postoperative course. Patients who show a significant decrease in $ScvO_2$ at 24 hours followed by a significant increase at 48 hours appear to have better outcomes. This is supported by our correlation analysis, which showed significant negative correlations between $ScvO_2$ levels and both ICU length of stay and mechanical ventilation duration.

Our results are in line with those Mahrous et al. (11) who reported that, $ScvO_2$ in correlation to ICU length of stay showed patients stayed in the ICU less than 48 hours had significant p-value < 0.001 and patients stayed in the ICU more than 48 hours had a non-significant p-value 0.693 indicating more significant change in $ScvO_2$ in patients with favorable outcome. They found that $ScvO_2$ in correlation to postoperative duration of mechanical ventilation showed patients stayed on mechanical ventilation less than 12 hours had significant p-value 0.004 and patients stayed on mechanical ventilation more than 12 hours had a non-significant p-value 0.724 indicating more significant change in central venous oxygen saturation in patients with favorable outcome.

Our study showed a high sensitivity of ScvO2 level in prediction of unfavorable outcome on induction of anesthesia (86.4%) and 48 hours postoperative (73.4%) at cut off < 73.5 & 71.5 respectively, with significant high-test accuracy of 80% and 68% respectively.

In agreement with the literature, Miranda et al. (16) revealed similar intraoperative findings to those reported postoperatively, with a significantly higher proportion of patients with intraoperative $ScvO_2$ < 70% in the non-survivor group (31.8% vs. 13.1% in the survivor group; $p = 0.046$). The most important findings of their study were the association between early intraoperative $ScvO_2$ < 70% and risk of death, while $ScvO_2$ > 80% over the same period did not mean greater risk of mortality. Therefore, considering that the multiple logistic regression analysis model confirmed that $ScvO_2$ < 70% after anesthetic induction is an independent risk factor associated with mortality (OR = 2.94; $p = 0.032$), they strongly emphasize that patients with early intraoperative values below 70% requires efforts to improve tissue perfusion. Thus, the optimization of blood volume, cardiac output and/or hemoglobin should be considered. This recommendation is based on the Fick equation, which states that $ScvO_2$ is a passive variable determined by arterial oxygen saturation, hemoglobin, cardiac output, and oxygen consumption.

However, Balzer et al. (17) showed that high $ScvO_2$ levels on ICU admission indicate a greater risk than low levels. They found that rate of mortality and complication increased in patients with ScvO2 above 80% in patients after cardiac surgery. This phenomenon could be the result of inadequate oxygen uptake due to vasoconstriction or cytopathic hypoxia (18).

Conclusion

Our study demonstrated that central venous oxygen saturation (ScvO2) is a valuable predictor of outcomes in patients undergoing valve replacement surgery. Significant changes in ScvO2 levels over time were strongly associated with ICU length of stay and duration of mechanical ventilation, with lower ScvO2 levels on induction and at 48 hours postoperatively correlating with worse outcomes, such as longer ICU stays and prolonged mechanical ventilation. ScvO2 showed high sensitivity in predicting unfavorable outcomes, particularly at induction and 48 hours post-surgery, with cut-off values of <73.5% and <71.5%, respectively. These findings suggest that monitoring ScvO2 could aid in early identification of patients at risk of complications and unfavorable outcomes, potentially guiding more targeted postoperative care.

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