



CLINICAL RESEARCH

Perioperative central venous oxygen saturation and its correlation with mortality during cardiac surgery: an observational prospective study



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Abstract

Background: Cardiac surgery can produce persistent deficit in the ratio of Oxygen Delivery (DO_2) to Oxygen Consumption (VO_2). Central venous oxygen Saturation ($ScvO_2$) is an accessible and indirect measure of DO_2/VO_2 ratio.

Objective: To monitor perioperative $ScvO_2$ and assess its correlation with mortality during cardiac surgery.

Methods: This prospective observational study evaluated 273 patients undergoing cardiac surgery. Blood gas samples were collected to measure $ScvO_2$ at three time points: T0 (after anesthetic induction), T1 (end of surgery), and T2 (24 hours after surgery). The patients were divided into two groups (survivors and nonsurvivors). The following outcomes were analyzed: intrahospital mortality, length of Intensive Care Unit (ICU) and hospital stay (LOS), and variation in $ScvO_2$.

Results: Of the 273 patients, 251 (92%) survived and 22 (8%) did not. There was a significant perioperative reduction of $ScvO_2$ in both survivors ($T0 = 78\% \pm 8.1\%$, $T1 = 75.4\% \pm 7.5\%$, and $T2 = 68.5\% \pm 9\%$; $p < 0.001$) and nonsurvivors ($T0 = 74.4\% \pm 8.7\%$, $T1 = 75.4\% \pm 7.7\%$, and $T2 = 66.7\% \pm 13.1\%$; $p < 0.001$). At T0, the percentage of patients with $ScvO_2 < 70\%$ was greater in the nonsurvivor group (31.8% vs. 13.1%; $p = 0.046$) and the multiple logistic regression showed that $ScvO_2$ is an independent risk factor associated with death, $OR = 2.94$ (95% CI 1.10–7.89) ($p = 0.032$). The length of ICU and LOS were 3.6 ± 3.1 and 7.4 ± 6.0 days respectively and was not significantly associated with $ScvO_2$.

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PALAVRAS-CHAVE

Procedimentos de cirurgia cardíaca;
Mortalidade;
Cuidado perioperatório;
Análise de gases no sangue;
Cateterismo venoso

Conclusions: Early intraoperative ScvO₂ < 70% indicated a higher risk of death. A perioperative reduction of ScvO₂ was observed in patients undergoing cardiac surgery, with high intraoperative and lower postoperative levels.

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Correlação entre saturação venosa central de oxigênio perioperatória e mortalidade em cirurgia cardíaca: estudo prospectivo observacional

Resumo

Justificativa: A cirurgia cardíaca pode produzir déficit persistente na razão entre oferta (DO₂) e consumo de oxigênio (VO₂). A Saturação venosa central de Oxigênio (SvcO₂) é uma medida acessível e indireta da razão DO₂/VO₂.

Objetivo: Monitorar a SvcO₂ perioperatória e avaliar sua correlação com a mortalidade em cirurgia cardíaca.

Método: Este estudo observacional prospectivo avaliou 273 pacientes submetidos a cirurgia cardíaca. Coletamos amostras de sangue para medir a SvcO₂ em três momentos: T0 (após indução anestésica), T1 (final da cirurgia) e T2 (24 horas após a cirurgia). Os pacientes foram divididos em dois grupos (sobreviventes e não sobreviventes). Os seguintes desfechos foram analisados: mortalidade intra-hospitalar, tempo de permanência na Unidade de Terapia Intensiva (UTI) e de internação hospitalar, e variação na SvcO₂.

Resultados: Dos 273 pacientes, 251 (92%) sobreviveram e 22 (8%) não. Houve queda significativa da SvcO₂ perioperatória nos sobreviventes (T0 = 78% ± 8,1%, T1 = 75,4% ± 7,5% e T2 = 68,5% ± 9%; *p* < 0,001) e nos não sobreviventes (T0 = 74,4% ± 8,7%, T1 = 75,4% ± 7,7% e T2 = 66,7% ± 13,1%; *p* < 0,001). No T0, a porcentagem de pacientes com SvcO₂ < 70% foi maior no grupo não sobrevivente (31,8% vs. 13,1%; *p* = 0,046) e a regressão logística múltipla mostrou que a SvcO₂ é um fator de risco independente associado ao óbito, OR = 2,94 (95% IC 1,10– 7,89) (*p* = 0,032). O tempo de permanência na UTI e de hospitalização foi de 3,6 ± 3,1 e 7,4 ± 6,0 dias, respectivamente, e não foi significativamente associado à SvcO₂.

Conclusões: Valores precoces de SvcO₂ intraoperatória < 70% indicaram maior risco de óbito em pacientes submetidos à cirurgia cardíaca. Observamos redução perioperatória da SvcO₂, com valores maiores no intraoperatório e menores no pós-operatório.

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Introduction

A persistent deficit in the ratio of Oxygen Delivery (DO₂) to oxygen consumption (VO₂) leads to multiple organ failure and death.¹ Cardiac surgery is an important risk factor for this deficit, as it can increase oxygen consumption and also cause hemorrhage and myocardial dysfunction.¹⁻³ Thus, monitoring tissue oxygenation is essential to ensure the adequacy of perfusion in this scenario.

Tissue oxygenation can be indirectly evaluated using the oxygen extraction ratio, which is derived by measuring the mixed venous saturation (SvO₂).⁴ As SvO₂ is obtained by pulmonary artery catheterization, central venous Oxygen Saturation (ScvO₂), which is measured in the superior vena cava or the right atrium, has been suggested as a reliable substitute.^{5,6} Despite ongoing debate about the feasibility of this substitute, ScvO₂ is commonly used in place of SvO₂ because the current literature discourages the use of pulmonary artery catheters.⁷ Furthermore, a central venous

catheter is less complex, less costly, and is routinely used during cardiac surgery.

The use of ScvO₂ as a parameter of hemodynamic optimization has gained importance following the study of Rivers et al. that established values > 70% as the target for management of septic patients.⁸ In patients scheduled for cardiac surgery, some studies indicate that ScvO₂ levels < 70% on admission to the Intensive Care Unit (ICU) are associated with a higher risk of death.⁹ Other authors suggest that ScvO₂ levels > 80% pose a higher risk of death than lower levels.¹⁰ However, the normal intraoperative level of ScvO₂ is yet to be defined.³ In addition, the relationship of ScvO₂ levels at each specific perioperative stage with mortality during cardiac surgery is not fully understood; this makes their interpretation context-dependent.¹ Therefore, it is necessary to study in detail the characteristics and course of this easily accessible variable, which guides patient management and can improve perioperative tissue perfusion.

This study aimed to observe the perioperative levels of ScvO₂ and their correlation with mortality in patients undergoing cardiac surgery.

Methods

This prospective, observational, single-center study was conducted between April 2015 and January 2018. This study was approved by the Ethics Committee of the School of Medicine of Jundiaí and by the Brazilian Ministry of Health (n^o 1.266.057), and is in accordance with the ethical standards of the Declaration of Helsinki and adheres to all Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement guidelines.

Adult patients (> 18 years) scheduled for elective cardiac procedures like myocardial revascularization, valve replacement, myxoma resection, or thoracic aortic aneurysm repair were included. All study participants were required to sign a free informed consent form. We excluded patients with infections or any type of arteriovenous shunt (interatrial or interventricular communication, arteriovenous fistula etc.) and those who died before completing 24 hours after surgery or had incomplete postoperative follow-up.

The anesthetic technique was general anesthesia with sufentanil administered as a target-controlled infusion (Gepts model) at plasma concentrations of 0.5–1.8 ng.mL⁻¹ (the sufentanil dose was decided according to the surgical stimulus), etomidate, rocuronium, midazolam, and sevoflurane. The patients were monitored using cardiocscope, pulse oximetry, invasive blood pressure monitoring, capnography, oropharyngeal thermometer, and bispectral index monitoring. The following vasoactive drugs were used according to the need of each patient: dobutamine, sodium nitropruside, and noradrenaline. All patients were admitted to the ICU while still anesthetized and administered mechanical ventilation. The target was to extubate the patients within 6 hours after surgery.

Venous blood samples were collected through a central venous access, obtained after anesthesia induction, at three time points during the perioperative period:

T0 – after anesthetic induction with the patient under mechanical ventilation and without suffering surgical trauma.

T1 – at the end of surgery, with the patient anesthetized and under mechanical ventilation.

T2 – 24 hours after surgery.

The patients were allocated into two groups: survivors and nonsurvivors. Considering that in the current literature some authors consider ScvO₂ < 70% a risk factor, while others consider ScvO₂ > 80% to mean even greater risk, these two groups were further divided into three subgroups according to the ScvO₂ levels at the three time points: Normal (N) – ScvO₂ 70–79.9%, Low (L) – ScvO₂ < 70%, and High (H) – ScvO₂ ≥ 80%. The samples were collected using the BD A-Line[®] syringe (Plymouth, UK) and analyzed using the GEM[®] Premier 3500 system (Werfen, MA, USA). The calibration was validated with the GEM[®] Calibration Validation Product (CVP) Multipak (Werfen, MA, USA). The samples were analyzed immediately after collection according to the method recommended by the clinical analysis laboratory team. In addition to ScvO₂, hemoglobin levels and arterial oxygen sat-

uration were also measured from arterial blood gas samples collected concomitantly with the venous blood gas samples, since these factors also influence ScvO₂ levels.

The following outcomes were observed: perioperative variation in ScvO₂, intrahospital mortality during this hospitalization, and length of ICU and hospital stay for patients who survived.

Statistical analysis

Considering a prevalence of death of 26%,¹¹ a margin of error (absolute difference) of 6% and a probability of type I error (alpha) preset at 5%, the sample size resulted in 205 cases. All patients that attended the inclusion criteria were enrolled in the present study.

The SPSS v.13.0 software (IBM; Armonk, New York, United States) was used for statistical analysis, with the level of significance set at 5% (*p* < 0.05). Age was compared using the Student *t*-test for independent samples. EuroSCORE II was compared using Mann-Whitney test. For gender and type of surgery, the Chi-Squared test with Yates' correction for continuity or Fisher's exact test was applied.

To compare the ScvO₂ at T0, T1, and T2, repeated multivariate analyses of variance (MANOVA) were applied separately to each group. Pairwise internal comparisons between time points were performed using the Student *t*-test for related groups. For hemoglobin, the nonparametric Kruskal-Wallis test was used to compare T0, T1, and T2 and the Wilcoxon test for pairwise internal comparison between the time points. Pearson's Chi-Squared test was applied to compare the distribution of patients according to ScvO₂ category (low, normal, and high). Multiple logistic regression model was applied considering four independent variables as possible predictors of death: SvcO₂, age, hemoglobin and EuroSCORE II. These variables were chosen because they presented significant results. There are still other reasons for the selection of these variables: hemoglobin is an important determinant of the SvcO₂, in addition of being a known variable that influences outcomes. Age was also assessed because it showed a significant difference between the two groups. EuroSCORE II was used because it is a tool that gathers different clinical characteristics that provide risk of death and turns them into objective and measurable data. Therefore, the objective of including such variables was to assess whether conditions such as anemia, age, and clinical condition were confounding factors in the analysis of mortality. The criterion for selecting variables was the forward stepwise considering a *p*-value of 0.05 for enter and 0.10 for out.

Results

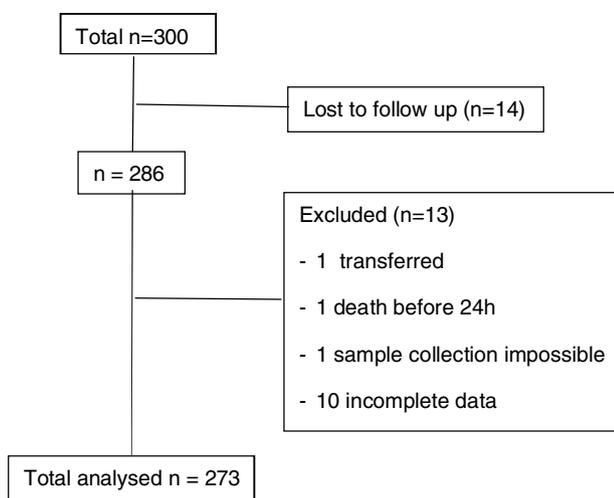
Of the 300 patients eligible for this study, 14 were lost to follow-up and 13 were excluded for various reasons (Fig. 1). Thus, the final sample consisted of 273 patients; of these, 251 (92%) survived and 22 (8%) did not. Of the patients who did not survive, 14 died due to sepsis, 2 due to cardiogenic shock, 3 due to ventricular fibrillation, and 3 due to sudden death of unknown cause.

Myocardial revascularization and valve replacement were the most common surgeries. There was a male predomi-

Table 1 Number of patients in the survivor and nonsurvivor groups according to age (years), EuroSCORE II (%), and surgery performed (n, [%]).

	Total number	Survivors	Nonsurvivors	p-value
Age (years \pm SD)		57.4 \pm 11.8	63.7 \pm 8.9	0.015 ^a
EuroSCORE II		1.29% \pm 1.79	1.72% \pm 1.02	0.004 ^a
Myocardial revascularization without cardiopulmonary bypass	83 (30.4%)	75 (29.9%)	8 (36.4%)	0.695
Myocardial revascularization with cardiopulmonary bypass	97 (35.5%)	90 (35.9%)	7 (31.8%)	0.883
Correction of aortic aneurysm	3 (1.0%)	3 (1.2%)	0	> 0.999
Correction of aortic aneurysm + aortic valve replacement	11 (4.0%)	10 (4.0%)	1 (4.5%)	> 0.999
Mitral valve replacement	34 (12.5%)	29 (11.5%)	5 (22.7%)	0.168
Aortic valve replacement	28 (10.3%)	27 (10.8%)	1 (4.5%)	0.710
Mitral + aortic valve replacement	7 (2.6%)	7 (2.8%)	0	> 0.999
Aortic valve replacement + myocardial revascularization	3 (1.1%)	3 (1.2%)	0	> 0.999
Mitral valve repair	6 (2.2%)	6 (2.4%)	0	> 0.999
Myxoma	1 (0.3%)	1 (0.4%)	0	> 0.999

Age was compared using the Student *t*-test for independent samples. EuroSCORE II was compared using Mann Whitney test. For type of surgery, the Chi-Squared test with Yates' correction for continuity or Fisher's exact test.

**Figure 1** Patients allocation.

nance both in the survivor and nonsurvivor groups (72.8% and 70%, respectively). The mean age was lower in the survivor group (57.4 \pm 11.8 vs. 63.7 \pm 8.9 years; $p = 0.015$). The mean EuroSCORE II was higher in the nonsurvivor group (1.72% \pm 1.02 vs. 1.29% \pm 1.79; $p = 0.004$) (Table 1).

The ScvO₂ levels were higher at T0 and showed a significant decrease over the study period in both groups ($p < 0.001$) (Table 2). There were no significant differences in ScvO₂ between the groups at any of the time points (T0, T1, or T2). Based on the results obtained, the following average normal levels of ScvO₂ were established: 78% at T0, 75.4% at T1, and 68.5% at T2. (Table 2)

Similar to ScvO₂, a significant decrease was observed in hemoglobin values over time, both in the survivor ($p < 0.001$) and nonsurvivor groups ($p = 0.002$) (Table 3). Regarding arterial oxygen saturation, there were no significant differences between time points or between groups.

Analysis of the distribution of patients at T0 according to ScvO₂ category showed a higher proportion of patients with low ScvO₂ in the nonsurvivor group compared to the survivor group (31.8% vs. 13.1%), while the percentage of

patients with high ScvO₂ was greater among survivors compared to nonsurvivors (43.8% vs. 27.3%) ($p = 0.046$) (Table 4). To determine the effect of ScvO₂ on mortality and exclude confounding factors, we performed an analysis using a multiple logistic regression model, evaluating the variables age, ScvO₂, hemoglobin and EuroSCORE II. ScvO₂ < 70% after induction was an independent risk factor associated with mortality: Odds Ratio (OR) = 2.94 (95% CI 1.10–7.89) ($p = 0.032$). Age was another independent risk factor that was also associated with mortality OR = 1.05 (95% CI 1.01–1.10) ($p = 0.023$) (Table 5). According to this model, ScvO₂ > 80% at T0 had no association with mortality. No significant differences were observed between survivors and nonsurvivors at T1 or T2.

The length of ICU and hospital stay was 3.6 \pm 3.1 and 7.4 \pm 6 days respectively and was not significantly associated with ScvO₂ levels.

Discussion

The most important findings of this study were the association between early intraoperative ScvO₂ < 70% and risk of death, while ScvO₂ > 80% over the same period did not mean greater risk of mortality.

Within this context, Pearse et al.¹² showed that decreased postoperative ScvO₂ levels are independently associated with postoperative complications. Similarly, Pölonen et al. demonstrated better outcomes in patients in whom ScvO₂ remained above 70% from the time of ICU admission to 8 hours after cardiac surgery.⁹ In agreement with the literature, our study revealed similar intraoperative findings to those reported postoperatively, with a significantly higher proportion of patients with intraoperative ScvO₂ < 70% in the nonsurvivor group (31.8% vs. 13.1% in the survivor group; $p = 0.046$). Therefore, considering that the multiple logistic regression analysis model confirmed that ScvO₂ < 70% after anesthetic induction is an independent risk factor associated with mortality (OR = 2.94; $p = 0.032$), we strongly emphasize that patients with early intraoperative values below 70% requires efforts to improve tissue perfusion. Thus, the optimization of blood volume, cardiac output

Table 2 Values of SvcO₂ (at times T0, T1, and T2) of the survivor and nonsurvivor groups.

ScvO ₂	T0	T1	T2	p-value ^a
Survivors (n = 251)	78.0 ± 8.1 ^b 78.0 (72.2–84.0)	75.4 ± 7.5 ^b 75.6 (70.6–80.0)	68.5 ± 9.0 69.0 (62.4–74.2)	< 0.001
Nonsurvivors (n = 22)	74.4 ± 8.7 ^c 76.1 (67.8–80.7)	75.4 ± 7.7 ^c 75.0 (70.7–82.2)	66.7 ± 13.1 65.4 (55.9–65.4)	

^aMANOVA.

Survivors: T0 > T1 and T2; T1 > T2 (^b*p* < 0.001); *t*-test for paired samples.

Nonsurvivors: T0 > T2 (^c*p* = 0.036) and T1 > T2 (^d*p* = 0.028); *t*-test for paired samples.

Note: Values are represented as mean ± standard deviation; median (1st quartile; 3rd quartile).

Table 3 Hemoglobin values (in g.dL⁻¹) (at times T0, T1, and T2) of the survivor and nonsurvivor groups.

Hb	T0	T1	T2	p-value ^a
Survivors (n = 252)	12.9 ± 1.69 ^b 13.0 (11.8–14.0)	12.0 ± 1.69 ^b 11.8 (10.9–13.1)	10.7 ± 1.82 10.5 (9.6–11.7)	< 0.001
Nonsurvivors (n = 22)	11.9 ± 2.00 ^c 12.0 (10.7–13.5)	11.6 ± 1.68 ^d 11.6 (10.2–13.3)	10.1 ± 2.36 9.8 (8.8–11.2)	

^aKruskal-Wallis (Non-normal distribution).

Survivors: T0 > T1 and T2; T1 > T2 (^b*p* < 0.001); Wilcoxon for paired samples.

Nonsurvivors: T0 > T2 (^c*p* = 0.001) and T1 > T2 (^d*p* 0.014); Wilcoxon for paired samples.

Note: Values are represented as mean ± standard deviation; median (1st quartile; 3rd quartile).

Table 4 SvcO₂ values, at time T0, distributed into 3 categories: Low (SvcO₂ < 70%), Normal (SvcO₂ 70%–79.9%), and High (SvcO₂ > 80%).

ScvO ₂	Low	Normal	High	Total	p-value ^a
Survivors	33 (13.1%)	108 (43.0%)	110 (43.8%)	251	0.046
Nonsurvivors	7 (31.8%)	9 (40.9%)	6 (27.3%)	22	

^a Pearson Chi-Square test.

Table 5 Variables associated with death (Multiple logistic regression model^a; n = 269).

Variable	Coef.	SE coef.	OR	95% CI OR	p
Age (years)	0.052	0.023	1.05	1.01–1.10	0.023
ScvO ₂ (< 70%)	1.080	0.503	2.94	1.10–7.89	0.032
Constant	-5.799	1.463			< 0.001

^aIndependent variables: Age (years); ScvO₂ at T0 (< 70%: 1; ≥ 70%: 0); Hemoglobin at T0 (< 13 g.dL⁻¹: 1; ≥ 13 g.dL⁻¹: 0); EuroSCORE II in T0.

Standard Error (SE), Coefficient (Coef), Odds Ratio (OR), Confidence Interval (CI).

and/or hemoglobin should be considered. This recommendation is based on the Fick equation, which states that ScvO₂ is a passive variable determined by arterial oxygen saturation, hemoglobin, cardiac output, and oxygen consumption.¹³

Lower ScvO₂ levels are understandably associated with higher mortality in cardiac surgeries because they are indicators of anemia, hypovolemia, increased metabolic requirements, or myocardial dysfunction, all conditions known to be harmful. However, Balzer et al.¹⁰ showed that high ScvO₂ levels on ICU admission indicate a greater risk than low levels. This phenomenon could be the result of inadequate oxygen uptake due to vasoconstriction or cytopathic hypoxia.^{1,13} Our results disagree with these findings and indicate that SvcO₂ > 80% in anesthetized patients is harmless, since univariate analysis showed that the por-

portion of patients with high ScvO₂ at T0 was greater among survivors compared to nonsurvivors (43.8% vs. 27.3%; *p* = 0.046), and the multiple logistic regression analysis did not identify SvcO₂ > 80% as a risk factor for mortality. Furthermore, by studying only the time of ICU admission, Balzer et al. were unable to observe the natural trend of ScvO₂, which is high at the end of surgery in both survivors and nonsurvivors due to the residual effects of anesthesia. Thus, it is impossible to conclude based on a single measurement whether a high ScvO₂ on ICU admission is the pathological result of poor oxygen uptake or only a favorable consequence of anesthesia. Therefore, it is necessary to monitor the course of ScvO₂ and assess tissue oxygenation based on the respective normal values for each perioperative stage in order to prevent the misinterpretation of results.

Our findings showed different normal reference values of ScvO₂ for each perioperative stage and a significant reduction of these levels over the study period. Higher levels were observed in anesthetized patients, while lower levels predominated during the postoperative period in both survivors and nonsurvivors. This pattern of distribution can be explained by the characteristics of each stage.

The T0 stage is characterized by a significant decrease in metabolism and increased DO₂ provided by anesthesia, thereby increasing ScvO₂.¹⁴ Squarra et al.¹³ demonstrated an inversely proportional relationship between VO₂ and ScvO₂, i.e. the lower the VO₂, the higher ScvO₂. In agreement with the literature, our results showed the highest values at T0 for both survivors and nonsurvivors (78% vs. 74.4%). Therefore, considering that the highest values are expected at this time, low ScvO₂ values at T0 are indicative of impaired perfusion.

The slight, but significantly, decrease in ScvO₂ observed at T1 in the survivor group may be due to an increase in metabolism secondary to the neuroendocrine-metabolic response to surgical aggression, or to eventual postoperative myocardial dysfunction.¹ Studying patients with heart failure, Jain et al. showed that cardiac index is directly correlated to ScvO₂. In that study, a cardiac index of 1.3 L.min⁻¹.m⁻², 2 L.min⁻¹.m⁻², and 2.3 L.min⁻¹.m⁻² resulted in a ScvO₂ of 30%, 59%, and 60% respectively.²

The lower ScvO₂ levels found at T2 might be explained by an intensification of the inflammatory response, which increases oxygen uptake in a patient whose oxygen supply is no longer as abundant as intraoperatively. This fact has also been reported by Pearse et al., who found that ScvO₂ significantly oscillates during the postoperative period and that the reduction in ScvO₂ is not always caused by a decrease in oxygen delivery but rather by an increased consumption.¹⁵ Another important finding is that the lowest hemoglobin levels were observed at T2. According to Fick's equation, hemoglobin is an essential factor for tissue oxygenation and is directly correlated with ScvO₂,¹³ i.e. the lower the hemoglobin, the lower ScvO₂.

Each perioperative stage has its peculiarities that interfere with the interpretation of ScvO₂. It is, therefore, necessary to identify the normal reference parameter for each stage. However, there is no consensus on the normal ScvO₂ value during the intraoperative period,³ probably because this is the most dynamic period and is subject to alterations in the DO₂/VO₂ ratio resulting from unpredictable changes in metabolism, microcirculation, blood volume, and myocardial function; thereby impairing standardization of normal reference values. Moreover, ScvO₂ is not an absolute number, but a dynamic result of a complex equation involving various aspects of oxygen transport and utilization, making it difficult to establish an exact cut-off.¹³ Besides that, Squarra points out that targeting a unique ScvO₂ threshold, independently of the scenario, may cause hazardous results. In addition, most studies on ScvO₂ analyze ICU admission values and do not evaluate intraoperative values.^{16,17} In our study, the average normal levels at T0, T1 and T2 were 78%, 75.4%, and 68.5% ($p < 0.001$), respectively, and these values could be used as an approximate parameter of normality for those specific moments, in the studied population included in the present manuscript.

Thus, values lower than this at their respective time points might indicate a worsening of tissue oxygenation that needs to be investigated and treated. It is important to highlight that the evaluation of tissue oxygenation should not be guided by a single variable. Such assessment should be done with as much information as possible, involving macro and micro-hemodynamic aspects.

Identification of the normal reference values of ScvO₂, for each perioperative stage and understanding how they change across this period, although approximate, facilitates the accurate interpretation of results; this will, in turn, improve the management plan and help to establish appropriate therapies, especially when monitors evaluating DO₂ and VO₂ are not available. However, it is important to note that, due to the difficulty to define the exact cut-off for different scenarios, the most adequate treatment consists of maintaining the variables that determine ScvO₂ within an acceptable range.¹³

The main limitation of this study was the lack of monitors to estimate important parameters like cardiac output, DO₂, and VO₂. Such limitation is common for many anesthesiologists due to the lack of such monitoring, so indirect assessment of tissue oxygenation through ScvO₂ should be encouraged as an alternative. In addition, this study analyzed a specific surgical context whose conclusions should not be extrapolated to other scenarios. A multicenter study investigating the association of DO₂ and VO₂ with ScvO₂ in different perioperative phases may provide a basis to better assess tissue perfusion and define normal reference values of ScvO₂ with greater accuracy. In addition, there was a disagreement between the low EuroSCORE II values and the high mortality rate. More than that, the multiple regression analysis showed that EuroSCORE II, although significantly higher in the non-surviving group, was not an independent risk factor associated with death. This can be explained by the fact that EuroSCORE II has become more complex and poorly calibrated to predict mortality in our country.¹⁸ Therefore, the Euroscore II may not be able to predict risk for our population as efficiently as it does in European countries, and this could be a limitation on mortality risk stratification. At last, due to the number of deaths, the use of more than three variables in the multiple logistic regression analysis could overfit the statistical model, and this could be a statistical limitation. Even so, we evaluated the variables ScvO₂, age, EuroSCORE II, and hemoglobin because they are variables with considerable clinical relevance, as previously discussed. In addition, it is important to highlight that the results found were significant and consistent with the current literature, corroborating the conclusions of the present study.

Conclusions

In conclusion, intraoperative ScvO₂ levels < 70%, observed a few minutes after anesthetic induction, were found to be an independent risk factor associated with mortality. Therefore, the intraoperative identification of low ScvO₂ demands the optimization of the variables that define it, such as hemoglobin, cardiac output, arterial oxygen saturation and oxygen consumption.

On the other hand, high ScvO₂ at the end of surgery can be interpreted as a natural tendency of anesthetized patients. So, it is essential to evaluate ScvO₂ perioperative evolution rather than a single measure alone obtained at ICU admission.

Conflicts of interest

The authors declare no conflicts of interest.

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