

TISSUE OXYGEN SATURATION (StO₂) IS NOT CORRELATED WITH MIXED VENOUS OXYGEN SATURATION (SvO₂) AND FAILS TO DETECT ADVERSE EVENTS DURING AND AFTER CORONARY ARTERY BYPASS GRAFT (CABG) SURGERY

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Jabbour K, Tohme J, Haddad F, Hayek G, Jabbour H, Madi-Jebara S. La saturation tissulaire en oxygène n'est pas corrélée à la saturation veineuse d'oxygène pour détecter les événements indésirables durant et après une chirurgie cardiaque élective sous circulation extracorporelle. *J Med Liban* 2018; 66 (2): 81-85.

ABSTRACT • Introduction : Mixed venous oxygen saturation (SvO₂), is an invasive monitoring technique that reflects the balance between systemic oxygen transport and tissue oxygen consumption. Whereas tissue oxygen saturation (StO₂) is a noninvasive technique that allows early detection of tissue hypoperfusion. The purpose of this study is to evaluate StO₂ in patients undergoing elective coronary surgery: single cardiopulmonary bypass (CPB), and to find a correlation between StO₂ and SvO₂.

Material and Methods : All patients scheduled for elective coronary surgery from May to July 2013, were included in the study. The anesthetic management and hemodynamic monitoring were the same. The following parameters: BP, HR, CI, SaO₂, SvO₂, StO₂ at the eminence thenar, Hb and ΔPCO₂ were monitored at the following times : T1: before anesthesia induction, T2 : after induction, T3 : 30 min after the beginning of CPB, T4 : after the weaning from CPB, T5 : H 12, at D1, D2 and at the occurrence of an adverse outcome such as anemia, hypotension, arrhythmia, hypoxia, fever with or without chills..

Results : Forty-five patients were included in this prospective study. Forty patients had 63 events : low cardiac output, isolated hypotension, hypoxia, anemia, AFib and atrial flutter. There was no statistically significant difference in StO₂ from pre-induction till up to 2 days postoperatively, except after the weaning from CPB and 12 hours postoperatively. No correlation was noted between SvO₂ and StO₂ during the events that occurred both during and after the operation.

Conclusion : Microcirculation at the eminence thenar may be altered after CPB. This fact is reflected by the decrease in StO₂ that was noted immediately after CPB and that returned to normal 12 hours postoperatively. However, StO₂ is not correlated with SvO₂ upon the occurrence of an event during or after elective cardiac surgery. Further studies are needed to show the benefit of this noninvasive monitoring in cardiac surgery.

Keywords : tissue oxygen saturation; mixed venous oxygen saturation; cardiopulmonary bypass; eminence thenar

RÉSUMÉ • Introduction : La saturation veineuse en oxygène (SvO₂) est un moyen de monitoring invasif, reflet de la balance entre le transport en O₂ systémique et la consommation en O₂ (VO₂) par les tissus. La saturation tissulaire en oxygène (StO₂) est un moyen de monitoring non invasif qui permet la détection rapide d'une hypoperfusion tissulaire et d'apprécier le degré de dysfonction microcirculatoire. Le but de cette étude est d'évaluer la place de la StO₂ dans la prise en charge des patients après une chirurgie cardiaque élective sous circulation extracorporelle (CEC) et de trouver une corrélation entre la StO₂ et la SvO₂.

Matériel et Méthodes : Tous les patients programmés pour une chirurgie coronaire élective, de mai 2013 à juin 2013, ont été inclus dans l'étude. La technique anesthésique et le monitoring hémodynamique ont été identiques pour tous les patients. Les paramètres suivants : PA, FC, IC, SaO₂, SvO₂, StO₂ au niveau de l'éminence thénar, Hb et ΔpCO₂, ont été monitorés aux temps suivants : T1 : avant induction anesthésique, T2 : après induction anesthésique, T3 : 30 minutes après le départ de la CEC, T4 : après la sortie de la CEC thorax fermé, T5 : H 12, à J1, à J2 et à la survenue d'un des événements suivants: anémie, hypotension, bas débit cardiaque, trouble de rythme, hypoxie, fièvre avec ou sans frissons.

Résultats : Quarante-cinq patients opérés de chirurgie coronaire élective ont été inclus dans cette étude prospective. Quarante patients ont présenté 63 événements : bas débit, hypotension isolée, hypoxie, anémie, FA et flutter auriculaire. Il n'y avait pas de différence statistiquement significative concernant StO₂ depuis la pré-induction jusqu'à 2 jours postopératoires, sauf après l'arrêt de la CEC et 12 heures postopératoires. Aucune corrélation n'a été trouvée entre SvO₂ et StO₂ lors des événements qui ont lieu durant et après la chirurgie.

Conclusion : La microcirculation au niveau de l'éminence thénar peut être altérée après pontage aorto-coronarien (PAC). Ceci est reflété par la diminution de la StO₂ immédiatement après PAC, avec retour à la normale à 12 heures postopératoires. Cependant, la StO₂ n'est pas corrélée à la SvO₂ lors de la survenue d'un événement durant ou après chirurgie cardiaque élective. D'autres études sont nécessaires pour montrer l'utilité de ce monitoring non invasif au cours de la chirurgie cardiaque.

Mots-clés : saturation tissulaire en oxygène; saturation veineuse en oxygène; pontage aorto-coronarien; éminence thénar

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INTRODUCTION

Tissue hypoperfusion is a serious concern for cardiac anesthesiologists during coronary artery bypass graft (CABG), since it has been shown that hypoperfusion is associated with higher in-hospital mortality [1]. Tissue hypoperfusion is usually detected by decrease in mixed venous oxygen saturation (SvO₂) [2]. SvO₂ reflects the balance between systemic oxygen delivery and tissue oxygen consumption and is monitored invasively via a Swan-Ganz catheter [3,4].

The tissue oxygen saturation (StO₂) is a noninvasive technique using near infrared spectroscopy (NIRS) aiming to detect early tissue hypoperfusion [5,6]. StO₂ has been used to measure tissue oxygenation and to detect early hypoperfusion in both septic and hypovolemic shock [5,6]. NIRS measures the ratio of tissue oxygenated hemoglobin to total hemoglobin (StO₂, expressed as a percentage) [7]. The hematological component of muscle oxygenation can thus be continuously, noninvasively, and reliably measured. Normal StO₂ values range from 80.2% to 93.0% in healthy persons [8].

Measurement of thenar StO₂ has been validated as a noninvasive measure of the adequacy of peripheral perfusion during cardiac surgery [9]. In fact, Soller *et al.* [9] showed that the average difference between the invasive and near infrared spectroscopic measurement was near zero for both the pH and PO₂ measurements in patients undergoing cardio-pulmonary bypass (CPB). However, physiologic events that determine StO₂ and SvO₂ variations are different, so the correlation between these two parameters is not always predictable.

The purpose of this study is to evaluate StO₂ in patients undergoing elective cardiac surgery with CPB and to try to define a correlation between StO₂ and SvO₂.

MATERIAL AND METHODS

This study was approved by the appropriate Hospital Ethical Committee. Written informed consent was obtained from all participants.

All patients scheduled for elective isolated coronary surgery from May to July 2013 were eligible for inclusion in the study. Patients were excluded if they had contraindications for use of the NIRS device (skin conditions; sensitive, friable, or broken skin or hematoma on the thenar eminence). Patient's demographics were noted including: age, gender, left ventricular function, hypertension, diabetes, smoking, dyslipidemia, renal impairment, extracardiac arteriopathy, number of coronary grafts, CBP time, and aortic cross-clamp time.

The same anesthetic and monitoring techniques were used in all cases; etomidate, fentanyl and cisatracurium were used for anesthesia induction. Anesthesia was maintained by isoflurane, reinjections of fentanyl and cisatracurium. All patients had five derivations EKG, pulse oxymetry, intravenous line, femoral arterial catheter, Swan-Ganz catheter and StO₂ monitoring at the eminence thenar. StO₂ was measured by using the InSpectra Tissue Spectrometer System Model 325 (Hutchinson Technology Inc, Arnhem, Netherlands) with an optical sensor spacing of 25 mm and a disposable adhesive optical shield.

Blood pressure, heart rate, cardiac output, arterial oxygen saturation, SvO₂, StO₂ at the eminence thenar, hemoglobin and venoarterial CO₂ gradient were monitored at different times – T1: before anesthesia induction, T2: after anesthesia induction; T3: 30 minutes after the beginning of CPB; T4: after the weaning from CPB; T5: 12 hours after surgery; T6: day 1; T7: day 2 –, and at the occurrence of an event defined as: anemia: hemoglobin < 10 g/dl; hypotension: systolic blood pressure < 80 mm Hg; low cardiac output: cardiac index < 2 L/min/m²; arrhythmia: atrial fibrillation (AFib) or flutter; hypoxia: arterial saturation < 95% or PaO₂ < 80 mm Hg; temperature > 38.5° C with or without chills.

The study data were analyzed using SPSS software for Windows, Version 19.0 (SPSS Inc., Chicago, IL, USA). A repeated measures ANOVA was used to compare the means of StO₂ changes over time. Pearson's correlation coefficient was computed to test the association between SvO₂ and StO₂. P-value less than 0.05 was considered statistically significant.

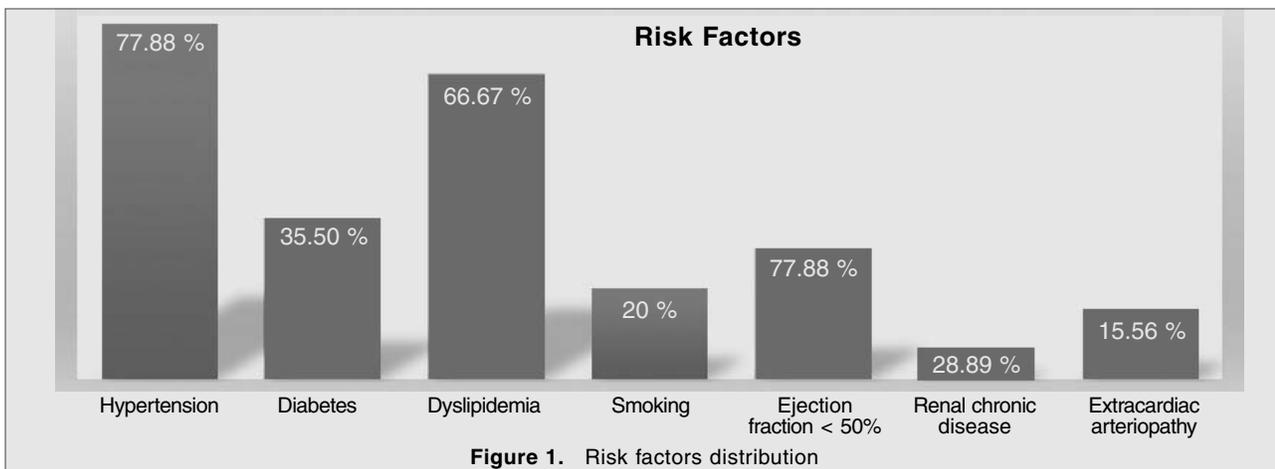


Figure 1. Risk factors distribution

RESULTS

Forty-five patients undergoing elective isolated coronary surgery were included in this prospective study. No patient was excluded. Demographic data are shown in Table I. The median age of the patients was 63 years old. Participants were predominantly male (66%). Concerning risk factors, 77.88% of patients had hypertension, 35.5% had diabetes, 66.67% had dyslipidemia, 20% were smokers, 6.67% had renal chronic disease, 28.89% had an ejection fraction < 50%, and 15.56% had extracardiac arteriopathy (Figure 1).

During their postoperative stay in the cardiac surgery unit (CSU), 40 patients presented 63 events as follows: 34 cases of low cardiac output, 6 cases of isolated hypotension, 6 cases of hypoxia, 9 cases of anemia, 6 cases of atrial fibrillation and 2 cases of atrial flutter.

SvO₂ and StO₂ means and standard deviations are presented at different perioperative times and events, in Tables II & III respectively. Mean StO₂ at baseline was 81.52% (SD 6.59). No differences were observed in baseline StO₂ by age, sex, diabetic status, extracardiac

arteriopathy, or baseline ejection fraction.

A repeated measures ANOVA with a Greenhouse-Geisser correction determined that StO₂ concentration differed statistically significantly between time points (F [4.248, 123.187] = 2.728, *p* = .029).

Post hoc tests using the Bonferroni correction revealed no difference in StO₂ between any two time points, except for T4 (after the weaning from CPB) and T5 (12 hours postoperatively), (*p* = 0.02). Therefore, we can conclude that except for two time points, there was no statistically significant difference in StO₂ from preinduction till up to two days postoperatively (Figure 2).

TABLE I DEMOGRAPHICS

Number of patients	45
Mean age (years)	63 ± 8
Male sex	66 %
Number of coronary graft	4.3 ± 0.9
Cardiopulmonary bypass time	90 ± 30 minutes
Aortic clamping time	70 ± 32 minutes

TABLE II StO₂ & SvO₂ MEANS AND STANDARD DEVIATIONS AT DIFFERENT PERIOPERATIVE TIMES

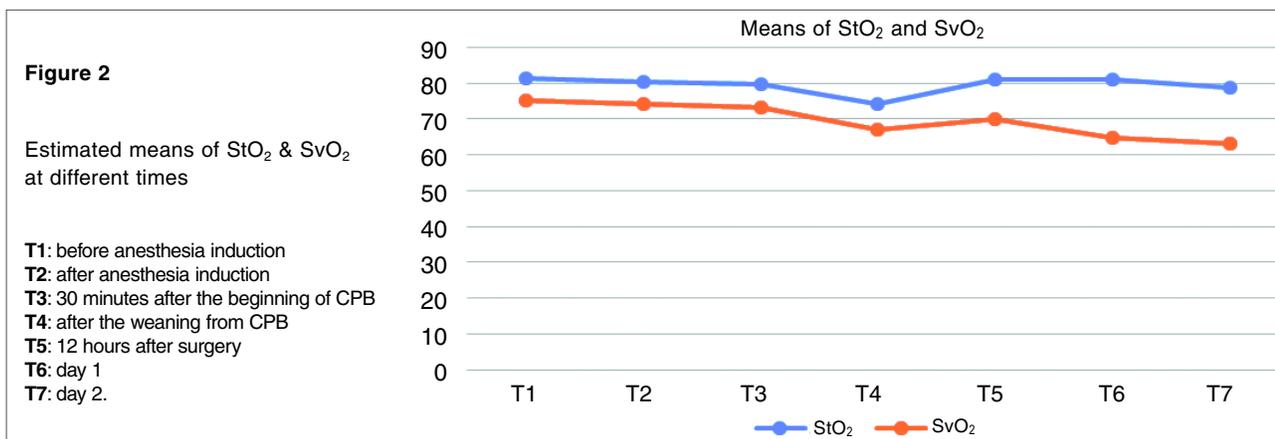
		After induction	30 mins after CPB	After weaning from CPB	12 hours after surgery	Day 1 after surgery	Day 2 after surgery
StO ₂	Mean	80.523	79.588	74.311	81.045	81.068	78.878
	SD	6.7435	10.874	11.082	8.308	7.3212	9.902
SvO ₂	Mean	74.262	73.291	67.022	70.032	64.682	63.251
	SD	8.3463	10.142	11.512	10.472	9.029	8.089

SD: standard deviation CPB: cardiopulmonary bypass

TABLE III StO₂ & SvO₂ MEANS AND STANDARD DEVIATIONS AT EVENTS

		Anemia	Arrhythmia	Hypotension	Low cardiac output	Hypoxia
StO ₂	Mean	77.636	77.722	72.751	76.810	76.549
	SD	9.182	11.964	5.675	9.311	9.716
SvO ₂	Mean	63.636	67.022	63.636	53.215	64.641
	SD	11.508	11.512	11.508	12.617	11.617

SD: standard deviation



SvO₂ changed with the variation of cardiac output at the onset of anemia, during hypotension, hypoxia and arrhythmia. However, no correlation was found between SvO₂ and StO₂ values at different time points or at the occurrence of any event (Table IV). Furthermore, no correlation between StO₂ and cardiac output could be demonstrated.

DISCUSSION

The aim of this study was to evaluate the importance and the pertinence of StO₂ to detect tissue hypoperfusion during and after cardiac surgery and to find a relationship between StO₂ and other hemodynamic parameters such as cardiac output and SvO₂.

StO₂ using NIRS was measured at the eminence thenar due the bareness of adipose tissue. NIRS is a validated tool to explore tissue oxygenation in cardiac surgery [9] and has been evaluated in a few studies [10-12]).

As expected, a clear correlation was identified in this study, between SvO₂ and cardiac output which correlates with other studies [13,14]. Holm J. *et al.* [15] concluded that a SvO₂ < 60% on admission to CSU was related to worse short- and long-term outcome after coronary artery bypass grafting, regardless of whether the patients were admitted to CSU with or without treatment for intraoperative heart failure.

Primary observations showed that StO₂ significantly decreased after weaning from CPB and returned to normal 12 hours postoperatively. These results are in accordance with many previous reports [10-12,16-18] that showed a significant decrease in StO₂ post CPB, to increase again 6 to 12 hours after surgery. In fact, the continued decrease during the first 20 minutes in the ICU is likely to indicate a widening gap between oxygen demand and delivery, where demand increases as the patient is warmed, as sedation is reduced and, possibly, as administration of paralyzing agents is discontinued [11]. However, it is also important to note that, despite the fact that StO₂ decreased in our study and in the study by Morel *et al.* [16], it always remained within the normal range i.e. above 70%, as underlined by other authors [10,19]. Therefore, StO₂ recorded values remained normal during the whole procedure and during CSU stay until 48 hours postoperatively.

Interestingly, when low cardiac output or hypotension was observed significant decrease in SvO₂ immediately followed. However, StO₂ remained normal and failed to detect early tissue hypoperfusion. Therefore, no correlation could be demonstrated between StO₂ and changes in cardiac output during and after cardiopulmonary bypass or at the occurrence of any hemodynamic event. Similarly no correlation was noted between StO₂ and SvO₂.

A possible explanation for these negative observations resides in the fact that the static StO₂ signal is not only based on capillary microcirculation. It comprises arte-

TABLE IV
CORRELATION BETWEEN StO₂ AND SvO₂ VALUES
AT DIFFERENT TIMES AND AT EVENTS

	Correlation coefficient	p value
After induction	0.256	0.109
After weaning from CPB	0.077	0.629
12 hours after surgery	0.087	0.568
Day 1 after surgery	0.138	0.378
Day 2 after surgery	0.212	0.188
Occurrence of anemia	-0.032	0.902
Occurrence of arrhythmia	-0.201	0.423
Occurrence of hypotension	-0.323	0.435
Occurrence of low cardiac output	-0.215	0.747
Occurrence of hypoxia	-0.047	0.586

CPB: cardiopulmonary bypass

rioles (20%), capillaries (10%), and venules (70%) with venules being considered as large microvessels (> 20 μm) [20]. However, no study concluded to an association between alterations in large microvessels circulation and patients' hemodynamic complications. This could explain the absence of any relationship between StO₂, SvO₂ and cardiac output demonstrated in this study.

There are three limitations in this study.

First, several generic issues related to the use of NIRS technology in measuring tissue perfusion should be noted: (a) Relative contributions of arterial, venous, and capillary blood within the measured volume of tissue cannot be determined, as NIRS does not measure microcirculatory blood flow [11,21]. (b) No gold standard exists for comparison of NIRS data, and making direct study comparisons is difficult because of the various NIRS systems used, with different wavelength selection and algorithms for StO₂ calculations [11,21,22].

Second, the sample size, that was relatively small, the short follow-up period, and the low-risk group of patients, resulted in low event numbers affecting analysis potential. However, this provided a relatively homogeneous group of patients with minimal comorbid conditions that could confound any results.

Third, this study did not focus on the relationship between StO₂ and patients' outcome, such as CSU or hospital stay, morbidity, or mortality. Studying such correlations would be of benefit in future studies, particularly, in studies done during the postoperative period.

In summary, in patients undergoing elective cardiac surgery, measurement of thenar StO₂ failed to detect tissue hypoperfusion. Therefore, NIRS-derived parameters seem to be of limited use in the cardiac surgery setting. However, further studies are needed to validate these results.

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