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Agreement between Central and Mixed Venous Oxygen Saturation Following Cardiac Surgery

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Abstract

Objective: To compare oxygen saturation of blood samples simultaneously taken from superior vena cava ($ScvO_2$) and pulmonary artery (SvO_2) in the various hemodynamic conditions that occurs in the early postoperative period following cardiac surgery.

Methods: Prospective, observational study in a tertiary cardiac center, 60 ICU patients included following cardiac surgery. 56 patients completed the study with three hundred measurements collected. Exclusion criteria included those with uncorrected valvular incompetence or intracardiac shunting, and frequent arrhythmia interfering with adequate cardiac output measurement. Samples taken simultaneously from the central venous catheter and the distal lumen of pulmonary artery catheter (PAC). Samples were obtained during each cardiac output measurement as requested by the attending intensivist according to his clinical judgment.

Results: The correlation between SvO_2 and $ScvO_2$ was (r=0.79, p <0.001). The mean bias between SvO_2 and $ScvO_2$ was 3.8 %, and the 95% limits of agreement were (+15.8 to – 8.2 %). Receiving operating characteristic curves demonstrated that an $ScvO_2$ of 70% or greater can predict SvO_2 of 70% or greater with a specificity and sensitivity of 92% and 62% respectively.

Conclusion: There is poor agreement between $ScvO_2$ and SvO_2 in patients following cardiac surgery. This agreement remains poor regardless changes in cardiac index, type of surgery and type of pharmacological support. We also conclude that a cutoff value of (70% and above) in $ScvO_2$ is a specific –but not sensitive- method to predict adequate mixed venous oxygen saturation.

Keywords: Mixed venous saturation; Central venous saturation; Cardiac surgery; Cardiac output

Introduction

Mixed venous O_2 saturation (SvO_2) is a clinical marker of global oxygen utilization, and it has been shown to be a surrogate for the interaction between cardiac output, arterial oxygen content and tissue oxygen uptake [1]. In the presence of good haemoglobin content and adequate oxygen saturation, changes in SvO_2 are therefore directly proportional to those in cardiac output [2].

The measurement of SvO_2 requires access to blood from the pulmonary artery through a pulmonary artery catheter (PAC), the insertion of which is a highly invasive procedure. Alternatively, the measurement of central venous blood O_2 saturation ($ScvO_2$) offers an attractive alternative to the measurement of SvO_2 [3]. There has been considerable debate regarding whether $ScvO_2$ is a satisfactory substitute for SvO_2. The previous studies evaluating the relationship between $ScvO_2$ and SvO_2 showed a significant variation in results because of different study designs and clinical setup which included intensive care patients with either sepsis, heart failure, or shock [4-7]. Studies involving such relationship during and after cardiac surgery [8-15] also showed contradicting results, this controversy is generating confusion among clinicians and further work is needed to explore this area.

The aim of this study is to compare oxygen saturation of blood samples simultaneously taken from superior vena cava and pulmonary artery in the various hemodynamic conditions that occur in the early postoperative period following cardiac surgery.

Methods

This is a prospective observational study of 60 patients admitted to an adult cardiac surgical ICU. After approval by the hospital ethics committee, patient's written and informed consent were taken. Measurements were collected from patients included in the study following cardiac surgery. 56 patients completed the study with collected total of three hundred measurements. Inclusion criteria were patients >18 years old, whose attending anaesthesiologist and/or intensivist inserted a Pulmonary Artery Catheter (PAC) and Central Venous Catheter (CVC) to guide hemodynamic management during and after cardiac surgery. Patients who were excluded from the study were those with uncorrected valvular incompetence or intracardiac shunting, and patients having frequent arrhythmia interfering with adequate cardiac output measurement.

On admission to the intensive care unit and before data collection, a chest x-ray confirms correct position of both pulmonary and central venous catheters. For the assessment of SvO_2, blood samples were drawn from the distal port of the CVC and simultaneously another sample was collected from distal lumen of PAC to measure the $ScvO_2$. Measurements were obtained during each cardiac output measurement as requested by the intensivist attending according to his judgment. Together with each SvO_2 blood sample readings Cardiac Output (CO) using thermodilution method was recorded. Haemoglobin and arterial blood gas readings were also recorded.

All data were expressed as mean ± Standard Deviation (SD). Correlations between $ScvO_2$ and SvO_2 were tested using linear regression analysis and Pearson test. Agreement between both values was tested using Bland and Altman method, limits of agreement were calculated as the mean difference ± 1.96 SD. Receiving operating characteristic (ROC) curve was constructed to asses the ability of $ScvO_2$ to predict SvO_2 70% or higher. All statistical calculations were performed using SPSS (Statistical Package for the Social Science; SPSS Inc Chicago, IL, USA) program.

Results

Patients' characteristics are presented in table 1. Normal Cardiac Index (CI) was defined as a value equal to or above 2, while low CI was defined as a value less than 2. Most of measurements were taken while patients were receiving pharmacological support. For the purpose of the study; dopamine, adrenalin and noradrenalin infusions were categorized as "Inotropes". Dobutamin and milrinon were categorized as "Inodilators".

Age (years)	67 ± 9
Sex (Male/Female)	30/26
Type of surgery:	
CABG	14(25%)
Valve	13(23%)
Combined	29(51%)
Pharmacological support:	
Inotropes	74/300
Inodilators	31/300
Combined	142/300
Cardiac Index >/= 2	259/300
Cardiac Index < 2	41/300

Table 1: Patients' characteristics (n=56, measurements=300) Data are expressed as mean ± Standard deviation (Age), ratio (Sex), number and percentage (Type of surgery), and number of measurements (pharmacological support and cardiac index), CABG: coronary artery bypass graft

The correlation between SvO_2 and $ScvO_2$ is shown in figure 1, the correlation coefficient was (r=0.79, p <0.001), the correlation remained strong in different subgroups (low cardiac index, patients on inotropes, patients on inodilators, CABG and valve surgery).

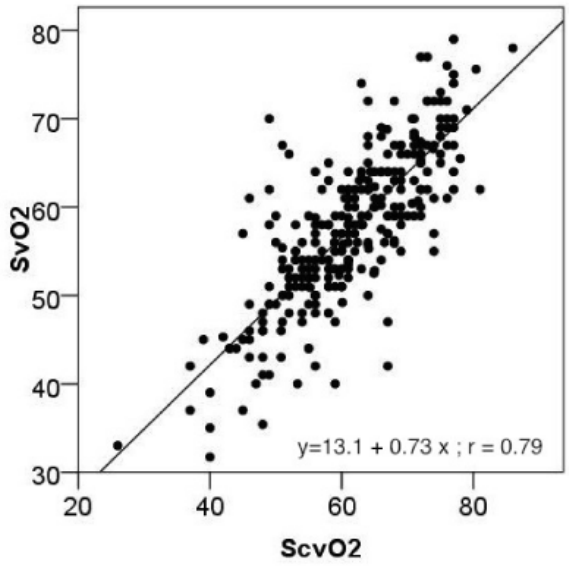

Figure 1: Correlation between central venous blood O2 saturation (ScvO2) and the measurement of mixed venous O2 saturation (SvO2)

Regarding the agreement between SvO_2 and $ScvO_2$, Bland-Altman analysis between both measurements is shown in figure 2, the mean bias between SvO2 and $ScvO_2$ was 3.8 %, the 95% limits of agreement were (+15.8 to – 8.2 %).

	Mean bias (SD) %	95% limits of agreement
All patients	3.8 (6)	+15.8 to – 8.2
Cardiac Index <2	2.6 (7)	+16.6 to -11.4
Cardiac Index >= 2	3.9 (5.8)	+14.9 to -7.1
Patients on Inotropes	3.4 (6.8)	+17 to -10.2
Patients on Inodilators	1.97 (5.2)	+12.4 to -8.4
Patients on both Inotropes and Inodilators	3.8 (5.5)	+14.8 to -7.2
CABG patients (n=14)	-0.1(8.2)	+16.3 to – 16.5
AVR patients (n=14)	5.2(7.9)	+21 to -10.6

Table 2: Mean bias and 95% limits of agreement. SD: Standard Deviation, CABG: Coronary Artery Bypass Graft, AVR: Aortic Valve Replacement

Further analysis of agreement in relation to cardiac index, types of pharmacological support and type of surgery is presented in Table 2.

Receiver operating characteristic (ROC) analysis was done to detect the ability of $ScvO_2$ to predict SvO_2 of 70% or more (i.e. adequate SvO_2). Figure 3 shows the ROC curve, area under the curve was 0.88, with significance level <0.001.

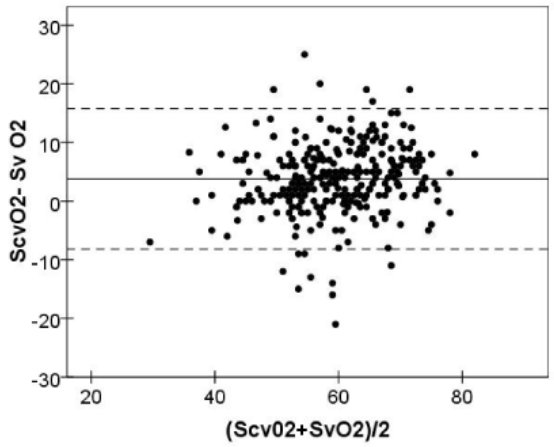

Figure 2: Agreement between central venous blood O2 saturation (ScvO2) and the measurement of mixed venous O2 saturation (SvO2)

The cut off value of $ScvO_2$ of 70% can predict SvO_2 of 70% or more with high specificity of 92% but with a low sensitivity of 62%.

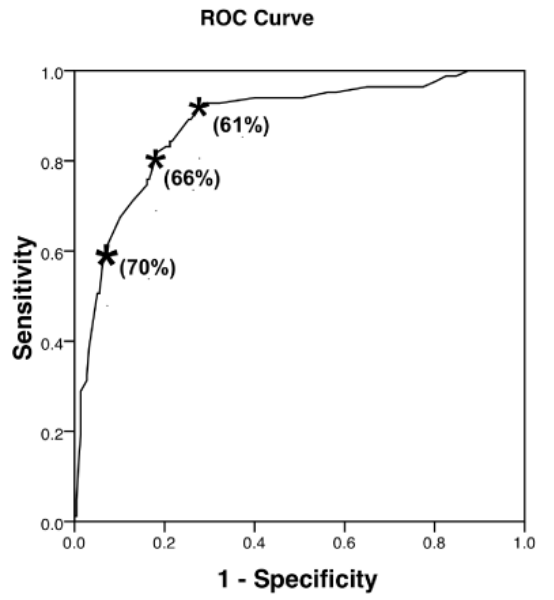

Figure 3: Receiver operating characteristic (ROC) curve assessing the ability of central venous blood O2 saturation (ScvO2) to predict mixed venous O2 saturation (SvO2) of 70% or more. Area under the curve (AUC) was 0.9, the numbers in bracket indicates different ScvO2 cut-off values

Discussion

This study tests the correlation and agreement between SvO_2 and $ScvO_2$ after cardiac surgery. The results show that $ScvO_2$ cannot be used as a surrogate for SvO_2 in this patient population. The limits of agreement are large between both readings. Even with changes in type of surgery, cardiac index and pharmacological therapy the agreement remained clinically unacceptable. However, the results show that in our settings, a cutoff value of (70% and above) in $ScvO_2$ is highly specific to predict adequate mixed venous oxygen saturation.

Evidence showed that following cardiac surgery, the most critical period regarding oxygen delivery to the tissues is the first 6-8 hours [2]. The value of mixed venous oxygen saturation in optimizing oxygen delivery is well established, using SvO_2 as a part of goal-directed therapy may reduce the incidence of postoperative derangements [16,17]. The attractive option of using trends of central venous saturation as a surrogate for SvO_2 was suggested.

In normal individuals, the difference is small between central venous saturation (which represents venous drainage from the upper half of the body) and mixed venous saturation (which represents, in addition, the flow from inferior vena cava and myocardial venous blood) [18]. Consequently, $ScvO_2$ is usually less than SvO_2 mainly due to high oxygen content in renal venous drainage2, this relationship changes in sick patients with hemodynamic changes, oxygen extraction become higher in renal and splanchnic circulation resulting in reversal of SvO_2-to- $ScvO_2$ relationship [19]. Two questions rise regarding this issue, first, is the gap between SvO_2 and $ScvO_2$ fixed or variable, second, if SvO_2-to- $ScvO_2$ gap is variable what are the clinical settings that may have minimal variability.

The use of $ScvO_2$ as a surrogate for SvO_2 is an issue of debate, previous studies have suggested close tracking of both measurements across a wide range of hemodynamic conditions [20], this included critically ill ICU patients [21], and during liver transplantation [22]. On the other hand, other studies presented an unacceptable agreement between both measurements [4,5,23,24].

In cardiac surgery patients, Berridge et al. [7] suggested $ScvO_2$ as a useful estimate of mixed venous oxygen saturation. Lorentzene et al10 suggested a possible use of $ScvO_2$ in patients undergoing CABG as compared to aortic valve replacement patients. In this study, the limits of agreement between SvO_2 and $ScvO_2$ were large (+15.8 % to – 8.2 %), this comes in line with other studies involving patients after cardiac surgery [11-15]. Alshaer et al. [8] examined the correlation during beating heart coronary surgery and concluded that SvO_2 and $ScvO_2$ are not interchangeable numerically but $ScvO_2$ can be useful if used as a trend. Soussi et al. [9] concluded that central venous saturation can not be an alternative to mixed venous saturation during cardiopulmonary bypass.

This study investigated whether patients with normal cardiac index had a reliable agreement between SvO_2 and $ScvO_2$ in contrast to those with low CI. Results showed that patients with cardiac index >/=2 had better limits of agreement than those with low cardiac index. However, in both subgroups the limits of agreement were large and using $ScvO_2$ as a surrogate for SvO2 seems hazardous. This comes in line with other studies involving cardiac surgery patients with a variable CI [11-14], or involving only low CI patients [15].

With regard to concomitant pharmacological therapy, our study found that patients receiving inodilators had better agreement than those receiving inotropes. However, limits of agreement remained large and difficult to accept. On the contrary, Lorentzen et al. [10] found that Patients receiving inotropic treatment had lower venous differences. Possible reason of different results was that they included only three patients on inotropes in their analysis. The lower SvO_2-to-$ScvO_2$ gap with infusions like dobutamin and milrinon as compared to

infusions like dopamine and adrenalin may be due to the different effect on splanchnic, renal and cardiac oxygen extraction. The type of surgery was also suggested as a factor that modulates the relation between SvO_2 and $ScvO_2$ [10]. Our results shows that the limits of agreement remained high and clinically unacceptable regardless the surgical procedure.

The Mixed venous oxygen saturation value of 70% and above has been suggested as marker of adequate tissue oxygen delivery in patients following cardiac surgery [25]. Similarly, Nogueira et al. [26] suggested that aiming for $ScvO_2$ value >/= 70% after cardiac surgery decreased postoperative organ dysfunction. Our result showed that using an $ScvO_2$ value >70% is highly specific to predict SvO_2 of 70% or more. This means that using this cut off value ($ScvO_2$ >70%) can reliably predict normal mixed venous saturation even if a pulmonary artery catheter is not there. On the other hand, and considering the low sensitivity; $ScvO_2$ values of less than 70% would not indicate reliably inadequate mixed venous saturation. This dissociation between the sensitivity and the specificity of this cut off value ($ScvO_2$ >70%) may explain the controversial results by previous studies. Sander et al. [14] concluded that after cardiac surgery; $ScvO_2$ >70% predicts adequate oxygen delivery. However, Lorenzten et al. [10] suggested it might not be a reliable sign of adequate tissue oxygenation.

There are limitations of this study. First, this study did not assess the ability of using $ScvO_2$ as a part of goal-directed therapy rather than just testing its agreement with SvO_2. We believe that clinical studies – including our study- have proved a lack of agreement in different subgroups in the cardiac surgery population, and that future studies should address the use of $ScvO_2$ as a monitor for adequate tissue perfusion. Secondly, the patient population was not restricted to either CABG or valve surgery, which could be described as lack of homogenous group, however the number of measurements were high, and we needed to explore the type of surgery as a factor affecting venous saturation.

We conclude that there is poor agreement between $ScvO_2$ and SvO_2 in patients following cardiac surgery, and this agreement remains poor regardless changes in cardiac index, type of surgery and type of pharmacological support. We also conclude that a cutoff value of (70% and above) in $ScvO_2$ is a specific –but not sensitive- method to predict adequate mixed venous oxygen saturation.

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