Central Venous Oxygenation for Mixed Venous Oxygen Saturation

Naresh Kumar Agarwal[1] Arun Subramanian[1]

[1]Department of Cardiac Anesthesiology, Manipal Hospitals, New Delhi, India

Address for correspondence Arun Subramanian, MD, MNAMS, DM, Department of Cardiac Anesthesiology, Manipal Hospitals, Dwarka Sector-6, New Delhi 110075, India (e-mail: aruncardiac@live.com).

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Abstract

Venous oxygen saturation has been traditionally used as a marker for tissue hypoxia. A wide range of factors can affect it. Literature abounds with articles on the use of the same in decision making and clinical management of patients in shock. Likewise, the application of venous saturation in patients undergoing cardiac and noncardiac surgery has been demonstrated. The controversy as to whether superior vena cava oxygen saturation can replace the traditional mixed venous oxygen saturation is never ending. Irrespective of the body of evidence, it is recommended that clinical decision should not be based on a single value, and a range of values needs to be incorporated to differentiate a critically ill from a noncritically ill patient.

Keywords
- hypoxia
- mixed venous oxygen saturation
- central venous oxygen saturation
- cardiac surgery
- shock
- oxygen demand
- oxygen supply

Introduction

Morbidity and mortality after major cardiac surgeries are serious issues to any health care system.[1] Even for the patients who leave the hospital, postoperative complications are an important determinant of long-term survival.[2] Thus it seems imperative that we devise strategies that can help us in identifying these patients quite early in their clinical course, so that we can implement measures to improve the outcome of such patients.

One of the major determinants of postoperative outcome is the cardiorespiratory function of the patient. It has been demonstrated that global tissue hypoxia is associated with poor results after major surgeries.[3,4] This can be reduced by optimal volume replacement and inotropes.[5,6] Despite this, it is important that we recognize the symptoms of tissue hypoxia in advance, so that we may be well equipped to handle the situation. Mixed venous oxygen saturation (SvO_2) and central venous oxygen saturation ($ScvO_2$) have been found to be surrogate markers of tissue hypoxia.[7,8] Clinicians must be aware of the measurement, advantages, and pitfalls of the above markers, so that they can be applied safely and effectively. The aim of this article is to describe the physiology of SvO_2 and $ScvO_2$, elucidate the findings of pertinent clinical investigations, and debate on the equality or interchangeability of SvO_2 and $ScvO_2$. We searched PubMed, Google Scholar, and Cochrane databases with the following keywords: *venous saturation*, *venous oximetry*, *tissue hypoxia*, and *cardiac surgery*.

Background Physiology

It is mandatory we understand the physiology of venous saturation before we apply it in the bedside management of the patient. What do SvO_2 and $ScvO_2$ represent? They represent the hemoglobin saturation of the blood in the pulmonary artery and superior vena cava, respectively. What are the factors influencing the saturation of the venous blood? The oxygen saturation of the venous blood is dependent on the hemoglobin levels (Hb), arterial oxygen saturation (SaO_2), cardiac output (CO), and tissue oxygen consumption (VO_2). Therefore, as per the Fick principle,[9] SvO_2 is described by the following formula:

$$SvO_2 = \frac{SaO_2 - VO_2}{CO \times Hb \times 1.34}$$

The normal range of venous saturation is usually 65 to 75% in healthy individuals; however, few studies exist, which showcase the normal values.[10] The earliest study,

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which provided an in-depth description of Hb saturation in the venous system of healthy patients, demonstrated mean values of 76.8% in the superior vena cava and 78.4% in the pulmonary arteries. It is usually recommended to target an $ScvO_2$ > 70% and an SvO_2 > 65% in all subset of patients. It is also recommended to follow a trend in the values rather than initiating therapy based on a single value.

How do we measure venous oxygen saturation? Although the measurement of $ScvO_2$ and SvO_2 was initiated in the catheterization laboratory in 1929, it was the landmark paper by Swann et al,[11] which described the floatation of the pulmonary artery catheter that facilitated the routine measurement of SvO_2. Nowadays, estimation of saturation can be done either intermittently by blood sampling or continuously through the use of a spectrophotometric catheter.[12,13]

A host of physiologic, pathologic, and therapeutic factors influence the venous saturation during the perioperative period (►**Table 1**). Recognizing the etiology is necessary for the safe use of venous saturation as a therapeutic goal.

Table 1 Factors influencing the venous oxygen saturation in the perioperative period

A. Decreased venous oxygen saturation
1. Decreased oxygen delivery—anemia, hypoxia, hypovolemia, cardiac failure.
2. Increased oxygen consumption—pain, fever, shivering, sepsis.
B. Increased venous oxygen saturation
1. Increased oxygen delivery—inotropes, fluids, blood and blood products, supplemental oxygen.
2. Decreased oxygen consumption—sedation, analgesia, hypothermia, paralysis.

Central versus Mixed Venous Oxygen Saturation

The interchangeability or equality of $ScvO_2$ and SvO_2 has been a matter of great debate over many years in pediatric and adult population[14–24] (►**Table 2**). In clinical practice, the simplicity of $ScvO_2$ measurement has always been a factor for clinicians to equate the two variables. The determinants of both the variables are nearly similar. Despite this, it has to be understood that they cannot always be used interchangeably. This becomes more valid in case of critically ill patients. The differences in the blood flow distribution and oxygen consumption by the vital organs such as the brain and heart in shock states explains this discrepancy.[25]

Normally, the difference between $ScvO_2$ and SvO_2 is around 5%, with the $ScvO_2$ lagging behind SvO_2. This is due to the relatively higher VO_2 of the brain and the higher oxygen content of the inferior vena cava.[26] However, in shock states the redistribution of blood to the upper extremities leads to a reversal in the relationship. Hence, in critically ill patients, the $ScvO_2$ overtakes SvO_2 by 15 to 20%.[27] Therefore, measuring the $ScvO_2$ in such cases may provide us a false sense of security that everything is quite rosy. This may also be expanded to the perioperative period although with mixed results. The general consensus during surgery is that while the two may a have a good positive correlation, they agree with each other only when measured as a trend and not as absolute values.[28] To conclude, clinicians must be very prudent in surmising the value of one variable from the other.

Table 2 Studies correlating SvO_2 with $ScvO_2$

Study	Design and setting	Result	Inference
Alshaer et al[14]	*n* = 34; coronary artery bypass grafting; OR and ICU; 12 measurements per patient	$ScvO_2$ higher than SvO_2 all through the study Mean of difference highest post ICU admission (6.3 and 4.6; $p < 0.05$)	$ScvO_2$ is equivalent to SvO_2 in the course of clinical decisions as long as absolute values are not required, but not interchangeable
Ali et al[15]	*n* = 40; 240 samples; pediatric cardiac surgery, OR	Wide limits of agreements between $ScvO_2$ and SvO_2 (14.2 to −15.3)	SvO_2 and $ScvO_2$ are not interchangeable in pediatric open-heart surgeries
Kopterides et al[16]	*n* = 37; septic shock	Mean SvO_2 below mean $ScvO_2$; mean bias −8.5% 95% limits of agreement −20.2 to 3.3%; this resulted in higher VO_2 values	$ScvO_2$ and SvO_2 not equivalent in ICU patients with septic shock; substitution of $ScvO_2$ for SvO_2 in calculation of VO_2 resulted in unacceptably large errors
El-Sherbeny and Belahith[17]	*n* = 56; 300 measurements; postcardiac surgery; ICU	Correlation between SvO_2 and $ScvO_2$ was $r = 0.79$ ($p < 0.001$). Mean bias between SvO_2 and $ScvO_2$ was 3.8%, and 95% limits of agreement were (+15.8 to −8.2%)	Poor agreement between $ScvO_2$ and SvO_2 in patients following cardiac surgery
el-Masry et al[18]	*n* = 50; liver transplantation; 450 measurements; pre-, during, and posttransplant	Strong positive correlation for SvO_2 with $ScvO_2$ (r = 0.98 and 0.87 at pre- and posttransplant, respectively) 95% limit of agreement ranged from −1.94 to 2.7 and −6.07 to 1.07 at pre- and posttransplant, respectively	Minimal bias between $ScvO_2$ and SvO_2; hence it can be interchanged

(Continued)

Table 2 Studies correlating SvO_2 with $ScvO_2$

Study	Design and setting	Result	Inference
Romagnoli et al[19]	*n* = 18; cardiogenic shock undergoing cardiac surgery; ICU; 72 paired samples	Bias of difference 6.82% 95% limits of agreement −3.7 to 17.3% between $ScvO_2$ and SvO_2	Poor agreement between $ScvO_2$ and SvO_2 in patients with cardiogenic shock following cardiac surgery
Pérez et al[20]	*n* = 30 (18 catecholamine refractory shock and 12 postoperative); critically ill pediatric patients; ICU	Bias of difference was 2% and 95% limits of agreement −6.9 to 10.9% between $ScvO_2$ and SvO_2	$ScvO_2$ and SvO_2 are closely related and interchangeable in critically ill pediatric population
Yazigi et al[21]	*n* = 60; postcoronary artery surgery; pre- (T0) and post-normalization (T1) of filling pressures and cardiac index	Bias between SvO_2 and $ScvO_2$ was −0.6% (T0) and −0.8% (T1). Limits of agreement were from 19.2 to 18% (T0) and from 15.6 to 14% (T1), and correlation coefficient was 0.463 (T0) and 0.72 (T1)	Disagreement between $ScvO_2$ and SvO_2; $ScvO_2$ not an alternative for SvO_2
Aggarwal et al[22]	*n* = 20; open-heart surgery; 200 measurements; OR	Strong correlation between SvO_2 and $ScvO_2$ Regression coefficient and intraclass correlation were 0.99 and 0.91, respectively	$ScvO_2$ is a reliable marker for SvO_2; can be interchanged
Lorentzen et al[23]	*n* = 20; elective cardiac surgery; ICU	Bias of difference between $ScvO_2$ and SvO_2 was 6.4 in aortic valve surgeries and 0.6 in coronary artery bypass grafting	$ScvO_2$ and SvO_2 are not interchangeable in aortic valve surgeries. They can be interchanged, though there is no complete accuracy in coronary artery bypass grafting
Redlin et al[24]	*n* = 20; pediatric cardiac surgery; OR; samples from superior and inferior vena cava, mixed venous samples from cardiopulmonary bypass	Linear correlation between inferior vena cava and mixed venous samples, no correlation between superior vena cava and mixed venous samples	$ScvO_2$ poorly reflects SvO_2

Abbreviations: DO_2, oxygen delivery; ICU, intensive care unit; OR, operating room; $ScvO_2$, central venous oxygen saturation; SvO_2, mixed venous oxygen saturation; VO_2, oxygen consumption.

Conclusion

The debate as to whether $ScvO_2$ and SvO_2 are interchangeable is never ending. Although it has generally been agreed that in critically ill patients they must be assessed individually, the same may or may not be applicable to a patient undergoing surgery. We must focus on well-defined population and use these variables with knowledge and discretion. In clinical practice, venous oxygen saturations should always be used in combination with vital signs and other relevant endpoints to tailor therapy. Finally, it needs not be stressed that a trend in the saturation monitoring is always preferred to a solitary value.

Conflict of Interests
None.

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