Central Venous Oxygenation for Mixed Venous Oxygen Saturation

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Abstract

Keywords

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

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.

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 (SvO₂) and central venous oxygen saturation (ScvO₂) 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 SvO₂ and ScvO₂, elucidate the findings of pertinent clinical investigations, and debate on the equality

or interchangeability of SvO₂ and ScvO₂. 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 SvO₂ and ScvO₂ 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 (SaO₂), cardiac output (CO), and tissue oxygen consumption (VO₂). Therefore, as per the Fick principle,⁹ SvO₂ is described by the following formula:

$$\text{SvO}_2 = \frac{\text{SaO}_2 - \text{VO}_2}{\text{CO} \times \text{Hb} \times 1.34}$$

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.

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 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 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.

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 SvO₂ with ScvO₂

Study	Design and setting	Result	Inference
Romagnoli et al ¹⁹	<i>n</i> = 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	<i>n</i> = 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	<i>n</i> = 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	<i>n</i> = 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	<i>n</i> = 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	<i>n</i> = 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: DO₂, oxygen delivery; ICU, intensive care unit; OR, operating room; ScvO₂, central venous oxygen saturation; SvO₂, mixed venous oxygen saturation; VO₂, oxygen consumption.

Conclusion

The debate as to whether ScvO₂ and SvO₂ 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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None.

References

- Pearse RM, Harrison DA, James P, et al. Identification and characterisation of the high-risk surgical population in the United Kingdom. *Crit Care* 2006;10(3):R81
- Khuri SF, Henderson WG, DePalma RG, Mosca C, Healey NA, Kumbhani DJ; Participants in the VA National Surgical Quality Improvement Program. Determinants of long-term survival after major surgery and the adverse effect of postoperative complications. *Ann Surg* 2005;242(3):326–341, discussion 341–343
- Murkin JM, Arango M. Near-infrared spectroscopy as an index of brain and tissue oxygenation. *Br J Anaesth* 2009;103(Suppl 1):i3–i13
- Jhanji S, Lee C, Watson D, Hinds C, Pearse RM. Microvascular flow and tissue oxygenation after major abdominal surgery: association with post-operative complications. *Intensive Care Med* 2009;35(4):671–677
- Pearse R, Dawson D, Fawcett J, Rhodes A, Grounds RM, Bennett ED. Early goal-directed therapy after major surgery reduces complications and duration of hospital stay. A randomised, controlled trial [ISRCTN38797445]. *Crit Care* 2005;9(6):R687–R693
- Wilson J, Woods I, Fawcett J, et al. Reducing the risk of major elective surgery: randomised controlled trial of preoperative optimisation of oxygen delivery. *BMJ* 1999;318(7191):1099–1103
- Perz S, Uhlig T, Kohl M, et al. Low and “supranormal” central venous oxygen saturation and markers of tissue hypoxia in cardiac surgery patients: a prospective observational study. *Intensive Care Med* 2011;37(1):52–59
- Marx G, Reinhart K. Venous oximetry. *Curr Opin Crit Care* 2006;12(3):263–268
- Fick A. Ueber die Messung des Blutquantums in den Herzventrikeln. *Verhandl Physik Med Gesellschaft Wurzburg* 1870;2:16–28

- 10 Nelson LD. Continuous venous oximetry in surgical patients. *Ann Surg* 1986;203(3):329–333
- 11 Swan HJ, Ganz W, Forrester J, Marcus H, Diamond G, Chonette D. Catheterization of the heart in man with use of a flow-directed balloon-tipped catheter. *N Engl J Med* 1970;283(9):447–451
- 12 Waller JL, Kaplan JA, Bauman DI, Craver JM. Clinical evaluation of a new fiberoptic catheter oximeter during cardiac surgery. *Anesth Analg* 1982;61(8):676–679
- 13 Baulig W, Dullenkopf A, Kobler A, Baulig B, Roth HR, Schmid ER. Accuracy of continuous central venous oxygen saturation monitoring in patients undergoing cardiac surgery. *J Clin Monit Comput* 2008;22(3):183–188
- 14 Alshaer A, Abdel-Meguid ME, Ibraheim O, et al. Mixed venous versus central venous oxygen saturation in patients undergoing on pump beating coronary artery bypass grafting. *Saudi J Anaesth* 2010;4(2):63–67
- 15 Ali MS, Abd-Elshafy SK, Abd Allah EM, Ghoneim AF. Can venous saturations from the central line and the venous side of the heart-lung machine be interchangeable with mixed venous saturation from the pulmonary artery in children undergoing open-heart surgery? *Egypt J Cardiothorac Anesth* 2017;11:48–52
- 16 Kopterides P, Bonovas S, Mavrou I, Kostadima E, Zakynthinos E, Armaganidis A. Venous oxygen saturation and lactate gradient from superior vena cava to pulmonary artery in patients with septic shock. *Shock* 2009;31(6):561–567
- 17 El-Sherbeny A, Belahith M. Agreement between central and mixed venous oxygen saturation following cardiac surgery. *J Anesth Clin Res* 2014;5:386
- 18 el-Masry A, Mukhtar AM, el-Sherbeny AM, Fathy M, el-Meteini M. Comparison of central venous oxygen saturation and mixed venous oxygen saturation during liver transplantation. *Anaesthesia* 2009;64(4):378–382
- 19 Romagnoli S, Balsorano P, Landucci F, De Gaudio A. Mixed and central venous oxygen saturation are not interchangeable in patients with cardiogenic shock after cardiac surgery. *Crit Care* 2013;17(Suppl 2):180
- 20 Pérez AC, Eulmesekian PG, Minces PG, Schnitzler EJ. Adequate agreement between venous oxygen saturation in right atrium and pulmonary artery in critically ill children. *Pediatr Crit Care Med* 2009;10(1):76–79
- 21 Yazigi A, El Khoury C, Jebara S, Haddad F, Hayeck G, Sleilaty G. Comparison of central venous to mixed venous oxygen saturation in patients with low cardiac index and filling pressures after coronary artery surgery. *J Cardiothorac Vasc Anesth* 2008;22(1):77–83
- 22 Aggarwal NK, Kapoor PM, Kiran U, Chowdhury UK. Intraoperative central venous oxygen saturation as a surrogate marker for mixed venous oxygen saturation in patients undergoing cardiac surgery. *J Anesth Clin Pharmacology* 2007;23(1):29–33
- 23 Lorentzen AG, Lindskov C, Sloth E, Jakobsen CJ. Central venous oxygen saturation cannot replace mixed venous saturation in patients undergoing cardiac surgery. *J Cardiothorac Vasc Anesth* 2008;22(6):853–857
- 24 Redlin M, Koster A, Huebler M, et al. Regional differences in tissue oxygenation during cardiopulmonary bypass for correction of congenital heart disease in neonates and small infants: relevance of near-infrared spectroscopy. *J Thorac Cardiovasc Surg* 2008;136(4):962–967
- 25 Lee J, Wright F, Barber R, Stanley L. Central venous oxygen saturation in shock: a study in man. *Anesthesiology* 1972;36(5):472–478
- 26 Dahn MS, Lange MP, Jacobs LA. Central mixed and splanchnic venous oxygen saturation monitoring. *Intensive Care Med* 1988;14(4):373–378
- 27 Reinhart K, Rudolph T, Bredle DL, Hannemann L, Cain SM. Comparison of central-venous to mixed-venous oxygen saturation during changes in oxygen supply/demand. *Chest* 1989;95(6):1216–1221
- 28 Ramakrishna M, Hegde D, Kumaraswamy G, Gupta R, Girish T. Correlation of mixed venous and central venous oxygen saturation and its relation to cardiac index. *Indian J Crit Care Med* 2006;10(4):230–234