SVO₂ Monitoring

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Q: Where is SVO₂ (percentage of oxygen saturation in the pulmonary arterial blood) measured in the body?

SVO₂ is measured in the pulmonary artery (PA), where venous blood mixes after circulating through the superior and inferior vena cavae, coronary sinususes, and the chambers in the right side of the heart. Although SVO₂ is the percentage of oxygen saturation in the pulmonary arterial blood, SVO₂ actually represents an average of all the venous oxygen saturations of the various organs and tissues.

Q: Describe the technology used to measure SVO₂.

The components of an SVO₂ monitoring system include a flow-directed thermodilution PA catheter that has conventional hemodynamic monitoring capabilities in addition to fiber optics for transmitting light (Figure 1), an optical module that contains a light-emitting source and a photodetector, and a microprocessor to analyze reflected light.

Reflectance spectrophotometry is used to differentiate oxygenated blood from deoxygenated blood in the PA. From the distal end of the PA catheter, light-emitting diodes transmit pulsating light of various wavelengths in the red and infrared spectra through an optical fiber to illuminate the blood. The red blood cells absorb various amounts of light depending on the amounts of oxygenated and deoxygenated hemoglobin that are present. The light reflected by the blood cells is transmitted through a second optical fiber to the photodetector, which converts light intensity into electrical signals for transmission to the microprocessor. After the microprocessor receives the electrical signals, the light intensities from oxyhemoglobin and deoxyhemoglobin are analyzed by detecting color changes in the red blood cells, and a ratio is computed. The SVO₂ value that is displayed on the oscilloscope represents a composite of measurements of multiple samples and is updated every few seconds.

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**Figure 1** Fiber-optic PA catheter and associated interconnections.

Abbreviations: CVP, central venous pressure; PA, pulmonary artery.

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Q: What clinically useful information can be obtained with SVO₂ monitoring?

Continuous measurement of SVO₂ is a practical method of globally assessing tissue oxygenation and cardiopulmonary function in the clinical setting. Clinicians may use continuous SVO₂ monitoring to detect cardiopulmonary instability and deterioration, because clinically important changes in SVO₂ may be observed before changes in other hemodynamic parameters are detectable.

SVO₂ monitoring may be especially useful in patients who have limited cardiac and oxygen reserves and who are at risk for tissue oxygen deprivation including:

- Before or during high-risk cardiovascular surgery
- Patients in advanced-stage heart failure
- Patients with acute myocardial infarction
- Patients with acute hypoxic respiratory failure (eg, pulmonary embolism, pulmonary infarction)
- Patients with severe burns
- Patients with multisystem organ failure
- Neurosurgery patients
- High-risk obstetric patients

SVO₂ monitoring is also used to do the following:

- Evaluate the adequacy of tissue oxygenation
- Detect adverse changes in oxygen delivery (DO₂) and oxygen consumption (VO₂) or impaired tissue oxygenation
- Evaluate the effectiveness of interventions to improve the balance between DO₂ and VO₂ including the administration of fluids (blood, crystalloids), pharmacological agents and use of mechanical assistance (eg, intra-aortic balloon pump, positive end-expiratory pressure)
- Evaluate the effects of routine medical and nursing procedures on tissue oxygenation
- Diagnose intracardiac shunting and cardiac tamponade
- Assist in the differential diagnosis of pathological conditions

Q: What is the relationship among SVO₂, DO₂, and VO₂?

DO₂ is the volume of oxygen delivered to the tissues each minute and is determined by the arterial oxygen content (CaO₂) and cardiac output. CaO₂ comprises arterial oxygen saturation (SaO₂), the amount of oxygen dissolved in the plasma (partial pressure of arterial oxygen, PaO₂), and hemoglobin level. Normal DO₂ is approximately 1000 mL/min. When indexed to body surface area (ie, DO₂ index), normal delivery is approximately 600 mL·min⁻¹·m⁻².

VO₂ is the amount of oxygen consumed each minute by the tissues for aerobic metabolism. Because the amount of oxygen needed for cellular metabolic functions (ie, oxygen demand) is difficult to measure in the clinical setting, VO₂ is used as a measurement to estimate oxygen demand. In healthy persons, VO₂ and oxygen demand are approximately equal. Normal values are approximately 250 mL/min for VO₂ and 120 to 140 for VO₂ index.

SVO₂ is a nonspecific multifactorial parameter that reflects the dynamic relationship (or balance) between DO₂ and VO₂ at the tissue level (Figure 2). DO₂ is normally 3...
or 4 times greater than VO₂. Under resting (stable) conditions, approximately 25% of oxygen delivered to the periphery will be consumed, and 75% will be returned to the right side of heart.10 Thus, SVO₂ values between 60% and 80% usually indicate a balance between DO₂ and VO₂.

Q: What constitutes a clinically significant change in SVO₂?

As previously stated, SVO₂ reflects the adequacy of DO₂ to satisfy the oxygen requirements of the tissues. The basic premise of continuous SVO₂ monitoring is that hemoglobin can release oxygen and that cells can extract oxygen from the blood, depending on the cellular oxygen needs and partial pressures of oxygen.11

When oxygen demand increases, extra oxygen is made available to the tissues by increases in cardiac output or oxygen extraction.

- If the oxygen extraction ratio (O₂ER) increases while cardiac output remains constant, less oxygen will remain in the venous blood, and SVO₂ will decrease.

- If cardiac output increases in response to an increase in oxygen demand and consumption, SVO₂ may remain stable.

SVO₂ values less than 60% may indicate either inadequate DO₂ or excessive VO₂.1 A clinically significant change in SVO₂ (>10% from baseline) may be an early indicator of physiological instability and cardiopulmonary deterioration.12,13

Conditions that may cause SVO₂ to decrease include decreases in cardiac output, hemoglobin level, and SaO₂ and an increase in VO₂. When DO₂ decreases to a critically low level, VO₂ may be limited to an amount of oxygen that is less than the amount required to meet the metabolic demand of the tissues (ie, VO₂ depends on DO₂).

In comparison, high SVO₂ values (>80%-95%) may be related to an increase in cardiac output, a decrease in oxygen demand, or a reduction in O₂ER. Various conditions, clinical events,10,14 and factors that may affect tissue oxygenation can cause significant changes in SVO₂ as described in the Table.

Q: How accurate is SVO₂ monitoring and what conditions may affect its accuracy?
The correlation between \( \text{SvO}_{2} \) measurements (range, 24%-85%) obtained with a bedside \( \text{SvO}_{2} \) monitor (in vivo) and simultaneous measurements obtained with a laboratory oximeter (in vitro) are between \( r=0.90 \) and \( r=0.97 \). The average amount of difference (bias) between in vitro and in vivo \( \text{SvO}_{2} \) measurements is \( \pm 4\% (\pm 2 \text{ SD}) \) for 95% of all measurements. Numerous studies support the accuracy of \( \text{SvO}_{2} \) monitoring systems.

Reliability is enhanced by a feature that monitors the optical intensity of the reflected light to guard against abnormal signal conditions (eg, a kink in the catheter, an occlusion or clot on the end of the catheter). An indicator of signal quality is continuously displayed on the monitor and is updated every few seconds. The signal quality indicator should be used by clinicians to evaluate the accuracy of \( \text{SvO}_{2} \) measurements.

Manufacturers of continuous \( \text{SvO}_{2} \) monitoring systems recommend that the system be calibrated in vitro before the catheter is inserted to ensure the accuracy of the measurements. Generally, an in vivo calibration is recommended every 24 hours for the duration of use of the system, if the system was not calibrated in vitro before insertion of the catheter, if the fiber optics may have been damaged, if the \( \text{SvO}_{2} \) value may be incorrect, and if the optical module becomes disconnected from the fiber-optic PA catheter.

Conditions that may alter the accuracy of the \( \text{SvO}_{2} \) measurement include hematocrit level, blood-flow characteristics, motion artifacts due to catheter “whip” against the vessel wall, blood temperature, and \( \text{pH} \).