Physiology and Venous Oximetry
Maintaining the balance between oxygen delivery (DO₂) and consumption (VO₂) to the tissues is essential for cellular homeostasis and preventing tissue hypoxia and subsequent organ failure. Traditional monitoring parameters (HR, blood pressure, CVP, and SpO₂) have been proven to be poor indicators of oxygen delivery secondary to compensatory mechanisms (Figure 1). Moreover, patients have demonstrated continued signs of tissue hypoxia (increased lactate, low ScvO₂) even after they have been resuscitated to normalized vital signs.

Continuous fiberoptic venous oximetry is a valuable tool for monitoring the balance between oxygen delivery and consumption at the bedside. Continuous venous oximetry is a sensitive real-time indicator of this balance, which can be applied as a global or regional indicator – with mixed venous oxygen saturation (SvO₂) and central venous oxygen saturation (ScvO₂) being the most commonly monitored. SvO₂ is a true reflection of the global balance between oxygen delivery and consumption since it is measured in the pulmonary artery, where venous blood returning to the right heart from the superior vena cava (SVC), inferior vena cava (IVC) and the coronary sinus (CS) have mixed. SvO₂ has been extensively studied and used clinically to monitor the global balance between DO₂ and VO₂. SvO₂ monitoring has been available through either co-oximetry laboratory analysis or through continuous fiberoptic monitoring with advanced technology pulmonary artery catheters since the 1970s and mid-1980s, respectively.
Continuous fiberoptic ScvO2 monitoring became available in 2003 on an 8.5F central venous catheter platform (PreSep catheter). This capability is also available via 4.5F and 5.5F central venous oximetry catheters (PediaSat catheter) for pediatric use (Figure 2). With the tip of the PediaSat central venous catheter placed in the SVC, ScvO2 can be measured and displayed on either a Vigileo or Vigilance monitor.

**Difference Between SvO2 and ScvO2**

Since SvO2 and ScvO2 are affected by the same four factors (cardiac output, hemoglobin, oxygenation, and oxygen consumption), and trend together clinically, they are considered nearly interchangeable.\(^3,5\) The exception is when calculating global physiologic profiles that use SvO2, such as VO2.\(^4\)

SvO2 is a global indicator of the balance between DO2 and VO2 as it is a reflection of all venous blood; IVS, SVC, and CS. ScvO2 is a regional reflection (head and upper body) of that balance. Under normal conditions ScvO2 is slightly lower than SvO2 due in part to the mixing and amount of venous blood retuning. In hemodynamically unstable patients, this relationship changes with ScvO2 being higher than SvO2 by approximately 7%.

This difference can widen in shock states, up to 18%, but the values trend together more than 90% of the time.\(^3,5,6\)

**Global Venous Oximetry**

- SvO2 – mixed venous oximetry

**Regional Venous Oximetry**

- ScvO2 – head and upper extremities\(^7\)
- SpvO2 – peripheral venous oximetry

**Organ Specific Venous Oximetry**

- SjvO2 – cranial jugular bulb oximetry\(^8\)
- ShvO2 – hepatic venous oximetry\(^9\)
- ScsO2 – coronary sinus oximetry\(^10\)

**Continuous ScvO2 Monitoring Technology**

All venous oximetry is measured through reflection spectrophotometry. Light is emitted from an LED through one of the two fiberoptic channels into the venous blood; some of this light is reflected back and received by another fiberoptic channel, which is read by a photodetector. The amount of light that is absorbed by the venous blood (or reflected back) is determined by the amount of oxygen that is saturated or bound to hemoglobin. This information is processed by the oximetry monitor, and updated and displayed every two seconds as a percent value on the monitor (Figure 3).\(^3\)
Accuracy of Edwards Fiberoptic Continuous ScvO2 Compared to Co-oximetry

In a laboratory bench environment continuous fiberoptic venous oximetry monitoring accuracy is approximately ± 2% at oximetry range of 30-99% as compared to a co-oximeter.11 With oxygen saturations from 9% to 100%, the results of the fiberoptic oximetry systems correlated significantly (P < 0.0001) with the standard blood gas co-oximetry system (r = 0.99).12 In an animal model, fiberoptic ScvO2 technology correlated significantly (Pr = 0.96, P < 0.001) and had a close linear relationship as determined by regression analysis (r² = 0.91, P < 0.001). Bland-Altman analysis revealed a ± 0.03% difference of means (bias) with ± 4.11% precision. Clinical comparison measurements also showed a significant correlation (Pr = 0.94, P < 0.001) and close linear relationship as determined by regression analysis (r² = 0.88, P < 0.001). Difference of means (bias) was - 0.03% with a ± 4.41% precision.13

Interference with ScvO2 Readings

Technical issues and therapeutic interventions may affect fiberoptics. Both the large distal lumen and the sending/receiving optics reside at the tip of the catheter. Therefore, tip position may influence signal quality (SQI) and readings if the tip is positioned against a vessel wall. Fluids infused through the distal lumen may also influence SQI and readings (e.g., lipids such as TPN or propofol, green or blue dyes, and crystalloid infusions at high flow rates). Catheter kinking may also result in a high SQI.

Interpreting Venous Oximetry (SvO2 and ScvO2) Values

Normal range values for SvO2 are 60-80% and 70% for ScvO2. ScvO2 usually runs 7% higher than SvO2 in critically ill patients.

Low oximetry readings usually indicate either low oxygen delivery (DO2) or an increase in consumption (VO2).2 However, patients with cyanotic hearts may have extremely low ScvO2 levels, therefore it is important to establish a baseline for each patient.

Significantly elevated levels (>80%) may indicate an inability to use oxygen delivered oxygen, significant shunting, significantly high cardiac output, or technical errors.

When is Change Significant?

ScvO2 and SvO2 values are not static and fluctuate approximately ± 5%. These values may show significant changes with activities or interventions such as suctioning; however, the values should recover within seconds. Slow recovery is an ominous sign of the cardiopulmonary system’s struggle to respond to a sudden increase in oxygen demand. When monitoring ScvO2, clinicians should look for changes of ± 5 -10% that are sustained for more than 3-5 minutes and then investigate each of the four factors that influence ScvO2:

- Cardiac output
- Hemoglobin
- Arterial oxygen saturation (SaO2) and
- Oxygen consumption

The first three (above) are indicators of DO2, while the fourth is an indicator of VO2.

Clinical Applications of ScvO2

ScvO2 and SvO2 are affected by the same four factors and trend together more than 90% of the time. Thus most of the research and clinical applications documented for SvO2 should apply to ScvO2. Figure 4 provides examples of clinical situations where ScvO2 monitoring may be helpful in identifying imbalances between DO2 and VO2.4
ScvO2 is best used adjunctively with cardiac output monitoring, allowing the clinician to determine the adequacy of oxygen delivery and to differentiate between issues of oxygen delivery vs. oxygen consumption (Figure 5).

Summary
Continuous venous oximetry (ScvO2) monitoring is an early, sensitive, and real-time indicator of the balance between DO2 and VO2 that can alert clinicians to an imbalance when traditional vital signs may not. ScvO2 monitoring with the PreSep or PediaSat catheter is a practical tool which is no more invasive than a traditional central venous catheter. Venous oximetry is best used in conjunction with cardiac output monitoring. Moreover, keeping ScvO2 values above 70% has been proven to lead to better patient outcomes.14

For additional educational resources visit www.Edwards.com/Education.

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References:
1. Spenceley N. Continuous Central Venous Saturation During Pericardial Tamponade: Case Report.
11. Vigileo monitor directions for use.

* SVV is an indicator of preload responsiveness

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Cardiac Output

Hemoglobin

Oxygenation

Metabolic Demand

Bleeding

Hemodilution

SaO2

Shivering

Anemia

PaO2

Fever

FiO2

Anxiety

Ventilation

Pain

Oxygen Delivery

PEEP

ScvO2 70%

Muscle Activity

Oxygen Consumption

Optimal HR

Optimal R-R

Optimal A-R

Optimal HR

Pacing

SVV*

SVR

SVRI

Preload

Afterload

Contractility

CVP

SV

SVI

LVSWI

Optimal R-R

Optimal A-R

HR

SV

Minimally Invasive Algorithm

Figure 5. Minimally invasive algorithm breaking down components of oxygen delivery and consumption followed by sub-components investigating root cause of imbalance.