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Quick reference guide

Monitoring premature neonates

INVOS™ regional oximeter

Premature neonates may have immature organs with suboptimal functioning – putting them at risk for poor oxygen exchange and perfusion – which may be missed by routine vital sign monitoring that does not capture oxygen supply, demand, or content at the organ level.

Information from INVOS™ near-infrared spectroscopy (NIRS) monitoring of the cerebral, peri-renal, and splanchnic sites – individually, or in combination – can integrate with routine vital signs and labs to provide a more comprehensive picture of organ-specific oxygen extraction and utilization to inform hemodynamic management, ventilation, and resuscitation.

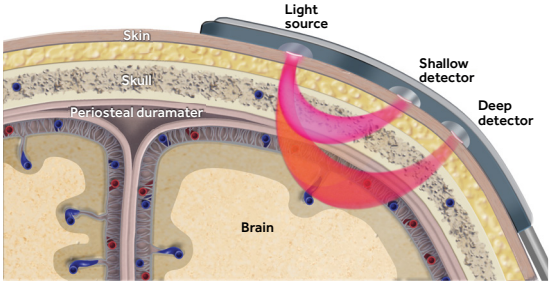
It is intended for use as an adjunct trend monitor of regional hemoglobin oxygen saturation of blood in tissue beneath the sensor in any individual, including neonates weighing less than 2.5 kg.

Blood pressure and pulse oximetry do not always reflect perfusion and oxygenation at the tissue level

	Hemodynamic instability	Suboptimal respiratory support and resuscitation
		
Causes	• Poor transition • Low cardiac output • Impaired autoregulation • Anemia • Shock, sepsis	• Impaired lung function • Poor gas exchange capabilities • Shunting
Management	• Volume expansion • Vasopressors / dilators • Inotropes • Blood transfusion	• Supplemental oxygen • Surfactant administration • Bag mask support in L&D • Non-invasive ventilation • Invasive ventilation
Challenges	Maintaining an arbitrary gestational age-based blood pressure target **does not guarantee optimal organ perfusion**	Pulse oximetry is an indirect measure of oxygen delivery to the organs; **too much or too little can cause long term damage**

The INVOS™ monitoring system provides continuous noninvasive measurement of organ-specific oxygenation

Measures the percentage of oxyhemoglobin or the venous reserve capacity following tissue oxygen extraction in a specific region/tissue under the sensor.



There is both a shallow pathway (shorter distance photodetector) and a deep pathway (farther distance photodetector). The short pathway is subtracted from the deep pathway so that the tissue of interest at 2.5 cm below the probe is interrogated, avoiding contamination from the skin, bone, and dura when monitoring rSO_2 of the brain.[1]

Provides noninvasive cerebral/somatic monitoring that measures regional, real-time tissue oxygen extraction and utilization

Provides oxygen saturation from vascular beds to assess organs individually, or in combination to track brain/body perfusion shifts

Can help clinicians identify ischemic threats in the cerebral and peripheral circulatory systems so they can intervene earlier[2]

Regional oxygen saturation (rSO_2) reflects post-extraction oxygen balance of the tissue

Allows for more personalized, patient-centered approaches — helping delineate the underlying pathophysiology more effectively when added to clinical assessments.[2]

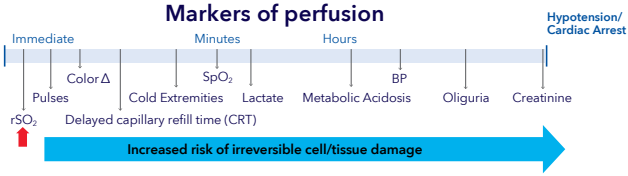
Regional oxygen saturation (rSO_2)

- Venous-weighted :
  - ~ 25% arterial contribution
  - ~ 75% venous (post-extraction) contribution
- The rSO_2 value reflects the balance between oxygen supply, demand, and content in the tissue — how much oxygen is left after the tissue extracts a portion of what is available[1]

Factors affecting rSO_2 values

- Blood pressure (supply)
- Cardiac output (supply)
- Shunting (supply, content)
- Carbon dioxide (supply)
- Transfusion (content)
- Brain activity (demand)
- Temperature (demand)

Standard of care vital signs and labs are incomplete markers of tissue perfusion and oxygenation



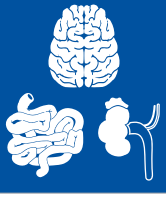
Courtesy of Scott Duncan, M.D.

The rSO_2 measurement may be an **early and more sensitive warning** to a perfusion change

Routine clinical monitors do not detect changes in systemic vascular resistance which result in redistribution of cardiac output

Monitoring site-specific perfusion often provides an earlier warning of developing pathology and deterioration than systemic measures or lab tests[2]

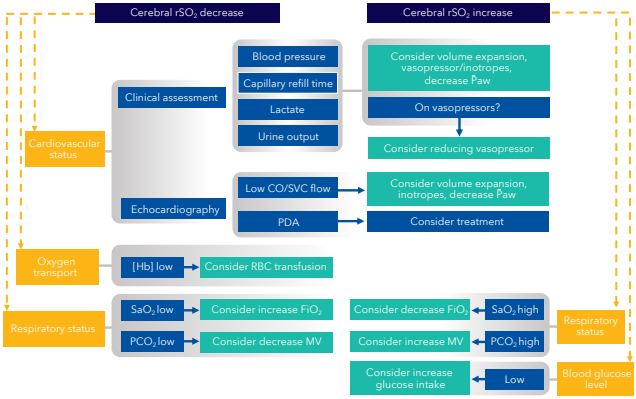
Monitoring rSO_2 at single sites or in combination can reveal changes in cardiac output and impending shock

	What do rSO_2 values and trends look like at this site?	What can monitoring rSO_2 tell you?
Cerebral 	• High flow • High oxygen extraction • Stable values • Typical rSO_2 = 60 to 80%[4]	Monitors for **changes in cerebral perfusion, oxygen content, and oxygen extraction**
Peri-renal 	• Lower flow • Lower oxygen extraction • Variable values • Typical rSO_2 = 5 to 15 points higher than cerebral[4]	Reveals changes in organ-area perfusion related to **low cardic output or compensated shock states**
Splanchnic 		
Multi-site 	Somatic rSO_2 trending lower than cerebral rSO_2 may indicate abnormal pathology	Combining cerebral and somatic monitoring can indicate **changes in cardiac distribution**[1]

To avoid pressure sores, do not apply external pressure (e.g., headbands, wraps, or tape) to the sensor. Medtronic recommends using a new sensor every 24 hours or if adhesive does not seal the sensor to the skin adequately.

rSO_2 changes can alert clinicians to investigate changes in cardiovasular status, oxygen transport, respiratory status, and blood glucose[3]

Although the NIRS monitor may indicate an abnormality, **the clinician should understand all the possible underlying causes** of rSO_2 changes



Abbreviations:

rSO_2, regional tissue oxygen saturation of hemoglobin
CO, cardiac output
SVC, superior vena cava
$\bar{P}aw$, mean airway pressure
MV, minute ventilation
PDA, patent ductus arteriosus
[Hb], blood hemoglobin concentration
RBC, red blood cells
SaO_2, arterial hemoglobin saturation
FiO_2, inspired oxygen fraction
PCO_2, partial pressure of carbon dioxide

Published case reports to illustrate use in a variety of clinical circumstances

There is a learning curve when using NIRS initially.

As you begin selecting babies to study, **start by choosing a neonate that has an identified and understood physiological process,** which allows for confirmation by NIRS. This helps clinicians develop an understanding and comfort level with this technology.

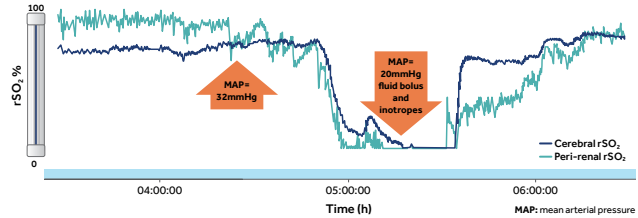
Case 1	**Hemodynamic management** 	**NIRS as a guide to manage hemodynamic instability and shock** 25-week gestational age neonate with early onset sepsis
Case 2	**Ventilation management** 	**NIRS as a signal of decreased perfusion due to excessive mean airway pressure** 28-week gestational age neonate on HFOV
Case 3	**Resuscitation** 	**NIRS as a guide to cardiopulmonary resuscitation after delivery** 24-week gestational age male neonate requiring immediate support after birth

Hemodynamic management

Case 1: NIRS as a guide to manage hemodynamic instability and shock[5]

Simultaneous near-infrared spectroscopy (NIRS) and amplitude-integrated electroencephalography (aEEG): Dual use of brain monitoring techniques improves our understanding of physiology

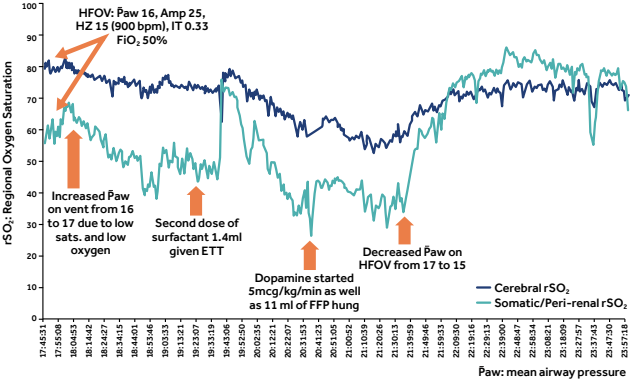
Variane GFT, Chock VY, Netto A, Pietrobom RFR, Van Meurs KP. (BRAZIL, USA)



Patient	• 25-week gestational age neonate weighing 610 g • Showed **early indicators of hemodynamic instability** • Diagnosed with early onset sepsis and intubated to manage respiratory distress syndrome
Situation	• **3 days post-birth: experienced severe hypotension and septic shock** • Peri-renal rSO_2 decreased 30% from baseline • 40 minutes later, cerebral rSO_2 decreased from 75% to 15% • **After intervening with fluids and inotropes, both peri-renal and cerebral rSO_2 improved**
NIRS	• **Although mean arterial blood pressure remained steady at 32mmHg, peri-renal rSO_2 began to drop steadily indicating impending instability**

Ventilation management

Case 2: NIRS as a signal of decreased perfusion due to excessive mean airway pressure (P̄aw)



On file at Medtronic

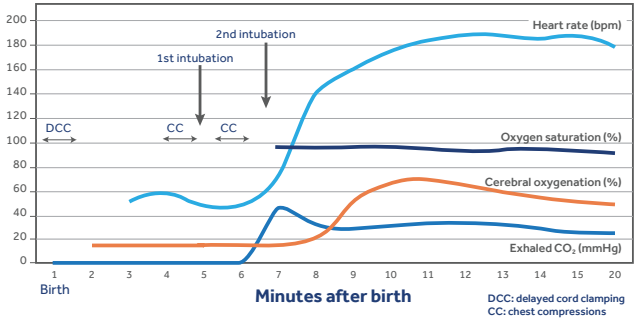
Patient	• 28-week gestational age neonate admitted to NICU with **respiratory distress syndrome** and to rule out sepsis
Situation	• High-frequency oscillatory ventilation (HFOV) support was initiated with a mean airway pressure (P̄aw) of 16 cmH_2O and subsequently increased to 17 cm H_2O • Steady decline in peri-renal rSO_2 over the first hour and a half • **Decrease in P̄aw from 17cmH_2O to 15cmH_2O lead to an immediate increase in peri-renal rSO_2**
NIRS	• NIRS indicated the peri-renal tissue was not adequately perfused • **With that information, they determined that the increased P̄aw was putting too much pressure on the heart decreasing oxygen delivery to the peri-renal tissue and clinicians were able to decrease ventilation support**

Resuscitation

Case 3: NIRS as a guide to cardiopulmonary resuscitation after delivery[6]

Respiratory function and near infrared spectroscopy recording during cardiopulmonary resuscitation in an extremely preterm newborn

Li ES, Cheung PY, Pichler G, Aziz K, Schmölzer GM. (Canada, Austria)

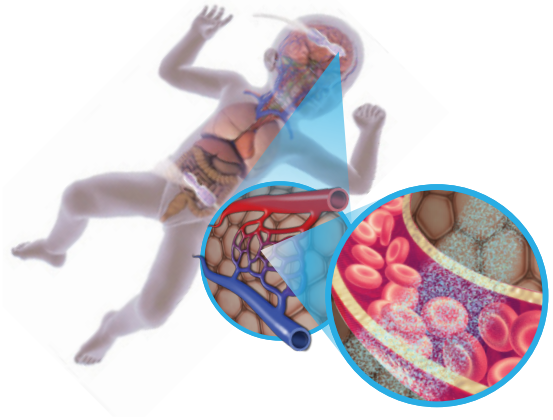


Patient	• 24-week gestational age male neonate weighing 650 g • Apgar scores were 3, 2, and 7 at 1, 5, and 10 minutes post-birth • **Neonate was "floppy", cyanotic, and apneic** after delayed cord clamping (DCC)
Situation	• Positive pressure mask ventilation did not improve the neonate's condition • **CPR was initiated and neonate was successfully intubated after two attempts between chest compressions (CC)** • Return of spontaneous circulation (ROSC) was observed after the second intubation attempt
NIRS	• **Despite an adequate arterial oxygen saturation of ~ 95% to 100%, cerebral rSO_2 remained very low at ~15% until ROSC** • Cerebral rSO_2 may provide a more complete picture of whether resuscitation efforts are sufficient for restoring cerebral perfusion and oxygenation

Summary

All three of these cases are examples of rSO_2 as an early alert of changes in oxygen supply and demand which could be indicative of possible impending deterioration or the impact of interventions.

Monitoring of cerebral, peri-renal, and splanchnic rSO_2 – individually, or in combination – may be used in the NICU to inform hemodynamic management, ventilation, and resuscitation.



The INVOS™ monitoring system should not be used as the sole basis for diagnosis or therapy and is intended only as an adjunct in patient assessment. Reliance on the INVOS™ system alone for detecting cerebral desaturation events is not recommended.

INVOS™ System and device discussed in this guide is referring to the INVOS™ 7100 system. The sensor shown in this guide may also be used with the INVOS™ 5100C system.

References

1. Marin T, Moore J. Understanding Near-Infrared Spectroscopy *J. Adv Neonatal Care* 2011 Dec;11(6):382-8
2. Mintzer JP, Moore JE. Regional tissue oxygenation monitoring in the neonatal intensive care unit: evidence for clinical strategies and future directions. *Pediatr Res.* 2019;86(3):296–304.
3. Pellicer A, Greisen G, Benders M, et al. The SafeBoosC phase II randomised clinical trial: a treatment guideline for targeted near-infrared-derived cerebral tissue oxygenation versus standard treatment in extremely preterm infants. *Neonatology*. 2013;104(3):171–178.
4. McNeill S, Gatenby JC, McElroy S, Engelhardt B. Normal cerebral, renal and abdominal regional oxygen saturations using near-infrared spectroscopy in preterm infants. *J Perinatol.* 2011;31(1):51-57. doi:10.1038/jp.2010.71
5. Variane GFT, Chock VY, Netto A, Pietrobom RFR, Van Meurs KP. Simultaneous Near-Infrared Spectroscopy (NIRS) and Amplitude-Integrated Electroencephalography (aEEG): Dual Use of Brain Monitoring Techniques Improves Our Understanding of Physiology. *Front Pediatr.* 2020;7:560.
6. Li ES, Cheung PY, Pichler G, Aziz K, Schmölzer GM. Respiratory function and near infrared spectroscopy recording during cardiopulmonary resuscitation in an extremely preterm newborn. *Neonatology*. 2014;105(3):200-204.

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Important: Please refer to the package insert for complete instructions, contraindications, warnings and precautions.

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