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Cerebral Oximetry: Current State & Applications

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Disclosure

The presenter has no financial relationships with any commercial interests pertinent to this presentation.

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Objectives

1. Recall the science and technology behind the use of cerebral oximetry.

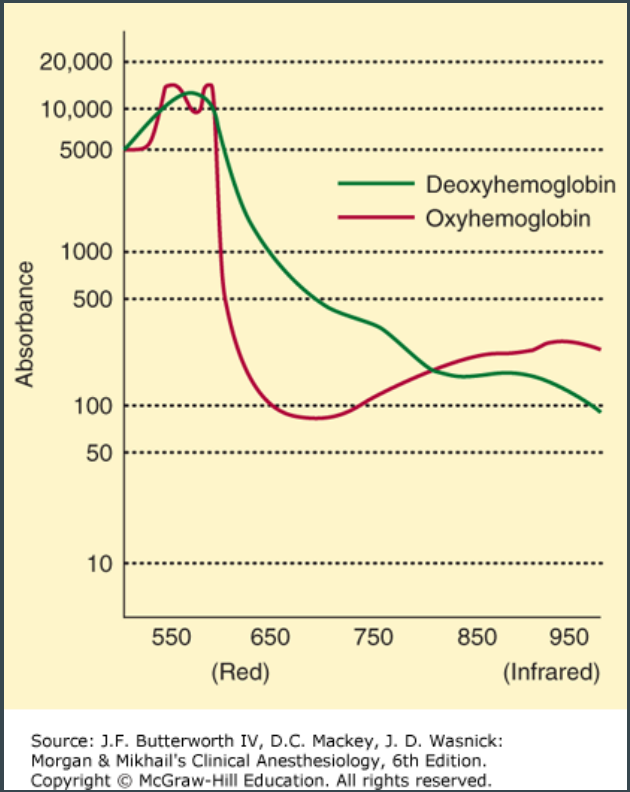
2. Describe the clinical applications of cerebral oximetry.

3. Recognize the modalities, industry options and estimated costs for clinical use of cerebral oximetry.

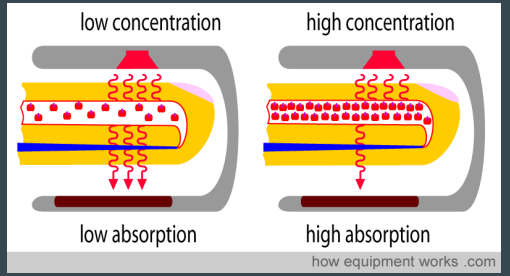
What is Oximetry?

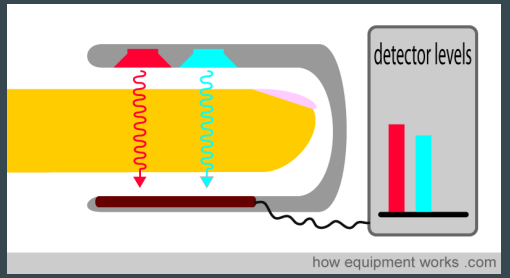
- Oximetry: Non-invasive means to measure the oxygen level (oxygen saturation) of the blood based on different light absorptions for oxygenated and deoxygenated hemoglobin
  - Standard monitor in anesthesia care: Pulse Oximeter
  - Optional standard monitor, but often used in certain clinical scenarios: Cerebral Oximeter
- Changes in baseline oximetry should represent changes in regional perfusion and oxygen delivery to a particular area of tissue
- Quickly identifying these changes should lead to interventions to limit the time sensitive tissues and exposed to hypoxemic (deoxygenated blood) conditions

Pulse Oximeter



- A probe passes two wavelengths of light through pulsating vascular bed
  - 660 nm deoxyhemoglobin absorbs more red light appears blue
  - 940 nm oxyhemoglobin absorbs more infrared light





Cerebral Oximetry

- Cerebral Oximeter: Measuring regional oxygen saturation within brain tissue (rSO2)
- Near Infrared Spectroscopy (NIRS): Technology utilized in clinical practice
  - Near infrared light is transmitted from a source embedded in a sensor attached to the forehead and directed toward the frontal lobe
  - Frontal lobe is a watershed region of cerebral blood flow and therefore sensitive to ischemia

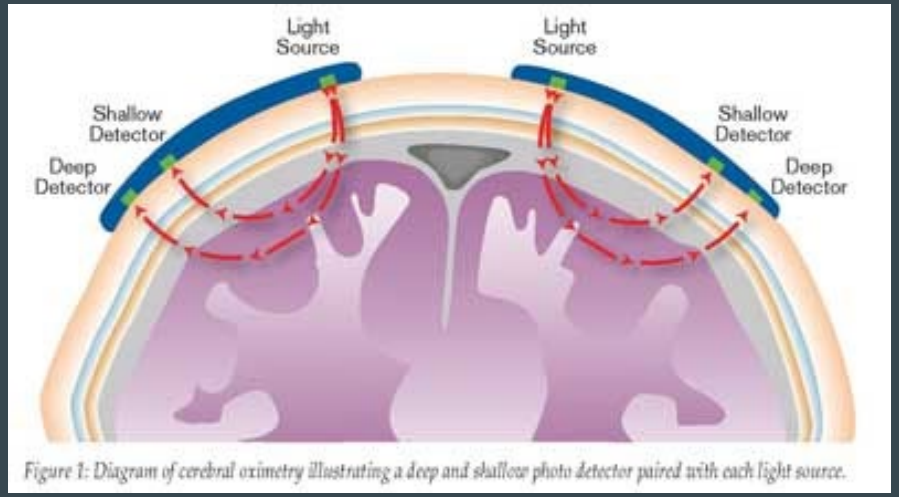
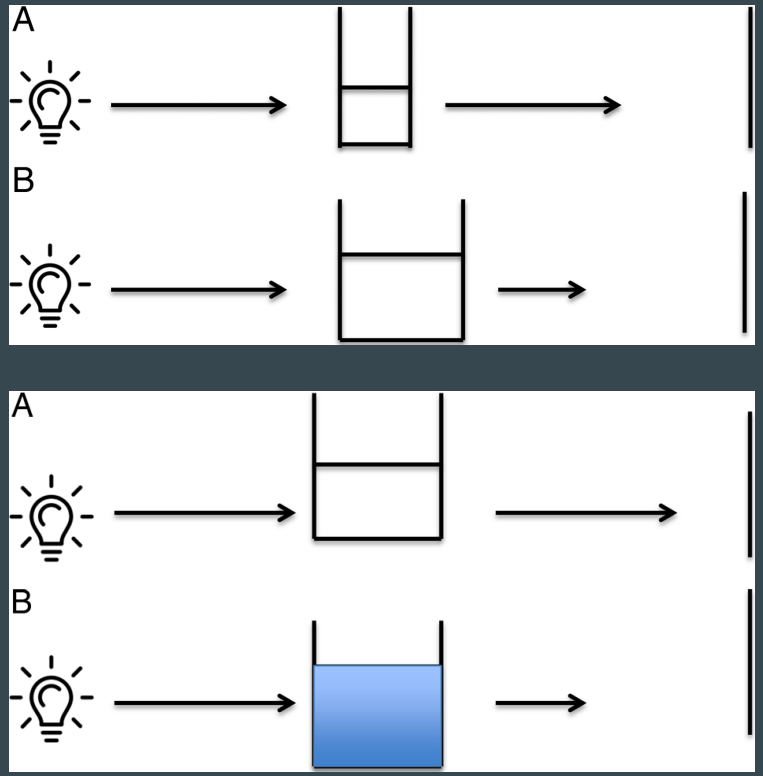


Figure 1: Diagram of cerebral oximetry illustrating a deep and shallow photo detector paired with each light source.

Cerebral Oximetry

- Beer's Law and Lambert's Law
- Primarily a surrogate for oxygen saturation in venous side of blood volume (~70-75% of blood volume)
  - Pulsatility not required
- "A tool providing non-invasive continuous access to the venous side of regional circulations"



Clinical Applications: Current

- Carotid Artery Surgery
- Adult Cardiothoracic Surgery
- Surgery in Beach Chair Position
  - Total Shoulder Replacement
  - Shoulder arthroscopy
- Pediatric Cardiac Surgery
- Pediatric Non-Cardiac Surgery

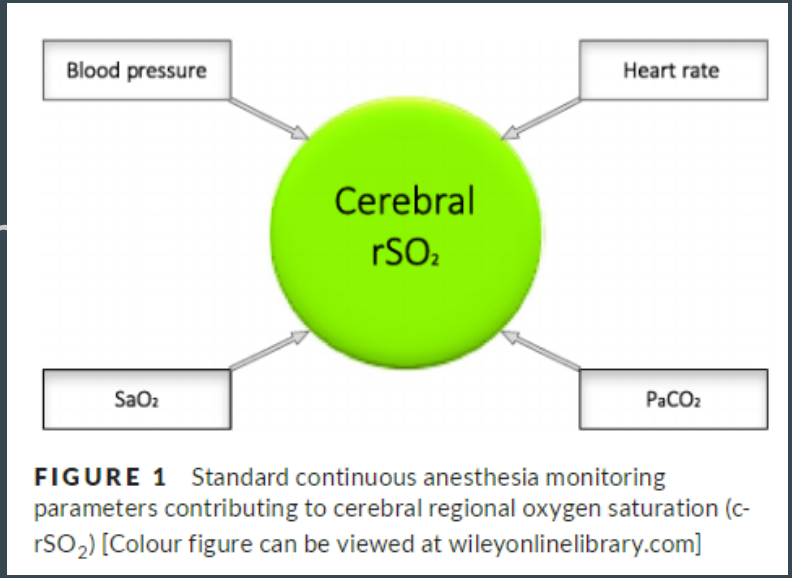
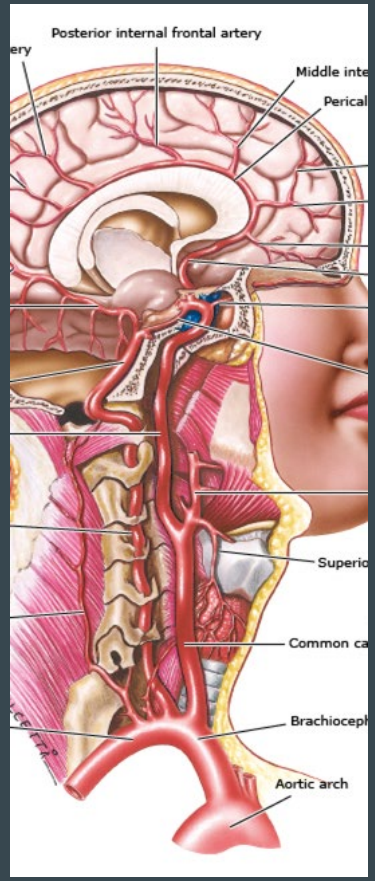
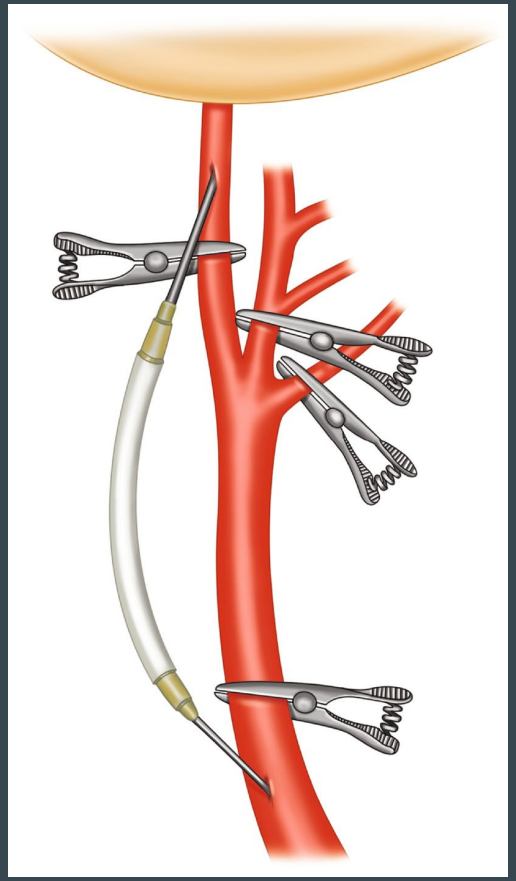


FIGURE 1 Standard continuous anesthesia monitoring parameters contributing to cerebral regional oxygen saturation (c-rSO_2) [Colour figure can be viewed at wileyonlinelibrary.com]

Carotid Artery Surgery

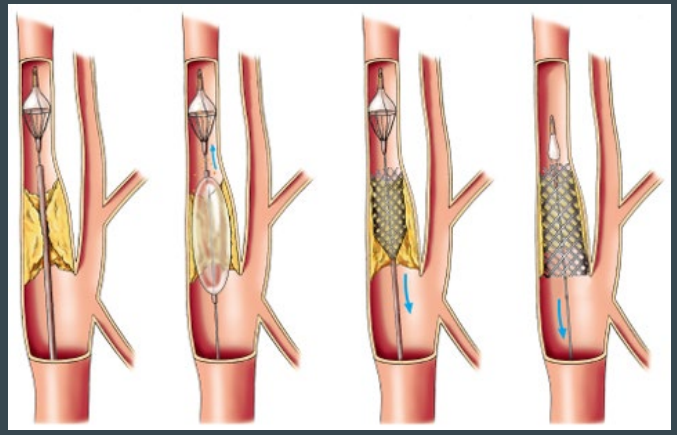
- Pre clamp ($rScO_2$) values
- Stroke Predictors
  - ↓rSO2 ⩾20% below baseline
  - Baseline rSO2 ≤50% pre-induction of GA
- Selective shunting
  - NIRS can guide under GA
  - What change from baseline should trigger shunt?
- Frontal lobe only sampling
- Multiple confounders
- Limited detection within entire brain





Carotid Artery Stenting

- Minimally invasive procedure
- Cerebral hyperperfusion syndrome (CHS)
  - Reperfusion => Possible Intracranial Hemorrhage (ICH)
  - Pre/Post Reperfusion rSO2 values
  - rSO2 at 3 min after reperfusion >10% => CHS

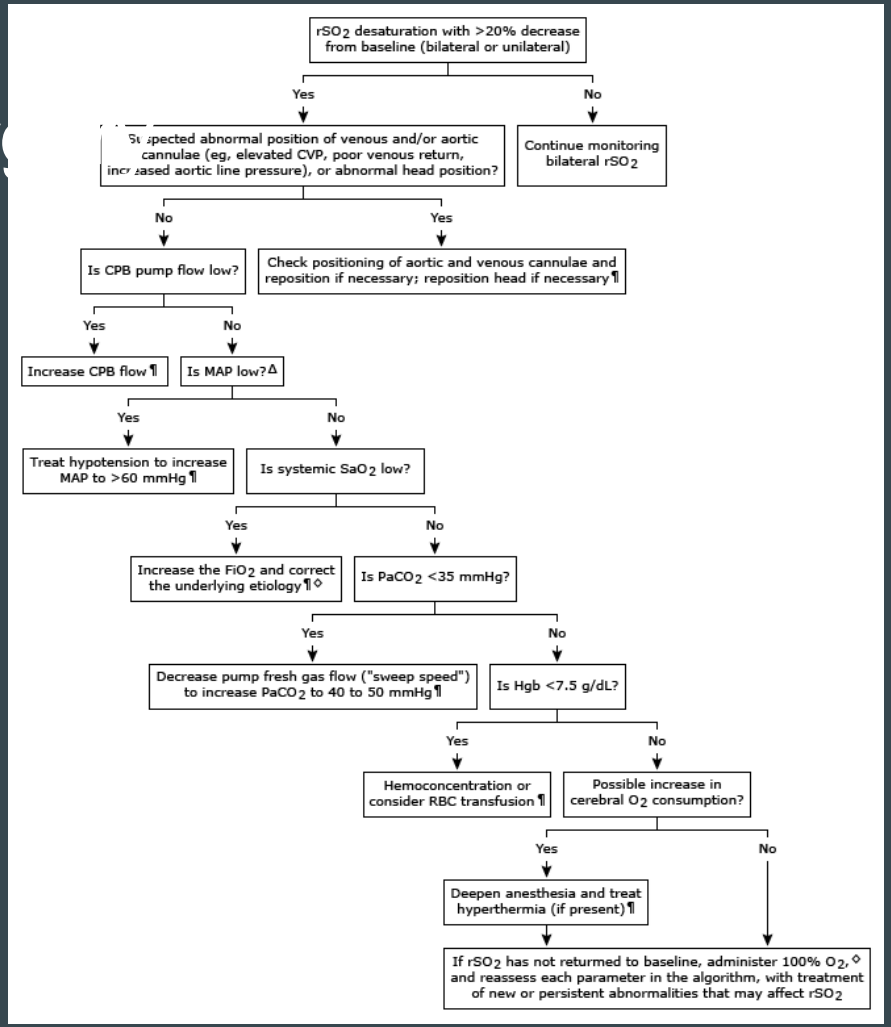


Adult Cardiothoracic Surgery

- Adult Cardiac Surgery:
  - General Goal is to remain within 20% of baseline values
  - No studies have shown that increasing or improving low rSO2 values can prevent stroke or poor postoperative outcome
  - Recent Studies have mixed results with NIRS as intervention:
    - 2018 Meta Analysis: Postoperative Cognitive Dysfunction at 1 week
    - 2019: No significant association was found between intraoperative rScO2 values and Postoperative Cognitive Dysfunction

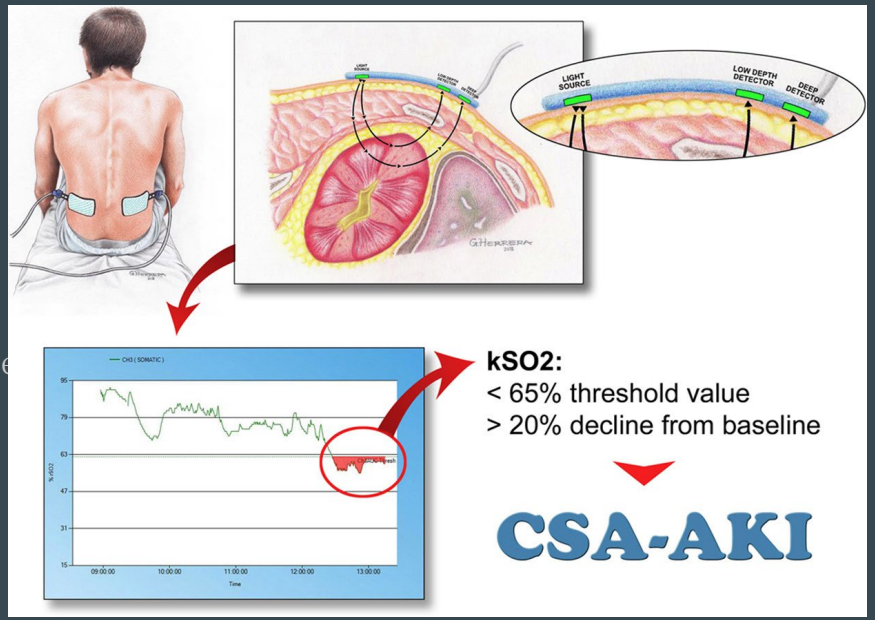
Adult Cardiothoracic Surg

- Management of↓rSO2 during Cardiopulmonary Bypass
  - Cannula Malposition
  - CPB Flow
  - MAP
  - Decrease PaCO2
  - Increase Hemoglobin
  - Deepen Anesthesia
  - Decrease Temperature
  - Increase O2 delivery



Adult Cardiothoracic Surgery

- Renal Perfusion: Postoperative Acute Kidney Injury
  - Continuous postoperative monitoring
  - 121 Patients evaluated along with brain oxygen saturation
  - 35 developed Acute Kidney Injury
  - Kidney sO2 <65% or ⩾20% below baseline



Pediatric Cardiac Surgery

Pediatric Anesthesia

Cerebral oximetry for pediatric anesthesia: why do intelligent clinicians disagree?

Nicholette Kasman, Ken Brady

First published:18 March 2011 | https://doi.org/10.1111/j.1460-9592.2011.03549.x | Citations: 29

- Widespread use like in Adult Population
- Limited data whether outcomes are improved
- No specific data to recommend or refute use in adults with congenital heart disease
- Easier to assess renal and splanchnic (gut)

Pediatric Non-Cardiac Surgery

An International, Multicenter, Observational Study of Cerebral Oxygenation during Infant and Neonatal Anesthesia

Conclusions: Mild and moderate low cerebral saturation occurred frequently, whereas severe low cerebral saturation was uncommon. Low mean arterial pressure was common and not well associated with low cerebral saturation. Unrecognized severe desaturation lasting 3 min or longer in infants seems unlikely to explain the subsequent development of neurocognitive abnormalities. (ANESTHESIOLOGY 2018; 128:85-96)

What We Know about This Topic

- Intraoperative cerebral hypoperfusion and ischemia in infants is a potential cause of later cognitive impairment
- The investigators thus evaluated cerebral saturation in 453 infants undergoing surgery
- Severe desaturation was rare and poorly associated with hypotension

What This Article Tells Us That Is New

- Cerebral desaturation seems an unlikely explanation for cognitive dysfunction
- Whether anesthesia provokes cognitive dysfunction in infants remains highly controversial
- But to the extent that it does, mechanisms other than cerebral desaturation should be considered

Pediatric Non-Cardiac Surgery

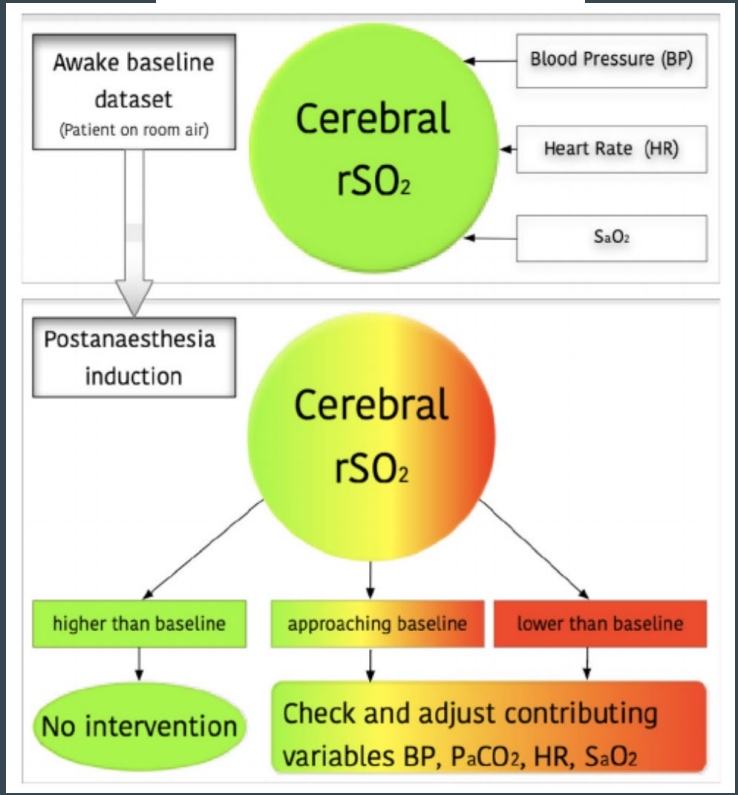
A practical approach to cerebral near-infrared spectroscopy (NIRS) directed hemodynamic management in noncardiac pediatric anesthesia

Pediatric Anesthesia

Pediatric Anesthesia. 2019;29:993–1001.

- Novel approach defining baseline awake c-rSO2 values as the lower limit
- Multisite NIRS: Cerebral, Renal, Muscle
- Fractional regional tissue oxygen extraction
  - [FTOE = (SaO2-rSO2)/SaO2]
  - Composite parameter reflecting the balance between oxygen delivery and consumption
  - Calculated real time with integrated device

"Baseline-Bottomline approach"



Beach Chair Position

- Beach Chair Position (BCP)
  - Arthroscopic shoulder surgery
- BP Monitoring
  - Arm BP = Brain BP ???
  - Cerebral autoregulation

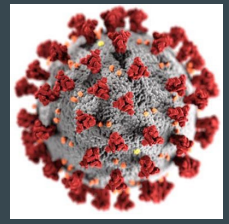
Beach Chair Position

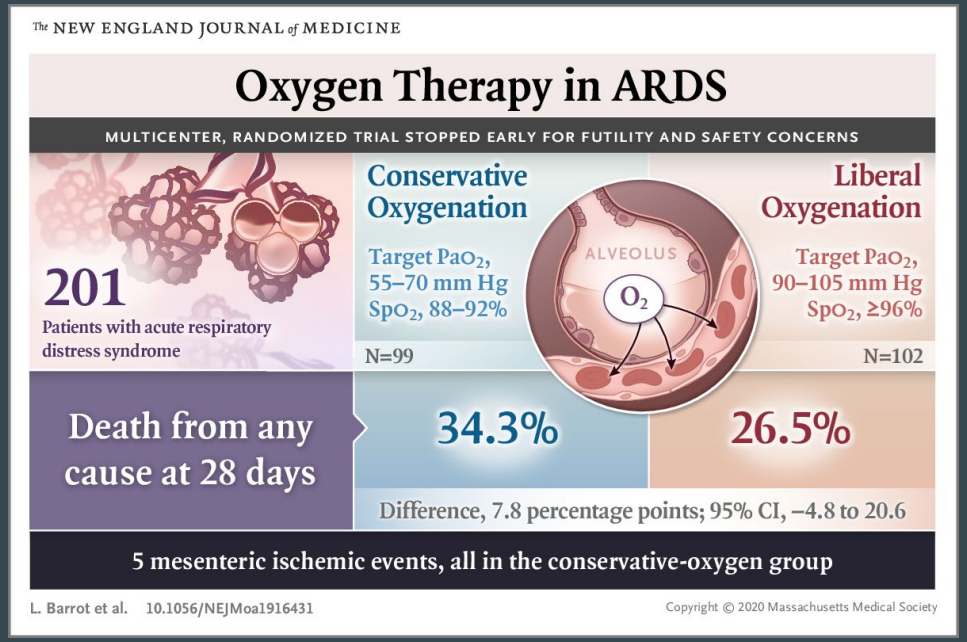
- Shoulder Surgery in Beach Chair Position (BCP)
  - Catastrophic stroke reported in 47 yo in BCP
- Anesthesia Patient Safety Foundation (ASPF): Comment 2013
  - Large clinical studies are underway and should offer more information regarding the risk of shoulder surgery in the BCP and possible clues toward a best practice in managing these patients.
  - However, a “best practice” will be difficult to define until we are able to better understand the definition of baseline blood pressure and to what degree a deviation from baseline is safe.
  - In the interim, clinicians should remain aware of the potential danger of cerebral malperfusion in this patient population.

Clinical Applications: Emerging

- Cerebral autoregulation & blood flow
  - Traumatic Brain Injury
  - Cerebrovascular Accident
- Intracranial hypertension
  - Hydrocephalus
- Tissue perfusion
  - Low Cardiac Output States
  - Renal/Mesenteric Perfusion
  - Sepsis
  - Congestive Heart Failure
- Fetal Oxygenation
  - Placental measurements
- Neonatal ICU
  - NEC Prediction
  - Cerebral hypoxia
  - Neurodevelopmental outcomes
  - Neonatal resuscitation
- Peripheral oxygen desaturation
  - COVID-19
  - Acute Respiratory Distress Syndrome (ARDS)
  - Chronic hypoxemia
  - Peripheral vascular disease

What do you want the Oxygen dial turned





Why COVID-19 Silent Hypoxemia Is Baffling to Physicians

Silent hypoxia: A harbinger of clinical deterioration in patients with COVID-19

Considerations for target oxygen saturation in COVID-19 patients: are we under-shooting?

Prehospital pulse oximetry: a red flag for early detection of silent hypoxemia in COVID-19 patients

Effects of Cardiovascular and Pulmonary Optimization on Cerebral Oxygenation in COVID-19 Patients With Severe ARDS (NIRS-COV)

Anesthesiologist's Perspective

Electroencephalography and Brain Oxygenation Monitoring in the Perioperative Period

Thomas W. L. Scheeren, MD, PhD,* Merel H. Kuizenga, MD,* Holger Maurer, MD,†
Michel M. R. F. Struys, MD, PhD,* and Matthias Heringlake, MD†

Maintaining brain function and integrity is a pivotal part of anesthesiological practice. The present overview aims to describe the current role of the 2 most frequently used monitoring methods for evaluation brain function in the perioperative period, ie, electroencephalography (EEG) and brain oxygenation monitoring. Available evidence suggests that EEG-derived parameters give additional information about depth of anesthesia for optimizing anesthetic titration. The effects on reduction of drug consumption or recovery time are heterogeneous, but most studies show a reduction of recovery times if anesthesia is titrated along processed EEG. It has been hypothesized that future EEG-derived indices will allow a better understanding of the neurophysiological principles of anesthetic-induced alteration of consciousness instead of the probabilistic approach most often used nowadays.

Brain oxygenation can be either measured directly in brain parenchyma via a surgical burr hole, estimated from the venous outflow of the brain via a catheter in the jugular bulb, or assessed noninvasively by near-infrared spectroscopy. The latter method has increasingly been accepted clinically due to its ease of use and increasing evidence that near-infrared spectroscopy–derived cerebral oxygen saturation levels are associated with neurological and/or general perioperative complications and increased mortality. Furthermore, a goal-directed strategy aiming to avoid cerebral desaturations might help to reduce these complications. Recent evidence points out that this technology may additionally be used to assess autoregulation of cerebral blood flow and thereby help to titrate arterial blood pressure to the individual needs and for bedside diagnosis of disturbed autoregulation. (Anesth Analg 2019;128:265–77)

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CONCLUSIONS

There is increasing evidence that the use of brain function monitoring by processed EEG and brain oxygenation monitoring by NIRS are useful adjuncts for improving patient care in the perioperative period.

In contrast, increasing evidence suggests that avoiding a mismatch between brain oxygen delivery and demand by goal-directed optimization of NIRS-derived cerebral oxygen saturation leads to a reduction of neurological and/or general perioperative complications. Recent evidence points out that this technology may be additionally used to assess autoregulation of CBF and thereby help to titrate arterial blood pressure to the individual needs and for bedside diagnosis of disturbed autoregulation.

Limitations

- Equivocal data showing definitive improvement in outcomes
  - Not yet received as standard of care for all patients
  - Cochrane database review: “found no evidence that pulse oximetry affects the outcome of anesthesia for patients” ???
- Mixture of arterial and venous oxygen saturation
- Localized sampling
- Widespread baseline values
- No accepted guidelines as of yet
- Approximate Cost
  - Monitors: $15,000-$25,000
  - Sensors ~$200/patient

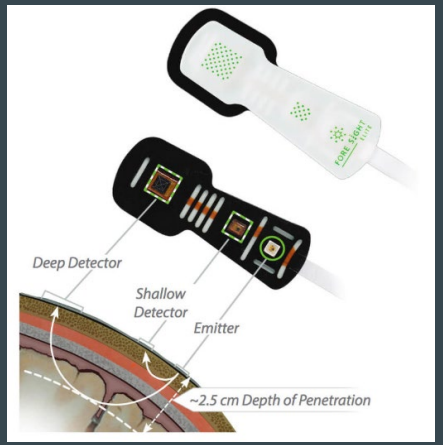
Medtronic: INVOS™ 5100C Cerebral/Somatic Oxim

Masimo: Root® with O3® Regional Oximetry

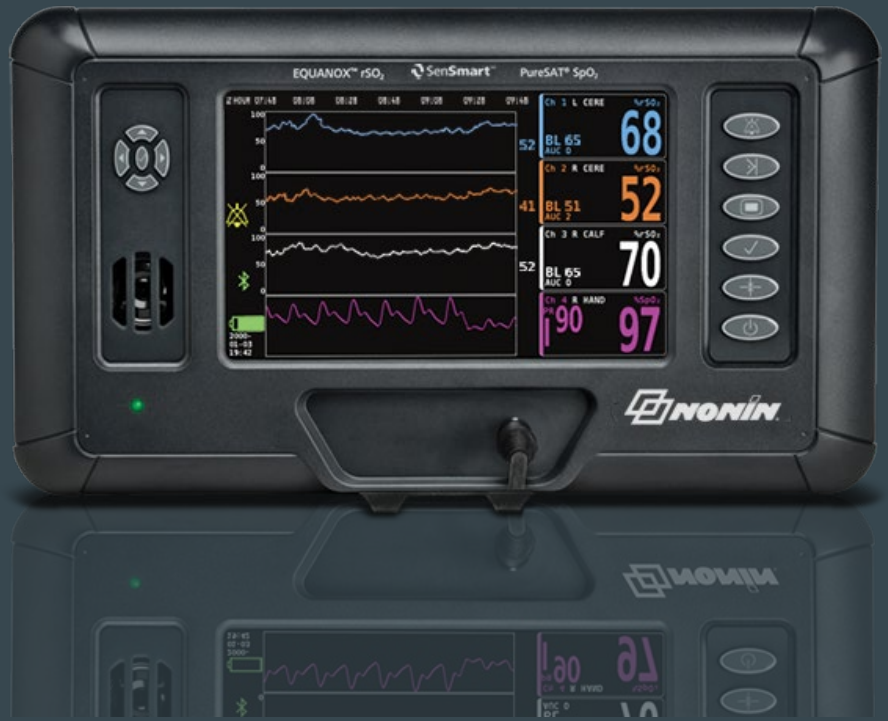
Edwards: ForeSight Elite tissue oximetry system

5 wavelengths of near infrared light (NIRS) for effective tissue interrogation

ForeSight Elite sensor technology allows for effective tissue interrogation. By incorporating 5 wavelengths of near-infrared light to analyze tissue, ForeSight Elite system provides a broad spectrum of NIRS wavelengths (685, 730, 770, 810, 870nm). This technology allows for effective tissue interrogation at points where oxygenated and deoxygenated hemoglobin are more greatly distinguished for highly accurate performance.

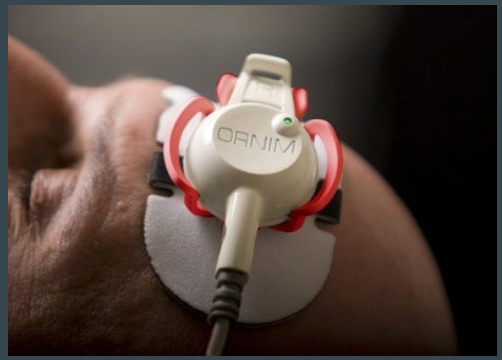


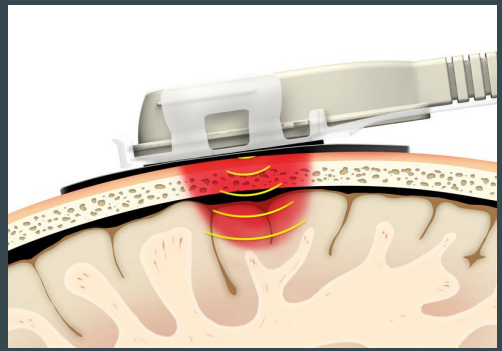
NONIN: SenSmart® Universal Oximetry Systems



Future Technology

- Ultrasound+NIRS
  - Hybrid Device - Single Probe
  - CerOx (Ornim Medical Ltd., Israel)
  - Simultaneous Measurement of
    - Brain Oximetry
    - Blood Flow Monitor
  - Estimates changes in microcirculator blood flow





Integration

Integration

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Thank you

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