

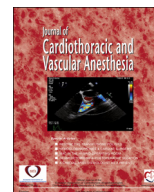
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Case Report

A Proposed Approach to Cerebral and Somatic Desaturation in the Intensive Care Unit: Preliminary Experience and Review

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IN RECENT YEARS, frontal cortex tissue saturation (rSO₂) using near-infrared spectroscopy (NIRS) has been serving as continuous, noninvasive monitoring of balance between cerebral oxygen delivery and consumption in the operating room (OR) setting. In the authors' center, cerebral NIRS has been used for more than 15 years during cardiac surgeries.¹ Since 2013, the authors frequently have used the rSO₂ electrodes during the early postoperative period of cardiac surgery patients. This was the consequence of one single center and one multicenter trial by Deschamps et al that showed that brain desaturation in the intensive care unit (ICU) is as common as it is in the operating room.^{2,3} However, the role of NIRS in the ICU remains controversial for several reasons. These include the relatively small sensor area coverage, sampling errors, extracranial contamination,⁴ prohibitive cost, lack of extensive literature, and the absence of clinical trials in the ICU.⁵⁻⁷

To the authors' knowledge, the use and potential benefits of combining regional cerebral and somatic tissue oxygenation monitoring with NIRS in the ICU setting rarely have been reported. The aim of this article is to illustrate 4 different

clinical cases in which cerebral and/or somatic tissue saturation monitoring in the ICU played a role in the identification of the underlying pathology to guide therapeutic intervention. Data were recorded with Health Canada-approved monitoring devices from EQUANOX Classic 7600 (Nonin Medical Inc., Plymouth, MN) and INVOS 5100-PB (Covidien/Medtronic Inc., Boulder, CO).

Case 1 (Hemothorax)

A 70-year-old female was admitted to the ICU after aortic valve replacement by minimally invasive surgery with right thoracotomy. Initial right-sided chest tube drainage was 200 mL/h for 3 consecutive hours; the patient had normal coagulation studies and 5 units of platelets were transfused based on preoperative antiplatelet medication use. Bleeding resolved and hemodynamic parameters were maintained by infusion of crystalloid solution, 5% albumin, and vasopressors (10 µg/min of norepinephrine). Despite minimal subsequent chest tube drainage, further instability requiring additional volume resuscitation and an associated significant fall in cerebral saturation values prompted a rapid patient reassessment. A chest X-ray showed a large right-sided pleural effusion associated with a reduction in blood hemoglobin

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concentration from 104 to 66 g/L. Restoration of circulating volume with 2 units of packed red blood cell and 500 mL of 5% albumin corrected the hypotension and restored cerebral saturation values to normal. The patient then was returned to the OR where the surgeons removed 1 L of coagulated blood from the right thoracic cavity.

Case 2 (Tamponade)

A 73-year-old female was admitted to the ICU after urgent surgical revascularization following an acute anterior myocardial infarction complicated by cardiogenic shock necessitating intra-aortic balloon pump placement. After a successful coronary artery bypass graft procedure, the patient's sternum was left open because of hemodynamic instability at the time of sternal closure. Early complications included acute renal failure requiring continuous venovenous hemofiltration, left leg ischemia prompting removal of the intra-aortic balloon pump, and a pericardial tamponade requiring bedside evacuation on postoperative day 1 despite an open thorax. The following day, sudden significant instability necessitating increases in vasopressors was followed by a drop in cerebral saturation values. The thorax was re-explored at the bedside and blood clots compressing the cardiac cavities were removed. The intervention led to a significant reduction in vasopressors and increase in cerebral saturation values.

Case 3 (Right Ventricular Failure)

A 70-year-old male patient with severe viral cardiomyopathy for which a total mechanical heart had been implanted (CardioWest) was sent to the OR for a heart transplant. Because of hemodynamic instability at the time of sternal closure, the patient's chest cavity was left open and packed with surgical gauze. On arrival to the ICU, the patient was on high doses of vasopressors and inhaled nitric oxide but maintained stable vital signs and normal cerebral saturation (66%). Later, despite a seemingly adequate arterial pressure of 110/50 mmHg, the patient experienced bilateral cerebral desaturation down to 37%, low mixed venous oxygen saturation (40%), and high veno-arterial carbon dioxide differences (18 mmHg). The transesophageal echocardiographic evaluation showed normal left ventricular function with severe right ventricular dysfunction. The patient was taken to the OR, surgical dressings possibly compressing the heart were removed, and a central right ventricular assist device was implanted. Right ventricular function improved over time and the mechanical assist device was removed successfully 3 days later.

Case 4 (Pancreatitis)

A 31-year-old previously healthy male was referred to the ICU for acute pancreatitis. Two days after peripancreatic percutaneous drainage, the patient underwent laparotomy for open debridement and subsequent subtotal pancreatectomy. The immediate postoperative period was complicated by active bleeding resulting in abdominal compartment syndrome and

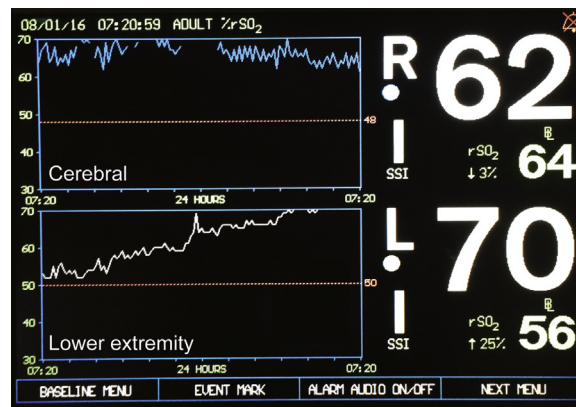


Fig 1. Case 4—Pancreatitis. Minimal changes in the cerebral oximetry signals (R) associated with progressive changes in the somatic oximetry signals (L) as the intra-abdominal pressure was reduced.

severe hemodynamic instability. At that time, tissue oximetry was placed on both the forehead and the femoral muscle to monitor tissue saturation. Urgent decompressive laparotomy and pancreaticoduodenal artery embolization were performed. The surgical decompression was successful in lowering the intravesical pressure from 21 to 9 cmH₂O, which also temporally was related to a rise in femoral muscle tissue oximetry from 52% to 71% (Fig 1) without any significant changes in the cerebral saturation values.

Discussion

These 4 cases illustrated the use of continuous oxygen transport and delivery monitoring with both cerebral and somatic NIRS in various types of shock (hemorrhagic, obstructive, cardiogenic, and abdominal compartment syndrome). In order to use this technology to its full potential, it must be recognized that a NIRS value taken at a single specific location can either reflect local or global oxygenation. When looking specifically at cerebral rSO₂, any low value is an alarm signal for a significant threat to patient homeostasis, but this information is rather nonspecific regarding the causes or the mechanism of the said cerebral desaturation.

A physiopathology-based classification can help organize differential diagnosis and guide further investigations. The development in 2007 of an algorithm to approach brain desaturation led to further single² and multicenter validation.^{3,8} However, this approach has not been used or validated in the ICU and does not incorporate somatic NIRS signal. Those signals increasingly are recognized as having important prognostic value in the ICU.⁷

In order to improve the use of both cerebral and somatic NIRS as a more useful tool of global patient evaluation, the following approach is proposed (Table 1). With the use of 3 bilateral anatomic sites (Fig 2) providing cerebral and somatic (upper and lower extremities) sampling sites, NIRS monitorings would enable a clinician to suspect and identify several different life-threatening mechanisms.

Starting from the head, a purely isolated brain desaturation would more likely have an intracranial origin from awakening or hypocarbia or either an arterial or venous compromise such

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