Reversal of Decreases in Cerebral Saturation in High-Risk Cardiac Surgery

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Objectives: **To measure the incidence of cerebral desaturation during high-risk cardiac surgery and to evaluate strategies to reverse cerebral desaturation.**

Design: **Prospective observational study followed by a randomized controlled study with 1 intervention group and 1 control group.**

Setting: **Tertiary care center specialized in cardiac surgery.**

Participants: **All patients were scheduled for high-risk cardiac surgery, 279 consecutive patients in the prospective study and 48 patients in the randomized study.**

Interventions: **An algorithmic approach of strategies to reverse cerebral desaturation. In the control group, no attempts were made to reverse cerebral desaturation.**

Measurements and Main Results: **Cerebral saturation was measured using near-infrared reflectance spectroscopy. A decrease of 20% from baseline for 15 seconds defined cerebral desaturation. The success or failure of the interventions was noted. Demographic data were collected. Models for predicting the probability and the reversal of cerebral desaturation were based on multiple logistic regressions. In the randomized study, 12 hours of measurements were continued in the intensive care unit without interventions. Differences in desaturation load (% desaturation × time) were compared between groups. Half of the high-risk patients had cerebral desaturation that could be reversed 88% of the time. Interventions resulted in smaller desaturation loads in the operating room and in the intensive care unit.**

Conclusions: **Cerebral desaturation in high-risk cardiac surgery is frequent but can be reversed most of the time resulting in a smaller desaturation load. A large randomized study will be needed to measure the impact of reversing cerebral desaturation on patient's outcome.**

KEY WORDS: NIRS, near-infrared spectroscopy, cardiac surgery, high-risk patients, algorithm, prospective study, randomized study, cerebral oxygen saturation, cerebral desaturation, intervention to reverse cerebral desaturation

OVER THE LAST DECADE, near-infrared reflectance spectroscopy (NIRS) has been used increasingly as a noninvasive device to monitor regional saturation and blood flow in the cerebral frontal region during cardiac surgery. Originally developed as a neurologic monitor,[1,2] decreases in NIRS values have been used to detect catastrophic cerebral events when more invasive monitors remain silent.[1,3] Also, NIRS has been useful in detecting patients at risk of early cognitive decline after cardiac surgery.[4-6]

Given this evidence, clinicians would expect the use of NIRS technology to be prevalent in cardiac surgery patients. However, this is not necessarily the case, as NIRS often is regarded as a "doom-and-gloom" monitor, the one that tells anesthesiologists that something is wrong with the patient but for which little can be done. In an attempt to use NIRS as an intervention monitor, a few randomized studies have used strategies to reverse decreases in values of regional cortical oxygen saturation (rSO_2) and to measure its effect on outcome. In major abdominal surgery, reversing decreases in rSO_2 values is associated with better postoperative Mini-Mental State Examination scores, in shorter lengths-of-stay in the postanesthesia care unit and in the hospital.[7] In cardiac surgery, reversing decreases in rSO_2 values is associated with a lower risk of major organ dysfunction.[8] However, others have failed to follow specific strategies to reverse cerebral desaturation during their study.[4] Thus, evidence that significant decreases in rSO_2 values successfully can be reversed during cardiac surgery remains scarce.

To consolidate a strategic approach for the reversal of decreases in rSO_2 values, a clinical algorithm based on 10 years of experience with NIRS technology in cardiac surgery was proposed.[3] Using this algorithm, the authors hypothesized that the majority of decreases in rSO_2 values during cardiac surgery can be reversed and that this reversal will reduce the total desaturation load (calculated area of depth of desaturation over time) of patients. This measure consistently has been associated with a bad outcome.[1] Therefore, the goal of the present study was 2-fold. First, the authors prospectively tested the efficacy of the algorithm to reverse decreases in rSO_2 values in consecutive patients undergoing high-risk cardiac surgery. Second, in a pilot study, the authors randomized patients to an intervention (INTERV) group and a control (CONT) group (no intervention) to verify that the interventions actually resulted in a reduction of the desaturation load during the course of surgery and in the intensive care unit (ICU).

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METHODS

Subjects and Data Collection

Prospective Study

Institutional Ethics approval was obtained for the prospective part of the study. Consecutive patients requiring complex cardiac surgery with cardiopulmonary bypass (CPB) were included in the study regardless of comorbidities. High-risk surgery was defined as redo surgery, adult congenital surgery, thoracic aortic surgery with and without circulatory arrest, and combined procedures surgery. Combined surgery included coronary artery bypass graft (CABG) and valvular surgery or multiple valvular surgery or valvular and aortic surgery. Patients with a perioperative risk estimation score >15 using the Parsonnet score[9] also were included in the study regardless of the surgery intended. Exclusion criteria included patients under the age of

18, emergency surgery, first time CABG surgery, and single-valve surgery in patients with a perioperative risk estimation score <15. Descriptive data were collated on the patients.

Randomized Pilot Study

The Institutional Ethics Board approved the randomized study, and informed consent was obtained from every patient. Inclusion and exclusion criteria were identical to the prospective study except for patients with planned circulatory arrest because the anesthesiologists and surgeons insisted on the use of NIRS in these cases. The patients were randomized into 2 groups: an INTERV group in which the algorithm was followed to reverse decreases in rSO_2 values, and a CONT group in which the NIRS values were hidden from the anesthesiologists.

Measurement of rSO_2 Values and Strategies to Reverse Significant Decreases in rSO_2

Cerebral oxygen saturation was measured using near-infrared spectroscopy (NIRS, INVOS 4000) with the sensors placed on each side of the forehead of the patients, as previously described.[3] Baseline rSO_2 values were obtained with the patient in a supine position breathing a mixture of oxygen and air with nasal prongs. Significant decreases in rSO_2 values were defined as a decrease >20% from baseline lasting 15 seconds or more.[8]

The algorithmic approach for the reversal of significant decreases in rSO_2 has been described previously and is shown in Figure 1.[3] When a significant decrease in rSO_2 values occurs, an alarm is activated and the anesthesiologist in charge follows the algorithm in an attempt to reverse the desaturation. The neutral position of the head is verified as extreme rotations can hinder jugular venous return or carotid flow. During CPB, the position of the venous cannula is verified to rule out obstruction (step 1 in Fig 1). If the head and cannula are placed correctly (or not placed yet) and blood pressure (BP) is lower than 20% of the mean baseline for the patient, vasopressors or volume is given to increase BP (step 2 in Fig 1). If rSO_2 remains low after the increase in BP within 20% of the baseline, systemic oxygenation is verified with pulse oximetry and/or with the partial pressure of oxygen from an arterial blood gas (step 3 in Fig 1). If normal, end-tidal CO_2 is verified, and if below 35 mmHg, ventilator parameters are adjusted to increase end-tidal CO_2 between 35 and 45 mmHg (step 4 in Fig 1). When cerebral desaturation persists after the increase in end-tidal CO_2, hemoglobin levels are obtained and the anesthesiologists can transfuse the patient according to transfusion protocols (step 5 in Fig 1). When hemoglobin levels are above the lower limit for transfusion, the intervention is dependent on whether the patient is before, during, or after CPB. Before CPB, cardiac performance can be improved pharmacologically depending on the specific condition of the patient. During CPB, pump flow can be increased within acceptable levels. After CPB, right and

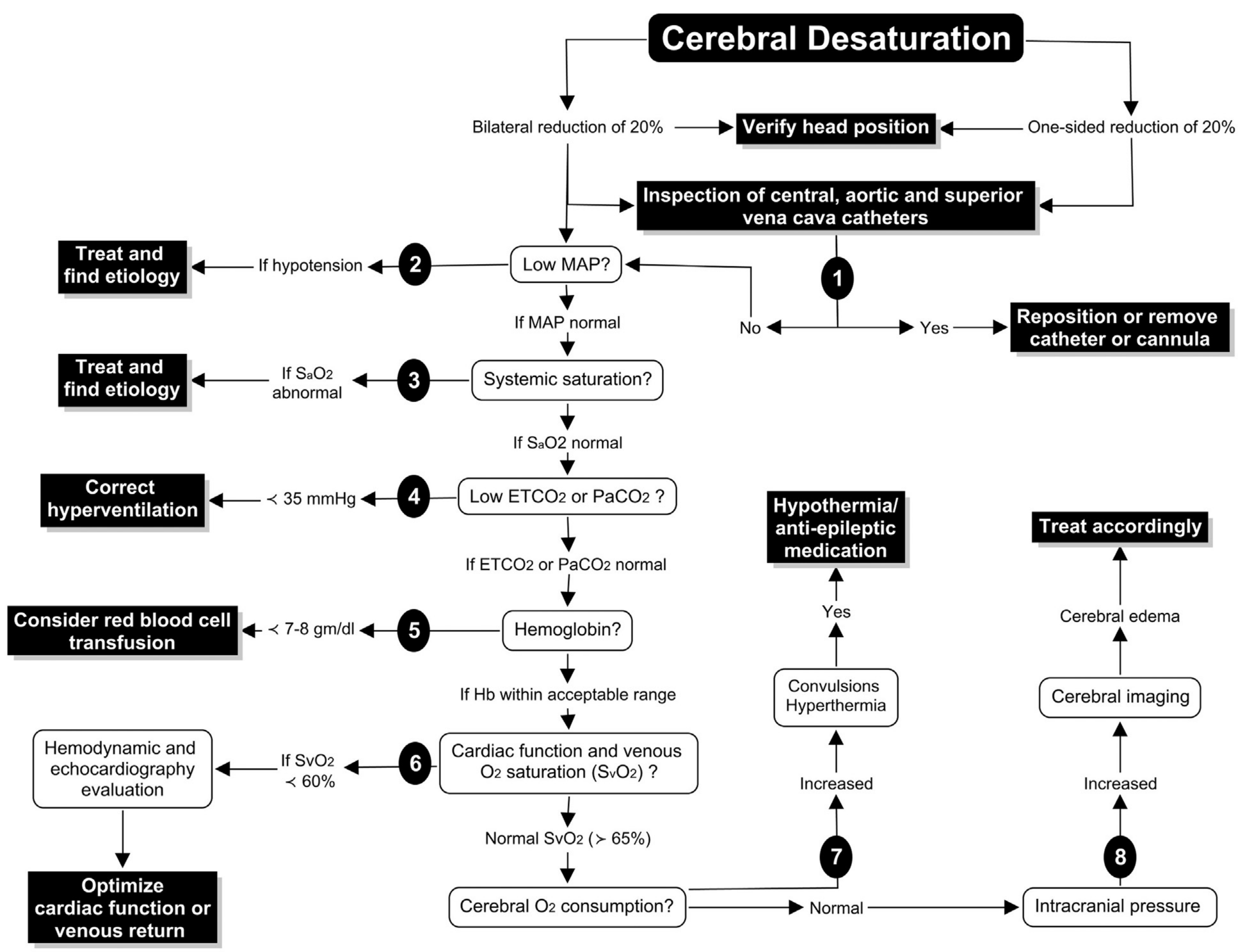

Fig 1. Algorithmic approach to the reversal of cerebral desaturation. MAP, mean arterial pressure; SaO_2, systemic arterial oxygen saturation by pulse oximetry; $PaCO_2$, partial pressure of arterial carbon dioxide; $ETCO_2$, end-tidal carbon dioxide concentration; Hb, hemoglobin; SvO_2, systemic venous oxygen saturation.