Part 2 of a 3-Part Series

Perioperative Patient Monitoring: Case Studies in Cardiac Surgery

Introduction

Although complications are a significant risk factor following any surgical procedure, there are particular neurologic complications often related to cardiac surgery, including embolic stroke and transient ischemic attacks, that are associated with high postoperative mortality. As with other types of surgery, the development of these neurologic complications may be linked to a patient’s preexisting comorbid condition, such as peripheral vascular disease, congestive heart failure, or a history of myocardial infarction. Patients at risk for embolic events may be screened using ultrasonography to determine the presence of aortic plaque near the sites for cannulation, cross-clamping, and saphenous vein grafting to avoid embolization. However, the etiology of serious neurologic complications also may be related to a second factor: hypoperfusion occurring within the perioperative period. This factor is of particular concern during cardiopulmonary bypass (CPB) when there is non-pulsatile blood flow and typically lower mean arterial blood pressure.

Neurologic complications are more common among patients undergoing surgery with CPB, especially when the surgery is complex, involves aortic valve replacement, or consists of surgery on multiple valves. Studies have shown an increased incidence of adverse perioperative outcomes including neuropsychological dysfunction, prolonged hospital length of stay (LOS), and major organ morbidity and mortality when patients experience intraoperative cerebral oxygen desaturation regardless of the type of surgery or whether the procedure is performed “on-pump” or “off-pump.” Low preoperative regional cerebral oxygen saturation (rSO2) values also may be related to adverse outcomes.

Regional Oxygen Saturation Assessment Using Cerebral Oximetry

Clinicians increasingly are employing cutaneous determination of rSO2 using real-time cerebral oximetry as a tool for reducing risk for perfusion-related complications. Technologies, such as the INVOS™ Cerebral/Somatic Oximeter, complement ultrasonography and hemodynamic monitoring by providing data that reflect the balance between oxygen delivery and consumption within the cerebral microcirculation. Because cerebral tissue (with its limited oxygen reserve) is sensitive to changes in oxygen delivery and consumption, rSO2 monitoring also may serve as an index of perfusion and decreased oxygen delivery to other major organs.

Real-time rSO2 monitoring provides critical information that guides clinicians to make adjustments of intraoperative parameters beyond traditional vital signs (heart rate, blood pressure [BP], central venous pressure, and pulse oximetry). Clinical judgment employs this real-time data to optimize the delivery and consumption of oxygen within the sampled brain tissue, and rSO2 increased (Figure). The patient awoke several hours following surgery with no apparent neurocognitive deficits. This case illustrates the utility of cerebral oximetry monitoring during a cardiac surgical procedure that is typically associated with significant physiologic and hemodynamic changes.

The Western Pennsylvania and Forbes Regional Hospitals use a systematic process that maintains or increases rSO2 values based on the most likely etiology. For example, decreases in rSO2 that occur before CPB are assessed in terms of hemodynamic perfusion. Cardiac function is evaluated using transesophageal echocardiography and by measuring cardiac output with thermodilution. Therapy for improving tissue oxygenation then is directed at increasing systemic vascular resistance or cardiac contractility, depending on the assessment of ventricular function. If decreased rSO2 occurs during CPB, increasing pump flow and/or systemic vascular resistance generally resolves the reduction in rSO2 values.

Case Study 1: 73-Year-Old Man Undergoing Aortic Valve Replacement and Repair of an Aortic Aneurysm

Christopher A. Troianos, MD
Professor and Chair of Anesthesiology
The Western Pennsylvania and Forbes Regional Hospitals
Pittsburgh, Pennsylvania

The patient presented for an aortic valve replacement for valve insufficiency and repair of an aortic aneurysm involving the ascending aorta. His American Society of Anesthesiologists classification was 4 (patient with severe systemic disease). Anesthetic induction primarily consisted of fentanyl supplemented with midazolam; anesthesia was maintained with isoflurane and fentanyl; midazolam was administered to maintain BIS (bispectral index) values less than 60.

Regional cerebral oxygen saturation (rSO2) monitoring using the INVOS system revealed baseline values of 67 and 68, and an interventional threshold of 54 (20% below baseline). The rSO2 values exhibited variability during placement of monitoring catheters with the left hemisphere exhibiting lower rSO2 than the right hemisphere, a trend that persisted throughout most of the surgery. The values from both cerebral hemispheres increased after induction of anesthesia and with 1.0 fraction of inspired oxygen. The rSO2 values decreased markedly after the institution of cardiopulmonary bypass (CPB), which was presumably related to anemia from hemodilution (hematocrit 25% and partial carbon dioxide alveolar pressure [PaCO2] 32.6 mm Hg). Physiologic parameters were adjusted whenever possible to increase rSO2 above the interventional threshold. The CPB sweep was adjusted to raise PaCO2 toward a maintenance level greater than 40 mm Hg. The patient then was cooled to 16°C in anticipation of deep hypothermic circulatory arrest (DHCA). These adjustments increased rSO2 above the interventional threshold. The rSO2 values decreased bilaterally during DHCA, with rSO2 on the left side breaching the interventional threshold. Reinstitution of circulation with CPB restored rSO2 values, but they declined again during rewarming. Hemodynamic, respiratory, hemolologic, and anesthetic parameters were adjusted to optimize the delivery and consumption of oxygen within the sampled brain tissue, and rSO2 increased (Figure). The patient awoke several hours following surgery with no apparent neurocognitive deficits. This case illustrates the utility of cerebral oximetry monitoring during a cardiac surgical procedure that is typically associated with significant physiologic and hemodynamic changes.
hypo-oxygenation, and hypertension and tachycardia as an indicator of inadequate sedation/analgesia.

Murkin et al evaluated 200 patients undergoing coronary artery bypass using CPB. 2 Patients were randomized into 2 groups: a control group in which the INVOS system was used to obtain baseline rSO2 levels, but clinicians did not have access to the INVOS system data during surgery, or an intervention group in which cerebral oxygenation was used actively to drive a management protocol that was designed to maintain an rSO2 at or above 75% of the baseline threshold. 6 The authors found that fewer patients in the intervention group (n=11) suffered a stroke compared with patients in the control group (n=4). Following a secondary analysis, the authors found that patients in the intervention group (n=3) experienced significantly reduced rates of prolonged ventilation (>48 hours), central infection, renal failure, reoperation, and death compared with the control group (n=11). 7 Furthermore, use of the INVOS system with an intervention protocol was associated with a shorter duration of cerebral desaturation, shorter hospital LOS, and decreased major organ morbidity compared with the control method. A limitation of this study was that cerebral oximetry was not continued to the ICU. The authors noted that interventions guided by the INVOS system intraoperatively could have been continued in the ICU setting. 8

Evaluating Depth of Anesthesia And Level of Consciousness

One potential therapeutic intervention for improving the rSO2 levels obtained using cerebral oximetry is to administer anesthetic agents that reduce cerebral metabolism. This intervention improves rSO2 levels because rSO2 values represent a mix of arterial and venous cerebral oxygen sampling in an approximately 1:3 ratio, respectively, and therefore primarily reflect venous sampling as opposed to the arterial sampling of a pulse oximeter. Reduced oxygen consumption increases venous oxygen saturation, thereby increasing rSO2. However, near-infrared spectroscopy cannot replace a more specific indicator of anesthetic depth, such as use of a BIS™ (bispectral index) monitor. Studies have demonstrated that a BIS value between 40 and 60 (on a scale of 0 to 100) reflects an appropriate level of sedation. Studies have shown that a BIS value less than 40 is associated with intermediate-term mortality, a hazard ratio of 1.29 per hour, or 29% increased risk for death for every cumulative hour a BIS value less than 45 was recorded. 9 Similarly, Leslie et al reported that BIS values less than 40 for more than 5 minutes during coronary surgery were associated with a hazard ratio of 1.41 for mortality compared with other BIS values. 10 Patients above BIS values of 40 showed improved survival and reduced morbidity. 11

Use of this technology during cardiac surgery has led to investigations using BIS in other postoperative settings (e.g., postanesthesia care unit, ICU) when patients require ongoing mechanical ventilation and sedation. Solanki et al reported that a closed-loop anesthesia delivery system using BIS to direct propofol infusion after open heart surgery resulted in patients spending a greater proportion of time within the sedation target range compared with manual adjustments of propofol infusions. 12

Conclusion

These case studies highlight various factors that affect regional cerebral oxygenation and anesthesia depth and alert the clinician to avert potential misalignment between cerebral oxygen delivery and consumption. The INVOS, Cerebral/Somatic Oximeter and BIS Brain Function Monitoring System can guide appropriate use of hemodynamic and anesthetic-based interventions in patients undergoing cardiac surgery and thereby optimize short- and long-term outcomes. Further studies to determine the utility of these systems in the postoperative period would be beneficial.

Case Study 2: 86-Year-Old Man With Stanford Type A Aortic Dissection

Michael E. Goldberg, MD
Professor and Chair, Department of Anesthesiology
Associate Director, Acute Care Services
Cooper Medical School of Rowan University
Chief, Department of Anesthesiology, Cooper University Hospital
Camden, New Jersey

Muhammad Muntazar, MD
Associate Professor of Anesthesiology
Cooper Medical School of Rowan University
Head, Division of Cardiothoracic Anesthesia
Cooper University Hospital
Camden, New Jersey

The patient was transferred from a local hospital where he presented with chest pain. His American Society of Anesthesiologists classification was 4E (emergency patient with severe systemic disease); his weight was 80 kg. Computed tomography angiography of the chest revealed Stanford type A dissection of the aorta, and he was scheduled for repair of the dissection. After being transferred to the operating room, a bilateral radial arterial catheter, 3.9-mm introducer, and pulmonary artery catheter were placed under sedation. In addition to the standard monitors, sensors for the BIS Brain Function Monitoring System and the INVOS Cerebral Oximeter were placed before induction, and baseline readings were recorded. After an uneventful induction and intubation, anesthesia was maintained with isoflurane, fentanyl, midazolam, and a muscle relaxant, Femoral–femoral bypass was initiated and surgical exposure was obtained using a midline sternotomy. Hypothermic circulatory arrest was initiated per protocol with administration of a standard pharmacological regimen (agents added to the perfusion pump 3 minutes prior to arrest: methylprednisolone 1,000 mg, sodium bicarbonate 50 mEq, and fentanyl 1 mg). When BIS values fell below 25 and remained between 23–25 minutes prior to arrest: furosemide 20 mg and midazolam 5 mg). Propofol 2 to 5 mg/kg was given to achieve a BIS reading near 0, and circulatory arrest was initiated. Cerebral protection was achieved by allowing perfusion to the brain via the innominate artery in addition to hypothermia and achievement of a flat line electroencephalogram (EEG), with a BIS reading close to 0. The pulsatile circulation to the brain was restored after 7 minutes, 31 seconds, which was confirmed by examination of the cerebral saturation. An aortic cross clamp was applied and the diseased aorta was replaced with a saphenous vein graft. Hemostasis was achieved and heparin was reversed with protamine. The patient’s chest was closed, and he was transferred to the ICU with extubation of his trachea on postoperative day 1. The BIS monitor allowed the clinician to gauge the depth of anesthesia, and was used as an EEG monitor during circulatory arrest to maintain the cerebral electrical activity as close to 0 as possible.

Once circulatory arrest was no longer required, the clinician allowed the BIS value to rise. BIS values were maintained within a range of 20 to 50 in order to act as an additional guide for depth of anesthesia and level of consciousness. Cerebral perfusion also was monitored using the INVOS system. Blood pressure, blood gas management, and hemoglobin concentration were adjusted as needed to maintain adequate cerebral perfusion, using cerebral oximetry as a gauge. Cerebral saturation was maintained at 20% of the baseline value except during the circulatory arrest. The BIS monitoring system was an effective tool available to the anesthesiologist, allowing for maintenance of anesthetic depth and simultaneous monitoring of EEG to keep readings as close to flat line as possible during circulatory arrest.

References


Disclosures: Dr. Goldberg reported that he is a consultant for and on the speakers’ bureau of Cadence Pharmaceuticals, Inc. Drs. Muntazar and Troianos reported no relevant financial conflicts of interest.

Disclaimer: This monograph is designed to be a summary of information. While it is detailed, it is not an exhaustive clinical review. McMahon Publishing, Covidien, and the authors neither affirm nor deny the accuracy of the information contained herein. No liability will be assumed for the use of this monograph, and the absence of typographical errors is not guaranteed. Readers are strongly urged to consult any relevant primary literature.

Copyright © 2013, McMahon Publishing, 545 West 45th Street, New York, NY 10036. Printed in the USA. All rights reserved, including the right of reproduction, in whole or in part, in any form.

ANESTHESIOLOGY NEWS • MARCH 2013