Background Information

In the US, about 465,000 cardiopulmonary bypass grafting (CABG) procedures are performed every year. Decreases in oxygen levels occur in about 17-23% of CABG procedures which cause brain injury even in uncomplicated surgeries, and may lead to stroke, cognitive dysfunction, longer ventilation times; longer ICU and hospital stays, and higher health care costs. Because of the brain’s high metabolic rate with limited oxygen reserves, only about 10 seconds at normal body temperature makes the brain is susceptible to oxygen deprivation. A study on patients who underwent CABG surgery found that incidence of cognitive decline was 53% at discharge and 42% at 5 years (Newman, 2001). Furthermore, elderly patients are more likely to develop cerebral desaturation because of age-related reductions in physiologic reserve (Casati, 2005), and the number of surgeries involving older patients is on the rise.

Near-infrared spectroscopy (NIRS) is increasingly used to monitor regional cerebral O$_2$ saturation (rScO$_2$) during cardiac surgery.

In a blinded study of 200 CABG patients randomized to either cerebral regional oxygen saturation (rSO$_2$) monitoring with active display and treatment intervention protocol (intervention) or blinded rSO$_2$ monitoring (control), more patients in the control group had prolonged cerebral desaturations (p=0.014) and longer ICU stays (p=0.029) compared to those in the intervention groups. There were also significantly more control patients with major organ morbidity or mortality (death, ventilation >48 hours, stroke, heart attack, return for re-exploration) compared to the intervention group (p=0.048) (Murkin, 2007; see Table 4 from Murkin paper, below).

Mean arterial blood pressure (MAP) targets are usually empirically chosen during cardiopulmonary bypass (CPB). Joshi et al demonstrated that real-time autoregulation monitoring using Near InfraRed Spectroscopy or cerebral oximetry is more accurate for delineating the MAP at the lower limit of autoregulation (LLA) during CPB than empiric determinations based on age, preoperative history, and preoperative blood pressure.

Surgical repair of the aortic arch remains technically challenging and is associated with considerable morbidity and mortality. Cerebral oximetry is a noninvasive technology that can monitor the regional oxygen saturation of the frontal cortex. In a study by Fischer et al., 20 patients underwent hemiarch replacement and 10 had total aortic arch replacement. Patients who spent more than 30 minutes under the absolute threshold of 60% had worse outcomes, had an extended hospital stay of 4 days leading to an additional cost of $8300 (Fischer, 2010).
Problematic cerebral oxygen desaturations can also occur in noncardiac procedures. A noncardiac abdominal surgery study randomized 122 elderly patients to either intervention (monitor was visible and rSO₂ was maintained at ≥75% of preinduction values) or control (monitor was blinded and anesthesia managed routinely). Cerebral desaturations occurred in 20% of the treatment group and 23% of the control group (NS). Among those with cerebral desaturation, patients in the control group had a lower Mini Mental State Exam scores on postoperative day 7 (26 v 28, p=0.02), longer time to postanesthesia care unit discharge (47 min v 25 min, p=0.01) and longer hospital stay (24 days v 10 days (p=0.007) (Casati, 2005). Cerebral oxygen desaturations have also been noted in shoulder arthroscopic procedures (Murphy, 2010) and carotid surgeries. The ability to assess the brain-at-risk during carotid endarterectomy (CEA) under general anesthesia remains a major clinical problem. In an observational study, the authors examined the correlation between a series of point-of-care monitors and lactate flux during CEA. They concluded that a correlation existed between cerebral oximetry and lactate flux during carotid cross-clamping. Cerebral oximetry in this particular instance the Fore-Sight monitor was of value as a point-of-care monitor during CEA under general anesthesia. A novel finding of this study was lactate flux into the brain in the presence of a large difference in cerebral oxygenation during cross-clamping of the carotid artery (Espenell, 2010).

During shoulder surgeries, cerebral hypoperfusion can occur with the patient in beach chair position. The blood pressure measurement in the non-operative arm is positioned well below the level of the
brain and hence does not reflect blood pressure in the cerebral vasculature. In addition decreased venous return, vasodilation, and head flexion may impede jugular venous flow and thus decrease cerebral perfusion. These physiologic changes require enhanced vigilance on the part of the clinicians caring for these patients. Use of a cerebral oximeter in this setting provides an additional tool in assessing adequate oxygen delivery to vulnerable cerebral tissue.

Although the majority of published data have demonstrated improved outcomes among cardiac surgical patients, the studies performed thus far among non-cardiac surgical patients are beginning to identify its utility in other clinical scenarios.

Need

We need to be able to continuously and easily measure the oxygen saturation of cerebral brain tissue during cardiothoracic procedures in order to prevent neurological injuries by timely intervention. Interventions include ensuring adequate CPB flow or cardiac output when patients are not on CPB, increasing MAP, avoiding hypocarbia (decreasing gas-inflow), deepening anesthesia, increasing the FiO₂, instituting pulsatile CPB flow, considering transfusion if indicated, administering anticonvulsant drugs when indicated, and considering hypothermia. Absolute cerebral oximeters are essential to alert physicians to low oxygen saturation levels to reduce potential morbidity and mortality.

Solution

**Indirect Methods** There are indirect methods to determine brain oxygenation, e.g., blood pressure, urine output, finger pulse oximetry. However, these are whole body measurements, and brain dysfunction can still occur when systemic measures are within normal ranges.

**Direct Methods** With cerebral oximetry, a direct method, we have real-time detection of site-specific oxygenation changes. Cerebral oximetry estimates the oxygenation of regional tissue by transcutaneous measurement of the cerebral cortex. Measurement is based on the ability of light to penetrate the skull and to determine hemoglobin oxygenation according to the amount of light absorbed by hemoglobin. Unlike pulse oximetry, which uses a single sensor, cerebral oximetry with NIRS uses two photodetectors each with a light source. The technology allows selective sampling of tissue beyond a specified depth beneath the skin. Near-field photodetection then can be subtracted from far-field detection to provide selective measurements of tissue oxygenation. Adhesive pads applied over the frontal lobes both emit and capture reflected near-infrared light passing through the cranial bone to and from the underlying cerebral tissue. The sampling is mainly venous rather than arterial (and value falls between the two) and independent of pulsatile flow.

**The Fore-Sight Cerebral Oximeter** (CAS Medical Systems, Bradford, CT), noninvasively and continuously measures absolute brain tissue oxygen saturation, which allows us to identify and immediately react to lowered brain oxygen saturation before the situation becomes critical. The measurement is updated every two seconds. Further, it provides absolute measurements, which means that monitoring can begin at any time.

**The Invos** (Somanetics Corp., Troy, MI), on the other hand, is a trend monitor which requires a baseline reading before any anesthetic agents are administered.
Current Usage of Fore-Sight

Georgia hospitals currently using Fore-Sight are Children’s Healthcare of Atlanta, Eastside Medical Center, Emory University Hospital, Grady Memorial Hospital, Gwinnett Medical Center, University Health Care System, and Southern Regional.

Benefits

The use of cerebral oximetry has been shown to significantly reduce adverse clinical outcomes, including permanent stroke and to lower healthcare costs via decreased post-surgical ventilation time, decreased intensive care unit stays, and decreased length of hospital stays.

Safety

Cerebral oximetry is portable and easy to use in operating room or at the bedside. It is a non-invasive technique involving application of adhesive pads as compared to invasive methods such as jugular bulb oximetry monitoring which involves floating a catheter into jugular vein.

Costs and Potential Savings

At Georgia Regents University, we averaged 150-200 CABG procedures including valve procedures last year. CEA and shoulder surgeries in the beach chair position accounted for additional cases. We are not able to charge directly for the use of the monitors as this is usually bundled up in the anesthesia costs. But we should see a reduction in hospital costs as a result of fewer events caused by decreased brain oxygen saturation. If we prevent even one postoperative hypoxic event per 200 patients, the cost savings to the hospital per year will be tremendous.

References


