Critical Care Guidelines Drive Use of Brain Tissue Oxygen Monitoring System in Traumatic Head Injury Patients

Creighton University Medical Center, a comprehensive healthcare, research, and education system located in Omaha, Nebraska, has served Omaha and the Great Plains for more than 125 years. The 278-bed medical center houses a Level I trauma center that treats greater Omaha-area patients four days per week, sharing this duty with the University of Nebraska Medical Center. The center employs three neurosurgeons, including Pradeep K. Narotam, M.B., Ch.B., M.Med. (Neurosurg), F.C.S. (SA) Neuro, F.R.C.S.(C), who joined the university in 2001 as an assistant professor of surgery.

A leading researcher in the field of neurosurgery, Dr. Narotam has become an advocate for brain tissue oxygen monitoring as an adjunct to multimodality monitoring of patients with traumatic head injury and other serious conditions. In May 2001, Dr. Narotam, working closely with Trauma Program Manager Diane Yetter, R.N., M.S.N., spearheaded the adoption of the LICOX® Brain Tissue Oxygen Monitoring System at Creighton University Medical Center, using the system in the center’s intensive care unit to monitor more than 100 patients to date.

Assessing Brain Tissue Oxygenation

While brain tissue oxygenation is a critical parameter in traumatic head injury and other patients, brain tissue oxygen levels traditionally are not directly measured—rather, they are inferred through other measurements such as intracranial pressure (ICP), cerebral perfusion pressure (CPP), blood pressure, and cardiac output. According to Dr. Narotam, though these measurements are critical, they require clinicians to make assumptions about brain tissue oxygenation levels. As a result, patient management often is based on incomplete or inaccurate information as to whether patients have sufficient levels of oxygen in their brain tissue.

A growing number of studies has demonstrated the significance of measuring the partial pressure of oxygen in brain tissue (PbtO₂). A 2000 study by van den Brink, et al., examined PbtO₂ in 101 patients with severe head trauma (Glasgow Coma Score ≤8) using the LICOX System. Despite aggressive conventional monitoring and treatment, hypoxic events were observed in more than half of patients. The depth and duration of tissue hypoxia were related to outcomes and proved to be an independent predictor of unfavorable outcome and death.
“Assessment tools such as ICP, CPP, blood pressure, central venous pressure, lab work, hemoglobin levels, and brain temperature all are critical in making a neurological judgment and guiding treatment,” Dr. Narotam said. “In the past, these tools helped us to basically guess whether the brain tissue was receiving the oxygen it required. To improve treatment and outcomes for trauma patients, however, we need to take away the guess work.”

According to Dr. Narotam, patient data gathered since the adoption of the LICOX System have shown that although Creighton University Medical Center’s staff has followed American Association of Neurological Surgeons, American College of Surgeons Committee on Trauma, and Advanced Trauma Life Support (ATLS) guidelines for patient management, many head trauma patients still have insufficient brain tissue oxygenation. “Adequate brain tissue oxygenation is particularly important with trauma because the most common cause of bad outcomes or death after patients survive the initial injury is poor oxygenation,” he said. “With the LICOX System, however, we know exactly how much oxygen is being delivered to the brain tissue itself. As a result, we can make changes in the management of the patient and see immediately if the manipulations are effective.”

The LICOX System
The LICOX System measures PbtO2 and brain temperature using an intraparenchymally placed oxygen-sensing catheter, inserted into the white matter of the brain using a proprietary bolt system with a single or multilumen design that allows monitoring of single or multiple parameters through one twist drill hole. The easy-to-use system is proven safe for patients, with a unique, patented hermetic seal for tight closure and infection control. The LICOX monitor features quick, easy, smart-card calibration and an easy-to-read digital display, and connects readily to bedside monitors.

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—Pradeep K. Narotam, M.B., assistant professor of surgery

The LICOX System provides direct, real-time measurement of oxygenation of brain tissue, allowing clinicians to identify patients with inadequate oxygenation and make immediate adjustments to restore PbtO2 to safe levels. Research has shown that PbtO2 levels in uninjured brain tissue range from 20–35 mm Hg. Additional studies have shown that extended periods with PbtO2 less than 15 mm Hg correlated with a greater chance of death. Any occurrence of a PbtO2 less than 6 mm Hg was associated with an increased risk of death, and PbtO2 less than 10 mm Hg has been associated with poor outcomes, including severe disability and death. Further, numerous hypoxic episodes have been observed in head injury patients despite aggressive management of ICP and CPP.

Creighton University Medical Center uses the LICOX System on patients with severe head injury requiring intensive care management, those with cerebral contusions, those undergoing ICP monitoring, and those with subarachnoid hemorrhage. Patients sustaining major trauma with head injury and altered level of consciousness and with an Injury Severity Score (ISS) of 25–30 or more are recommended for monitoring. In addition, Dr. Narotam frequently recommends the LICOX System for patients who have an altered level of consciousness with other intracranial pathology—i.e., subarachnoid hemorrhage requiring ICU treatment. The medical center has acquired six LICOX monitors, which have been successfully used on both adult and pediatric patients.

“Typically, we have found that at least 40 percent of patients with major trauma (ISS >16) already have cerebral hypoxia, despite being resuscitated to ATLS
guidelines,” Dr. Narotam said. “Although we are doing the best we know how, or knew how in the past, it is still insufficient—more needs to be done. The LICOX System is a tool that enables us to make sure that we’re delivering oxygen to the brain tissue, while the body and the brain heal.”

Critical Care Guidelines for Brain Tissue Oxygen Monitoring

Since the introduction of the LICOX System, together with intracranial pressure and brain temperature monitoring, Dr. Narotam and his colleagues have developed and implemented critical care guidelines that identify which patients should receive monitoring, as well as tissue oxygen thresholds and the steps to be taken to improve oxygenation.

“Once the LICOX sensor has been placed, we take the initial reading and follow the critical care guidelines to start therapeutic physiological manipulations on the patient,” he said. “We have the guidelines in diagram form, which staff can follow. Factors such as hemoglobin, blood pressure, and fluid levels are manipulated in real time, using LICOX readings as a guide to better deliver oxygen to the brain.”

The guidelines are designed with an underlying goal of keeping patients’ PbtO2 greater than 20 mm Hg. “Our goals are definitive,” Dr. Narotam said. “Any clinician can follow and use the critical care guidelines and can affect changes.”

The guidelines have undergone only one modification since implementation—increasing the optimal hemoglobin level. “Optimizing patients’ brain oxygen levels is like a juggling act,” Dr. Narotam said. “Several things have to be manipulated. When we initially designed the guidelines, we said 10 gm % hemoglobin is a reasonable number. But we have changed that to 12 gm % because we observed that if we give blood to patients whose oxygen and hemoglobin levels are both low, oxygen levels can increase by 10 points. As a result, we can reduce oxygen levels on the ventilators. This is something we could not have known without the LICOX monitor.

“If the numbers are good, things are going well,” he said. “If the numbers are bad, we have to double our efforts to find out what is occurring with the patient. The key thing about this technology is that it gives you immediate feedback. You know within a few minutes if your intervention is working.”

Impact on Patient Outcomes

Dr. Narotam and his colleagues have observed that the LICOX System assists in determining the appropriate treatment to improve patients’ chances for survival and recovery. They have analyzed data for the past two years using trauma scoring systems such as APACHE and have observed that mortality is lower in LICOX-monitored patients than would be expected for the same classic case in unmonitored patients. “In addition, we’re not finding that a patient who’s going to die remains in a vegetative state, but rather that some severely injured patients have made dramatic improvements at three months,” Dr. Narotam said. “We are in the process of quantifying these cases.”

In those who maintain strong oxygen levels, therapies that would typically be continued over a longer period of time can be tapered off sooner, often resulting in quicker patient recovery and hospital discharge. “When the numbers are good, when the oxygenation is satisfactory, we can adjust the ventilator setting and reduce therapy intensity levels,” Dr. Narotam said. “The patient often can come off the ventilator sooner, and we can discontinue medication more rapidly.”

Creighton University Medical Center has found that the LICOX System also provides an effective early warning system. Staff has observed that a sudden drop in brain tissue oxygen levels often is indicative of a major event occurring in the following 24 to 48 hours. “It’s also predictive of a bad episode, such as a fall in hemoglobin, a respiratory complication, or a blood pressure complication,” Dr. Narotam said. “When the level starts dropping, we start looking for causes and intervene in an attempt to prevent a decrease in oxygen delivery to the brain.”

According to Trauma Program Manager Diane Yetter, integration of the monitor has required collaboration among neurosurgeons, trauma surgeons, critical care nurses, and other clinicians
involved in the care of trauma patients. It also has required ongoing education. Trauma and general surgery residents are trained on how to insert the LICOX probe, and critical care nurses have become proficient at adjusting trauma patient care based on the critical care guidelines.

“Most of the nurses like the monitor,” Yetter said. “It’s one more tool to let us know whether we are doing the right thing, whether we are helping the patient. Most of the nurses who care for head-injured patients know how to use the monitor well and know the ‘tricks of the trade.’ There are some things they can do on their own, and some situations when they know to call the resident.”

**Conclusion**

Dr. Narotam believes that brain tissue oxygen monitoring will become a standard in the care of patients with major trauma and head injury. “All trauma centers that care for patients with any form of significant head injury should incorporate brain tissue oxygen monitoring,” he said. “I believe Level I or II trauma centers will be able to use the technology very effectively.”

Dr. Narotam added that the technology’s value goes beyond calculating a number. It also provides an important addition to multimodality monitoring, used within the context of critical care guidelines implemented by the team caring for head injury patients.

“You can’t just have a box providing a number,” he said. “You have to implement a protocol. The number means something, and we’re in the midst of developing that proof. We are learning what it means, what to do about it, and how it’s going to affect patients. With more experience, we will soon be able to show that there is a significantly better chance of patient recovery by using the LICOX System.”

**REFERENCES**

3. Saul TG. Management of Head Injury. Chicago, Ill.: American College of Surgeons, Committee on Trauma; April 1998.