Tracking trends in your patient’s condition

A key to preventing secondary brain injury is to limit the size of the initial injury. The following assessment values help you spot trends in your patient’s condition.

- Partial pressure of oxygen in brain tissue (PbtO$_2$)—normal range, 25 to 50 mm Hg. Values below 15 mm Hg indicate ischemia. Follow trends and intervene if values drop below 20 mm Hg.
- Intracranial pressure (ICP)—normal, less than 10 mm Hg. A value between 10 and 20 mm Hg is mildly to moderately elevated; above 20 mm Hg is severely elevated.
- Mean arterial pressure (MAP)—normal range, 70 to 110 mm Hg. A MAP below 60 mm Hg may indicate decreased cerebral perfusion pressure (CPP).
- CPP—normal range, 70 to 100 mm Hg. This value is calculated by subtracting ICP from MAP; a value below 50 mm Hg indicates compromised cerebral blood flow.
- End-tidal carbon dioxide (EtCO$_2$)—normal range, 30 to 40 mm Hg
- Paco$_2$—normal range, 35 to 45 mm Hg. A value less than 35 mm Hg may trigger cerebral vasoconstriction, reducing oxygen delivery to the brain. Keep Paco$_2$ in the normal range until you can determine how it affects PbtO$_2$.
- PaO$_2$—normal value, 80 to 100 mm Hg. Decreased PaO$_2$ can cause tissue hypoxia and reduced PbtO$_2$.
- Jugular venous oxygen saturation (SjvO$_2$)—normal range, 60% to 70%. Low values indicate a high extraction of oxygen characteristic of ischemia. However, problems with SjvO$_2$ technology limit its usefulness as a sole measure of cerebral oxygenation. Also, this technology won’t identify regional ischemia, so tissue hypoxia may be present despite normal or increased SjvO$_2$ values; some causes of tissue hypoxia are: decreased blood flow (ischemic hypoxia), low PaO$_2$ (hypoxic hypoxia), low hemoglobin concentration (anemic hypoxia), and hypermetabolic hypoxia caused by mitochondrial dysfunction and increased demand of cerebral tissues. Also, the tendency of catheters to migrate to the vessel wall and value errors, which require frequent blood sampling to calibrate the monitor, can limit the usefulness of SjvO$_2$ values.
coma scale score of 8 or less (on a scale of 3 to 15, with 15 being the best), are mechanically ventilated, and require standard neurologic and systemic hemodynamic monitoring.

Before any invasive neurologic monitoring device is inserted, any coagulopathies must be corrected. Contraindications to brain tissue oxygen monitoring include coagulopathy and insertion site infection.

**Probing for information**

At our facility, we use the Licox CMP Triple Lumen Monitoring System (Integra NeuroSciences, Plainsboro, N.J.) for PbtO₂ monitoring. The device measures PbtO₂, brain tissue temperature, and ICP. It consists of a bedside monitor and display screen connected to two probes to measure brain tissue oxygenation and temperature. A separate ICP monitor is connected to an ICP probe.

The physician drills a single burr hole and places an intracranial bolt, then inserts each probe through the dedicated port of the Licox housing system. Probe placement is based on the patient’s condition, a review of computed tomography (CT) scans, and therapy goals. If therapy is aimed at monitoring oxygen availability to damaged brain tissue, probes may be placed near (but not in) a cerebral lesion, avoiding areas of infarct or hematomas. If the probes can’t be placed on the side of injury (for example, because of a postoperative bone flap), they’re placed in the opposite hemisphere and used as a measure of global oxygenation.

Once the probes are in place, the physician applies a sterile dressing over the bolt site. The probe cables are connected to the monitor. The system is quickly and easily calibrated with a smart card.

After 10 to 120 minutes, when the brain tissue has stabilized from the microtrauma of probe insertion, the system continuously records and displays local cerebral oxygen and temperature measurements. The ICP probe is zeroed in the usual fashion and provides ICP data immediately. Some patients also may have a ventriculostomy for cerebrospinal fluid drainage.

**Performing an oxygen challenge**

After brain tissue has had time to stabilize following probe insertion, PbtO₂ measurements can be recorded and tested. Perform an oxygen challenge test, particularly if the PbtO₂ reading is unexpectedly low or you question the probe’s accuracy. To perform the oxygen challenge test, place the ventilator’s F₁O₂ setting on 100% for 2 to 5 minutes. We’ve found that 2 minutes of 100% F₁O₂ is adequate for testing probe sensitivity to oxygen, especially when F₁O₂ requirements are less than 80%. An accurate probe will reflect an increase in PbtO₂. If the patient’s PbtO₂ doesn’t respond to the increased F₁O₂, obtain a head CT scan to confirm correct probe placement. If the probe has been placed incorrectly, it must be removed and replaced at a new site through a new burr hole.

**Responding to changes in PbtO₂ values**

Here’s how to respond to various causes of changing brain tissue oxygenation (PbtO₂) values.

**Low PbtO₂ value (below 20 mm Hg)**

*Because of increased oxygen demand due to:*
- increased intracranial pressure. Treat with diuretics, cerebrospinal fluid drainage, sedation, craniotomy.
- pain. Administer analgesics.
- shivering. Administer meperidine, chlorpromazine, or a paralytic.
- agitation. Administer a sedative.
- seizures. Administer a benzodiazepine and adjunct anticonvulsive agent.
- fever. Administer acetaminophen or a nonsteroidal anti-inflammatory drug or use a temperature-regulating blanket. *Because of decreased oxygen delivery due to:*
- hypotension. Administer isotonic fluids, such as 0.9% sodium chloride solution or hypertonic saline, and vasopressors.
- hypovolemia. Administer isotonic fluids, such as 0.9% sodium chloride solution or hypertonic saline, and blood replacement.
- anemia. Administer blood replacement.
- hypoxia. Increase F₁O₂ and positive end-expiratory pressure.

**High PbtO₂ value (over 50 mm Hg)**

*Because of increased oxygen demand due to:*
- sedatives, anesthesia, or paralysis. Reduce sedation, anesthesia, or paralysis as needed. Treatment may not be necessary.
*Because of decreased oxygen delivery due to:*
- hyperdynamic state. Administer hyperventilation.
- hypothermia. Perform interventions to restore normothermia.
low 5 mm Hg indicate brain cell death.

The oxygenation value reflects oxygen delivery to the tissue around the probe and is interpreted as a marker of cerebral perfusion. Brain tissue temperature is also monitored because this value is needed to calculate the PbtO₂. Also, systemic temperature doesn’t always reflect brain temperature, which directly influences cerebral oxygenation and demand. A change of 1.8° F (1° C) in brain temperature can alter cerebral metabolism by 5% to 13%, affecting cerebral blood flow and ICP.

Brain tissue oxygenation values are just one piece of the clinical picture and shouldn’t be used as the sole basis for diagnosis or treatment decisions. Interpret PbtO₂ values in the context of other clinical findings. (See Responding to changes in PbtO₂ values.)

The Licox system is compatible with CT scanning, but not with magnetic resonance imaging (MRI). The MRI technician can perform a wand scan to detect incompatibilities, but the entire bolt system may need to be removed.

Monitor the insertion site for signs and symptoms of infection and contusion. However, these complications are rare.

Promising future
Monitoring for signs of secondary brain injury improves survival rates and helps minimize permanent neurologic deficits. Adding PbtO₂ monitoring to traditional neurologic monitoring parameters provides more detail to the clinical picture and has proven safe and effective for patients with severe brain injury.

SELECTED REFERENCES

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