Multimodal monitoring in neurocritical care

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For many years, monitoring in the intensive care unit was limited to clinical examination, heart rate, and blood pressure. In 1970, the Swan-Ganz pulmonary artery catheter was introduced,[1] and the specialty of critical care medicine was born. For the first time, clinicians could guide therapy based on physiologic parameters.

In the neurologic intensive care unit, monitoring has also been limited to the clinical exam and intracranial pressure. In the 1980s, much was learned about the importance of the cerebral perfusion pressure and cerebrovascular autoregulation. In the 1990s, the concept of "multimodal monitoring" was introduced—namely, cerebral blood flow monitoring, brain tissue oxygenation, and intracerebral microdialysis. Multimodal monitoring to assess metabolic function provides the neurointensivist with crucial information at the cellular level. This information can be used to detect potentially reversible secondary insults and to target therapy more precisely.

CEREBRAL BLOOD FLOW

Although we have been able to measure cerebral blood flow for decades, beginning in 1948 with Kety and Schmidt[2] and more recently with xenon-enhanced CT scanning,[3] these methods give only snapshots of cerebral blood flow and do not allow for continuous monitoring. Two methods are used for continuous monitoring at the bedside:

- With **laser Doppler flowmetry**, a *qualitative* estimate of regional cerebral blood flow, based on the Doppler shift principle, is displayed (in arbitrary units).[4]
- With **thermal diffusion**, a *quantitative* estimate of regional cerebral blood flow, based on the tissue's ability to dissipate heat, is displayed in mL/100 g/min.[5]

Cerebral blood flow monitoring can be useful for determining the state of autoregulation.

BRAIN TISSUE OXYGENATION

Brain tissue oxygen tension, or tissue partial pressure of oxygen ($PtiO_2$), can be measured using a small flexible probe that is inserted directly into the brain parenchyma, most commonly in the frontal white matter. The normal brain $PtiO_2$ varies depending on location, but it averages approximately 40 mm Hg.[6] Several studies have shown that cerebral oxygenation is strongly correlated with cerebral perfusion pressure.[7,8] Low brain $PtiO_2$ has also been associated with poor outcome.[9] Zauner and coworkers[10] showed that in patients who had a good recovery, the brain $PtiO_2$ was greater than 35 mm Hg. In patients with moderate to severe disability, the brain $PtiO_2$ was 26 to 35 mm Hg; in those with a poor outcome, it was 25 mm Hg or less.[10] Though intuitive, whether improving brain $PtiO_2$ improves patient outcome is inconclusive at this point. Further studies are needed.

INTRACEREBRAL MICRODIALYSIS

Introduced more than 25 years ago, microdialysis is a technique for monitoring the chemistry of the extracellular space in living tissue. The microdialysis probe is designed to mimic a "blood capillary." When a physiological salt solution is slowly pumped through the microdialysis probe, the solution equilibrates with the surrounding extracellular tissue fluid. After a while, it will contain a representative proportion of the tissue fluid's molecules. The microdialysate can then be extracted and analyzed

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in the laboratory or by the bedside.

The first human studies of microdialysis in the brain were published in the 1990s.[11] Subsequent studies have shown the potential of intracerebral microdialysis for monitoring in the neurologic intensive care unit.[12] This technique has been used to show early impaired cerebral blood flow after severe head injury, which was found to result in poor brain tissue oxygen delivery, lactate accumulation, and massive release of glutamate.[13] Unterberg and coworkers[14] have demonstrated changes in microdialysis in patients who develop vasospasm following subarachnoid hemorrhage.

■ CONCLUSION

Multimodal monitoring that includes cerebral blood flow monitoring, brain tissue oxygenation, and intracerebral microdialysis appears to have a unique potential for providing critical basic physiologic information about brain function in patients with brain ischemia. This approach, along with a new system for integrating these parameters in the neurologic intensive care unit, may revolutionize the way in which patients with brain injury are monitored and treated.

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