Brain Monitoring: The Next Frontier of ICU Monitoring

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You probably cannot recall when you last saw an intensive care unit (ICU) patient with abnormal cardiac function whose heart was not continuously monitored. Yet, it is standard practice to *not* monitor brain function in critically ill patients, including those who are encephalopathic or comatose. Why? It is certainly not because the brain is unimportant or because effective therapies are unavailable. Rather, it is because cerebral function has been more difficult to monitor than cardiac function. Fortunately, advances in computer and networking technology now make it practical to record brain activity continuously in critically ill patients. Thus, continuing to ignore brain function in ICU patients is now difficult to justify. Performing intermittent neurological exams is probably no more effective than periodically listening to the heart with a stethoscope. Similarly, the utility of daily EEGs is probably akin to that of daily EKGs. Historically, neurology has played "catch-up" with cardiology: examples include bypass, thrombolysis, angioplasty, stenting, and now even responsive electrical stimulation for seizures (perhaps loosely akin to defibrillation). Monitoring brain function in the ICU is no exception. This is not to imply that neurologists are less competent than cardiologists; rather, this is due to the fact that the brain is orders of magnitude more complex than the heart.

It is clear from virtually all studies of continuous EEG monitoring (cEEG) that most seizures in the critically ill are nonconvulsive and would go unrecognized without cEEG (Claassen et al., 2001; Claassen, Mayer et al., 2004; Pandian et al., 2004; Vespa et al., 1999, 2003). Although how aggressively nonconvulsive seizures (NCSzs) should be treated remains controversial, they are clearly associated with worse outcomes (DeLorenzo et al., 1998; Jaitly et al., 1997; Treiman et al., 1998; Vespa et al., 1999; Young et al., 1996). EEG can also identify cortical ischemia when still reversible (Astrup et al., 1981; Claassen, Mayer et al., in press; Claassen, Hirsch et al., 2004; Jordan, 2004, pp. 341–352; Vespa et al., 1997), and in this era of acute stroke treatment, cEEG offers significant potential for helping to prevent in-hospital stroke. CEEG has, however, remained largely unused for this purpose outside of the operating room. As cEEG is noninvasive, inexpensive, and continuous, it is the natural choice for routine brain monitoring. Currently, the main obstacles to cEEG in the ICU are logistical and to a lesser extent technological: maintaining working electrodes on the head, having EEG experts available 24 hours per day, developing effective detection algorithms for ischemia and seizures that set off bedside alarms, and so on. This issue of the *Journal of Clinical Neurophysiology* is dedicated to discussion on the current state of brain monitoring with neurophysiology (primarily EEG) in the critically ill, including the practical aspects of developing this highly demanded clinical service.

A concern occasionally raised, and perhaps more frequently contemplated, relates to legal liability: "If I try to monitor for seizures and ischemia and miss sometimes, won't I be sued?" The current state of the art is that while present technology makes cEEG feasible, greatly facilitating the recognition of NCSzs and potentially leading to more timely recognition

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of cerebral ischemia, reliable real-time detection of these events is simply not yet possible. Furthermore, continuous manual review and interpretation of EEG is impractical. Accordingly, failure to detect these events in real-time–or even to recognize all of these events on review of cEEG recordings–in order to prevent adverse and at times devastating outcomes can in no way be construed as representing either negligence or breach of the "standard of care." Indeed, the popular usage of the term "monitoring" in connection with cEEG is colloquial and somewhat inaccurate; current practice would better be described as "continuous recording, with periodic subsequent review." Only with improved technology will "monitoring" in the strict sense be feasible. Nonetheless, continuous EEG "monitoring," as currently performed, will allow us to detect many otherwise unrecognized seizures and probably some fraction of early ischemia; in some of these cases, this will prevent neuronal injury and neurologic disability. As the field progresses, our ability to detect a greater fraction of these events in real-time will certainly increase. Even if we can prevent only 10% of strokes in monitored patients, will this not be worth it? Although it would be naïve to dismiss concerns about legal exposure in a high-risk environment, it would be inappropriate to allow this fear of liability to impede medical advancement and prevent us from providing optimal care to critically ill patients. It is accordingly crucial that the limitations of current technology be clearly delineated and well understood.

The population is getting older, inpatients are getting sicker, and long-term survival after catastrophic illness is increasing. On the other hand, effective therapies now exist in critical care neurology and are expanding rapidly. CEEG will likely become central to the timely application of some of these therapies. The limits of the utility of cEEG are largely unknown at this time, as this field is still in its infancy. Hopefully another "special issue" of this journal on this topic will soon be necessary.

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