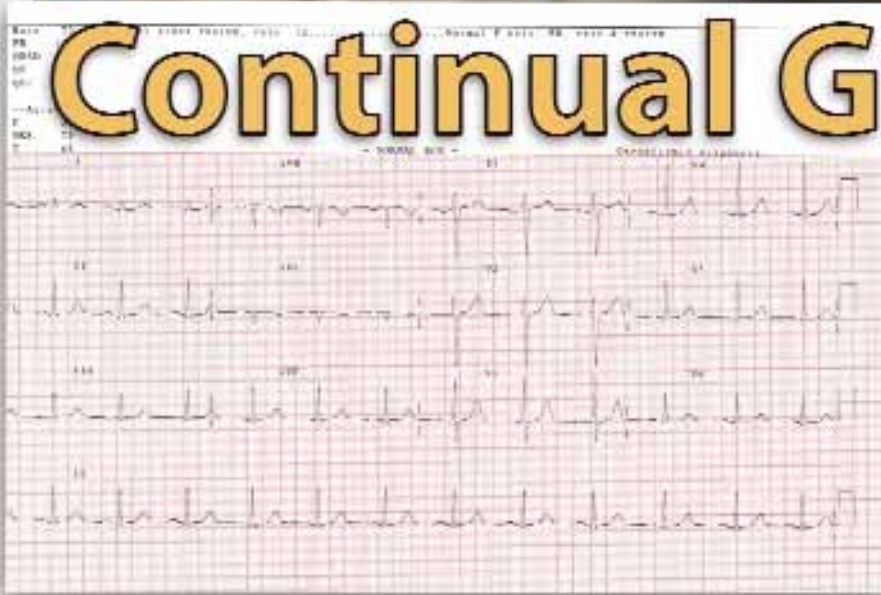




Continual Growth?



As continuous EEG evolves and becomes more efficient, it could improve patient care and present opportunities for specialized neurologists.

By Zac Haughn, Senior Associate Editor

"Special unit saves lives, nurses, money" was the title of a 1957 *Modern Hospital* article by Dr. William Mosenthal. His idea was simple: rather than scattering acute and nonacute patients through a hospital, group the sickest of them in one place to cluster nurses and resources there.

And with that, the intensive care unit model was introduced and soon spread on a wide scale in the US.

Obviously a lot has changed since then, and the role of ICU has evolved. Comatose patients in critical condition now are typically connected to a tangle of wires and machines. The next stage in ICU evolution may be the con-

tinuous EEG (cEEG). cEEG is primarily used to detect non-convulsive seizures, which are frequent and possibly associated with harm. The advent of continuous ICU EEG monitoring has revealed that non-convulsive seizures are much more prevalent than previously recognized among patients.¹

Twenty percent of a selected group of patients in stupor and coma are having nonconvulsive seizures and nonconvulsive status epilepticus, says Marc R. Nuwer, MD PhD, Clinical Professor in the Department of Neurology at the UCLA School of Medicine and Department of Clinical Neurophysiology at the UCLA Medical Center. “Untreated, those can cause permanent brain injury or at least delay recovery from coma. ICU EEG monitoring also can identify other complications in time to intervene before permanent damage occurs,” he says. “This is like monitoring the EKG in the CCU. In the Neuro-ICU, we should monitor the brain.” This kind of monitoring can provide dynamic information to hospital staff about brain function that allows early detection of changes in neurologic status, which is especially valuable when the clinical examination is limited.

In a review of cEEG,² Dr. Nuwer rewinds to what brought EEG where it is:

“Our situation now reflects the emergence of neurocritical care as a discipline and continuous ICU EEG monitoring as a technology. The original monitoring applications were compressed spectral arrays and amplitude integrated EEG, both products of 1970’s generation technology. They were limited in their presentation of data, formatting, storage, review, and clinical utility. They could detect possible generalized convulsions, but had difficulty separating real events from artifacts. The needed technological advances occurred only two decades ago. The technological and practical improvements included recording from large numbers of channels, storing all EEG for later expert review, trending frequency content to identify events and variability, remote review access for immediate review as needed, availability of post hoc digital montage reformatting and filtering, as well as teaching nursing staff to participate. Applications, investigation, and widespread use followed those technological advances only in the past decade. We now see more clearly where this field stands. That has defined our lack of understanding of some key issues.”

Nonconvulsive Seizures and Other Uses

Nonconvulsive seizures are electrographic seizures with little or no overt clinical manifestations requiring EEG for detection, while nonconvulsive status epilepticus occurs when nonconvulsive seizures are prolonged; a common definition is continuous or near-continuous electrographic seizures of at least a 30-minute duration.³

Friedman, Claassen, and Hirsch write in their August 2009³ publication that most patients with nonconvulsive seizures have purely electrographic seizures, but other subtle signs can be linked with nonconvulsive seizures, including face and limb myoclonus, nystagmus, eye deviation, pupillary abnormalities (including hippus), and autonomic instability. “None of these signs are highly specific for nonconvulsive seizures, and they are often seen under other circumstances in the critically ill patient; thus, cEEG is usually necessary to diagnose nonconvulsive seizures,” the authors write.

The three also break down the indications for cEEG monitoring in their study published in *Anesthesia & Analgesia*:

1. Detection of nonconvulsive seizures and characterization of spells in patients with altered mental status with a history of epilepsy (including fluctuating levels of consciousness, acute brain injury, recent convulsive status epilepticus, stereotyped activity, such as paroxysmal movements, nystagmus, twitching, jerking, hippus, autonomic variability)

2. Monitoring of ongoing therapy, such as in an induced coma, or for assessing level of sedation.

3. Ischemia detection, such as vasospasm in subarachnoid hemorrhage or cerebral ischemia in other patients at high risk for stroke.

4. Prognosis following cardiac arrest or acute brain injury.

“The reason that it is important to identify nonconvulsive seizures and non-convulsive status is that both discoveries represent treatable ‘emergencies’ that are associated with high mortality,” says John McHugh, SpR a Neurology and Research Fellow at St. Vincent’s Hospital in Ireland. Dr. McHugh points to the 1996 paper in *Neurology*, where Young et al. found that delay to diagnosis of nonconvulsive seizure was significantly associated with an increased mortality. “Whilst there are not—to my knowledge—any randomized trials examining the use of cEEG versus routine EEG, the above evidence suggests that prompt diagnosis confers survival benefit, and this is a powerful argument for the role of cEEG in ICU,” he says.

Dr. McHugh’s own study on the use of routine EEG telemetry in a routine general ICU in Ireland revealed that there were significant gaps between the pick-up rates for seizures in ICU patients using routine EEG (30 minute recordings) when compared to similar studies (and indeed more specialized patients with specific neurological injury such as post stroke, post subarachnoid hemorrhage, and post surgery). For the analysis Dr. McHugh and his team identified all routine EEGs performed within a general adult ICU in Ireland over three years, and analyzed the clinical and EEG data.

They found that 52 patients underwent single or repeated EEG evaluation during the time period. Epileptiform abnor-

malities were evident in 15 percent, periodic abnormalities in 14 percent, and electrographic seizures in just one patient (two percent) in their first or only routine EEG recording. “The finding that longer recordings have a higher yield than shorter ones is not a surprise, although perhaps the extent to which routine EEGs fail in comparison to continuous monitoring was a notable finding in our retrospective audit,” he says.

Brain Alarms

“The most important reason for [cEEG in the ICU] is to find nonconvulsive seizures, but as we can get better at it, it will be important for a variety of things including detecting ischemia and changes in brain function,” says Lawrence J. Hirsch, MD, Associate Clinical Professor of Neurology in the Comprehensive Epilepsy Center at Columbia University. And the EEG can show more about the state of a brain than just the presence or absence of seizures. “There are distinct electrographic patterns associated with different states of arousal and with different levels of focal and global brain dysfunction and, because of the continuous nature of EEG monitoring, it is possible to assess changes on a second-by-second basis and observe trends,” Friedman et al. write.

“It’s also a second alarm,” Dr. Hirsch says. “For example, if someone has an arterial line in and it shows a low reading, the nurse usually has to spend a significant amount of time trying to figure out if it’s accurate or if it’s not working. But if you have this brain alarm going off at the same time—which it will if they’re really hypotensive—then you’ll know it’s a real process and you won’t bother looking for the artifactual explanation.”

It’s important to note that some studies suggest cEEG monitoring can impact prescribing habits. Kilbride et al.³ sought to assess the effect of cEEG monitoring on the decision to treat seizures in the inpatient setting, particularly in the ICU. For the study, the authors looked at 300 consecutive nonelective cEEG monitoring studies performed on 287 individual inpatients over a 27-month duration. The findings show that “cEEG led to a change in AED prescribing in 52 percent of all studies with initiation of an AED therapy in 14 percent, modification of AED therapy in 33 percent,

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and discontinuation of AED therapy in five percent of all studies.” More specifically, the detection of electrographic seizures led to an alteration in AED therapy in 28 percent of all studies. The authors conclude, “The findings of continuous electroencephalographic monitoring resulted in a change in AED prescribing during or after half of the studies performed. Most AED changes were made as a result of the detection of electrographic seizures.”

Convulsive Status Epilepticus. DeLorenzo et al. found that 48 percent of patients monitored with cEEG for 24 hours after convulsive SE had stopped had nonconvulsive

seizure, and 14 percent had NCSE in their prospective study.³ Coma was the only clinical manifestation in most of these patients. Patients with NCSE after convulsive SE experienced more than a twofold greater mortality compared with the cohort whose seizures stopped when convulsive activity terminated.

Subarachnoid Hemorrhage. “Seizures have long been recognized to be sequelae of aneurysmal subarachnoid hemorrhage and several studies report a four percent to nine percent convulsive seizure rate after the initial bleed, often in the setting of a focal clot,” according to Friedman, et al.³ A study of 49 consecutive patients diagnosed with nonconvulsive seizure demonstrated 10 percent had subarachnoid hemorrhage.³

Intracerebral Hemorrhage. Intracerebral hemorrhage is associated with a three to 19 percent rate of in-hospital convulsive seizures, and in two recent studies using cEEG, 18 percent to 21 percent of patients with ICH had nonconvulsive seizure.³ cEEG findings may also predict outcome after ICH. Vespa et al. found that nonconvulsive seizure were associated with increased midline shift and were associated with a trend toward worse outcomes.³

Ischemic Stroke. Friedman et al. put estimates for the rate of acute clinical seizures after stroke in the range from two to nine percent in population and hospital-based studies.³ Several studies using cEEG show this seizure rate may be underestimated in the population.³ In one series, 11 percent of 56 patients with ischemic stroke who underwent cEEG had seizures; all but one was a nonconvulsive seizure.³

Data Analysis, Cost Effectiveness and Studies

Advances have allowed cEEG tools to decrease mountains of data to provide graphical representation of significant patterns and trends to speed up review.³ Hours of cEEG information “can be reduced to a single screen of time-frequency values using a compressed spectral array or density spectral array, for example,” say Friedman, et al.³

However, some level of difficulty remains in reading the outputs. “It’s new, it takes significant expertise—these are hard EEGs to interpret, you really require a well-trained electroencephalographer,” Dr. Hirsch says. But with Internet-based networking, physicians can now monitor dozens of patients in multiple ICUs remotely from home or from an off-campus hospital site using virtual private networks.³ Currently, cEEG is not yet a real-time technology at most centers. Instead, neurophysiologists or technologists review records at intervals, meaning that significant time can lapse between an event and reporting to the care team.

cEEG monitoring can be resource intensive, especially in large medical centers, but the cost-effectiveness remains somewhat murky due to a deficiency of studies. One such review of the early cEEG experience at University of California, Los Angeles, by Vespa et al. “found that cEEG accounted for only one percent of the total hospital costs of 100 patients with TBI and helped guide clinical decisions in 90 percent of the patients.”³ In that same time span there was a reduction in total costs and length of stay against controls, though the study didn’t take into account other simultaneous improvements in care that may have affected outcomes.³

At this time, there are unanswered questions due to the need of further studies. Dr. Nuwer surmises why studies in this area aren’t plentiful: problems in randomized design and recruitment. “Would you agree to enter a study if your child were in the ICU?” he asks. “We have a technique that can identify seizures. We have reason to believe that your child is in a situation where your risk of seizures is 20 percent. Only monitoring can see any nonconvulsive (partial) seizures if they are occurring. We believe that nonconvulsive status epilepticus causes brain damage. We want to test our beliefs. We want to randomly decide whether to use our monitoring tool to see if people have a better outcome with monitoring for seizures. Will you agree to a random selection to decide

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whether your child will be monitored for nonconvulsive seizures? That’s a hard sell to ethics committees, much less to family members of ICU patients.”

The Future

The consensus is that while cEEG is underutilized, it is rapidly spreading. “I’m routinely contacted by people who are starting a program, usually in academic centers, but some community hospitals are doing some form of this now.” Dr. Hirsch says. “It’s mostly practical issues like how to interpret read-outs, how often to

look at it, what kind of software needs to be used and how to keep up with the volume, that I don’t have a good answer for. It just takes a lot of people and a lot of effort.”

The US will likely have to lead the pack, as it may be hard to find examples from other countries. “I think that cEEG is growing at a greater pace in the USA than in Europe,” Dr. McHugh says. “Perhaps this may reflect differences in health-care funding. Within many European centers, and certainly within Ireland, availability of cEEG is inadequate for the demands of practicing neurologists and intensivists.”

The biggest next advancement will be having real-time monitoring, allowing hospitals to catch issues in real time, not the next morning on rounds. “That’s going to be next big step,” Dr. Hirsch says. To date, there appears to be two places in the country administering real-time monitoring, one of which is Clarion Health in Indianapolis. Another issue is the software behind the cEEG.

“The software is getting better but has a long way to go,” Dr. Hirsch says. “There are pretty dramatic changes that happen on the EEG with all kinds of events, whether they’re focal or generalized or systemic. The computer can theoretically pick them up but the main problem is dealing with artifact patient movement and other machines in the ICU.” PN

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