ICU EEG MONITORING: WHY, WHEN AND FOR WHOM

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In the last two decades much has been learned about the frequency with which seizures occur in critically ill patients. The use of continuous EEG (cEEG) monitoring in the intensive care unit (ICU) has made it possible to detect seizures in these patients. This paper summarizes the rationale (WHY), duration of monitoring (WHEN) and which patients benefit most (WHOM) from cEEG.

WHY

There are several indications for cEEG monitoring. These were recently summarized in a consensus statement issued by the American Clinical Neurophysiology Society (ACNS).[1] Foremost in these indications is the diagnosis of nonconvulsive seizures (NCS), nonconvulsive status epilepticus (NCSE) and other paroxysmal events and assessment of efficacy of therapy for control of NCS and NCSE. Other indications for cEEG include: identification of cerebral ischemia; monitoring of burst-suppression and sedation therapy; and assessment of severity of encephalopathy and prognostication.

Diagnosis of NCS/NCSE

To better understand the value of cEEG in the diagnosis of NCS and NCSE, an understanding of the definition of status epilepticus (SE) is important. This definition has gone through many iterations over the last 50 years. A commonly used definition describes SE as a condition that consists of "…more than 30 minutes of (1) continuous seizure activity or (2) two or more sequential seizures without full recovery of consciousness between seizures."[2] A more recent modification suggested that SE is more accurately "…defined as 5 minutes or more of (1) continuous clinical and/or electrographic seizure activity or (2) recurrent seizure activity without recovery (returning to baseline) between seizures."[3] This latter definition not only highlights the importance of cEEG in the diagnosis of SE, but also points out the changing thinking regarding this condition. Moreover, studies have shown that clinical features cannot easily be used to accurately identify which patients are likely to be in SE.[4] The International League Against Epilepsy (ILAE) revised the definition to include two important terms: t1 = time point beyond which a seizure should be regarded as "continuous" and t2 = time point at which on-going seizure activity results in risk of long-term consequences.[5]

The frequency of NCS and NCSE in critically ill patients is staggeringly high. Studies have noted that between 8-68% of patients undergoing cEEG monitoring may have NCS/NCSE.[6, 7] A recent study at the author's center noted 21% of patients undergoing cEEG monitoring had NCS/NCSE.[8] Importantly, most of the patients having seizures do not have consistent clinical manifestations and can only be diagnosed with cEEG.[8-10] Seizures and SE should be suspected when mental status is persistently altered after a convulsive seizures or SE, there is acute supratentorial injury with altered mental status, fluctuating mental status without known brain injury, EEG shows high risk patterns (periodic discharges), when there is pharmacologic paralysis, or when there are paroxysmal events suspected to be seizures.[1]

The value of cEEG monitoring has been shown in several ways. There is growing evidence that seizures in critically ill patients leads to worse outcomes. Pediatric studies have shown that children with NCSE, but not children with NCS, have increased mortality and worsened cognitive status.[11, 12] Long-term follow-up of children who have been in NCSE shows lower Glasgow Outcome Scores and lower quality of life scores. [13] Others have shown that serum neuron-specific enolase levels and lactate/pyruvate ratios are elevated in patients with NCSE.[14, 15] Another pediatric study showed that electrographic seizure activity lasting more than 20% of an hour (12 minutes) was more likely to be associated with worse outcomes.[16] Finally, a retrospective evaluation of hospital discharges of intubated patients that underwent routine EEG and cEEG showed that the latter group had lower in-house mortality and no difference in cost.[17]

Assessment of Efficacy of Therapy

It has been known for some time that many patients will continue to have electrographic seizures after control of clinical events. Up to 48% of patients continued to have NCS after generalized convulsive SE in one study.[18] Even after apparent control of seizures on EEG, cEEG may be needed to monitor burst-suppression or seizure suppression.[3]. Exactly how long such monitoring should be continued is controversial and discussed in more detail below.

Detection of Ischemia

The EEG undergoes predictable changes with increasing ischemia. With increasing hypoperfusion, there is loss of faster frequencies and gradual appearance of progressively slower activity.[19, 20] When ischemia reaches < 10 ml/100 g/min, infarction become likely. With the use of quantitative EEG (qEEG) instruments, such as alpha variability and alpha-delta ratio, ischemia can be detected many hours earlier than more conventional techniques like transcranial Doppler ultrasound.[21, 22] This can allow earlier intervention and treatment. There are some challenges to the use of cEEG for detecting ischemia, like constant observation of the EEG rather than the usual 2-3 times per day review. A recent clinical guidelines outlines a successful technique for instituting cEEG detection for cerebral ischemia.[23]

Prognostication

EEG can be used for prognosticating outcome of encephalopathy. There is some disagreement as to whether cEEG monitoring adds value to prognostication beyond a routine EEG. Certain patterns when seen on EEG are considered bad prognostic indicators. These include an isoelectric pattern, spontaneous burst-suppression, periodic patterns, and electrographic seizures. Other patterns are more favorable. These include background continuity, spontaneous variability, reactivity, and normal sleep patterns.[1]

<u>WHEN</u>

A routine 20-30 minute EEG is often not sufficient to detect NCS in critically ill patients. In adults and children, studies have shown that seizures are detected in only about 50% of patient with NCS in the first 30 minutes of recording. After 24 hours of cEEG, about 88% of patients with seizures are detected, and by 48 hours about 93% are detected.[8, 9, 24] There are some features of the EEG, however, that suggest a very low likelihood of subsequent seizures. In one study, patients who had only diffuse slowing in the first 30 minutes of the EEG did not subsequently develop seizures. Patients with periodic complexes had a much higher chance of having seizures.[8] Most clinicians will perform 24-48 hours of cEEG to screen for seizures.[25, 26]

WHOM

Many critically ill patients with fluctuating or persistently altered mental status should be considered for cEEG. A recently published guideline proposed a list of conditions that merit such monitoring.[27]. These conditions are discussed below.

Generalized convulsive SE

Urgent cEEG should be considered in patients with SE that do not return to functional baseline within 60 minutes of antiepileptic drug (AED) administration.

Refractory SE

Urgent cEEG (within 60 minutes) should be considered in patients with refractory SE.

Traumatic Brain Injury

CEEG should be considered in all traumatic brain injury (TBI) patients with unexplained and persistent altered consciousness. Additionally, cEEG should be considered in patients with GCS ≤ 8. The evidence for that latter indication is not as strong as the former.

Subarachnoid Hemorrhage

CEEG should be considered in all SAH patients with unexplained and persistent altered consciousness. Later in the course of the disease, cEEG should be considered to detect delayed cerebral ischemia in comatose patients. The evidence for that latter indication is not as strong as the former.

Coma After Cardiac Arrest

CEEG should be considered in patients who are comatose after cardiac arrest during therapeutic hypothermia and within 24 hours of rewarming. Additionally, the EEG can assist with prognosis. The evidence for that latter indication is not as strong as the former.

ICU Patients Without Acute Primary Brain Injury

CEEG should be considered in comatose ICU patients without an acute primary brain condition and with unexplained and persistent altered consciousness. Patients at greatest risk are those with sepsis and renal and hepatic failure.

Other Conditions

In patients with intracerebral hemorrhage, acute ischemic stroke and infectious and non-infectious encephalitis, cEEG should be considered when there is unexplained and persistent alteration in consciousness.

There are many reasons for considering obtaining cEEG monitoring in critically ill patients. The commonest reasons are to evaluate for NCS and NCSE and to monitor adequacy of therapy. In many instances, 24 hours of cEEG is used to screen for NCS/NCSE, but longer duration monitoring is sometimes considered if the clinical situation warrants and resources allow. Some EEG patterns are seldom associated with seizures, and when these are seen early, the duration of cEEG may be reduced. Many critically ill patients with neurologic and non-neurologic problem may benefit from cEEG monitoring.

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