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Editorial

Do we need continuous electroencephalography after cardiac arrest?

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Continuous electroencephalography (cEEG) is recommended to monitor patients after cardiac arrest,[1,2] but its availability is poor, interpretation variable and often delayed, and utility controversial. Proponents highlight that cEEG allows for the early identification and management of seizures (which are often subclinical or non-convulsive and otherwise undetectable[3]), that it can be used for risk stratification[4,5] or prognostication,[6,7] and aids in the interpretation of post-anoxic myoclonus.[8] Skeptics suggest cEEG is expensive, difficult to obtain, and unnecessary, especially since post-anoxic seizures almost invariably result in a poor neurological outcome, even with therapy.[9] It is sometimes said that cEEG after cardiac arrest is of academic interest — to professors and students, but not clinicians managing actual patients.

This publication of *Resuscitation* includes a novel manuscript from the Pittsburgh Post-Cardiac Service[10] which offers new data to feed, but probably not resolve this controversy, and careful interpretation is required. The authors treated patients at 2 academic teaching hospitals within the University of Pittsburgh system, each with a different approach to EEG monitoring after cardiac arrest. Center 1 (71% of study patients) typically applied cEEG on a clinical basis for 1–5 days, while Center 2 used intermittent "spot" EEG available for only 20–30 min at a time, and only at the initiation of bedside clinicians; more than half (52%) of their patients never received EEG monitoring. As the result of this natural experiment, in which the treating physicians were within the same group and shared treatment protocols but differed in their approach to EEG monitoring, we can see the clinical results of intensive cEEG monitoring versus brief, intermittent EEG on an as-requested basis.

Intensive cEEG monitoring at Center 1 identified more epileptiform activity, and more antiepileptic medications (AEDs) were utilized. The research team then evaluated the effects of this increased AED utilization, and found that despite an algorithm for treatment of epileptiform activity, very few of the patients with seizures or other high-risk ictal patterns survived, even fewer had good outcomes, and the increasing utilization of AEDs seemed to be associated with worse outcomes. Although the study results appear at first to discourage widespread use of aggressive EEG monitoring and AED utilization after cardiac arrest, cautious interpretation is warranted. Overall mortality was extremely high, reflecting the challenging case-mix which included >70% patients with initial non-shockable heart rhythms. Mortality at the two centers differed, as did the severity of illness. The proportion of out-of-hospital arrests was higher, age lower, and percentage of patients with a "PCAC" grouping of IV lower at Center 1 than Center 2; all features associated with less severe injury. This correlated with an in-hospital mortality rate of 69% at Center 1 compared to 79% at Center #2. We do not know the response time to treat seizure activity (e.g., how long it took when seizures occurred to identify them, administer AEDs, and verify resolution or escalate to more aggressive care). The AED regimen, the consistency of its application and other standard practices among providers within their physician group are not provided, nor how the treatment of seizures was incorporated into prognostication discussions with the family. If cEEG identified seizures at 1 AM which were not recognized until 9 AM or treated until noon, improved outcomes should not be expected. We do not know that gaps in care occurred, but we should not be sure that they did not occur. We also do not know how many patients with ictal patterns on EEG were prevented from progressing to seizures by the algorithm that was employed. As with any other diagnostic modality, monitoring can only affect outcomes if tied to an effective and efficiently-delivered therapy; in these cases we do not know if that therapy was delivered in a timely fashion, or that it was therapeutically effective.

The investigators have arranged the epileptiform activity they detected into a malignant hierarchy, with EEG patterns ranked by the association of each with outcome. Favorable patterns at one end of this spectrum included no abnormality or non-periodic epileptiform discharges, and extremely unfavorable patterns at the other end included seizures and suppression-burst patterns. Despite application of their treatment protocol, described as " . . . AEDs [administered] sequentially to suppress these patterns, except for rare or occasional non-periodic epileptiform discharges, which we did not treat", the recovery rates of patients with seizures and suppression-burst are discouragingly low. One striking finding is the very low rate of seizures. At Center #1 (71% monitored), true seizures were only seen in 2% of the population, though periodic discharges were seen in 6%, and non-periodic epileptiform discharges in 5%. Although 2% is markedly lower than other studies have identified,[11,12] we must also consider that these patients were receiving a "standardized AED treatment of EEG patterns

on the ictal-interictal spectrum" that might have prevented those with periodic discharges or non-periodic epileptiform discharges from progressing to seizures. In fact, patients in both groups received AEDs despite having no EEG checked or no epileptiform pattern on their EEG. Many more patients (25%) were found to have "polyspike bursts, with or without myoclonus", a pattern that may sometimes be confused for seizures, and that may sometimes evolve into seizures, but rarely or never results in a favorable outcome.[13,14] Because patients on the epileptic "continuum" received AEDs, we cannot assume that untreated patients would have a similar low rate of seizures.

Although patients with AEDS rarely had good outcomes, and an increasing number of AEDs correlated with worse prognosis, these findings should not be interpreted as meaning that EEG monitoring is unhelpful or the treatment of post-resuscitation seizures unnecessary. Increasingly refractory seizures are usually a marker of significant brain damage, and it has been shown that seizures arising from a nonreactive background — such as those arising from suppression-burst, are almost never recoverable.[15] The utilization of multiple AEDs may simply be a marker of brain injury, as opposed to a cause of worse outcomes, or they may simply not affect outcomes.

The work by Faro and his colleagues provides useful additional information to an understudied aspect of post-cardiac arrest care, and as with most pioneering research, it raises new questions as it answers others; their results should be seen as hypothesis-generating data that do not resolve these complex issues. Continuous EEG and seizure management after cardiac arrest must be studied prospectively, and randomized trials of EEG monitoring and seizure suppression are reasonable. Although it makes sense to monitor for and suppress seizures to prevent secondary injury, there are no data to show that such a strategy improves outcomes, and there is potential for harm related to the negative effects of AEDs on cognitive recovery,[16,17] and the tendency of intensive antiepileptic therapy to prolong treatment, confound prognostication, prolong the suffering of families, and increase the cost of care without improving outcomes. But before we conclude that any efforts to address this challenge are futile, we must perform well-designed prospective studies that can actually answer the question. There is unquestionably a high rate of epileptiform activity on the ictal-interictal continuum after cardiac arrest, suggesting such trials are feasible. In our experience, knowing whether to identify and treat epileptiform patterns after resuscitation is of routine concern, and one of the more important unanswered questions in post-resuscitation care.

Conflict of interest statement

On behalf of the authors, I attest that we have no pertinent financial or other conflicts of interest related to our editorial piece "Do We Need Continuous Electroencephalography After Cardiac Arrest?".

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