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Clinical paper

Utilization of electroencephalogram post cardiac arrest in the United States: A nationwide retrospective cohort analysis☆

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ABSTRACT

Objective: The use of electroencephalogram (EEG) has been demonstrated to have diagnostic and prognostic value in cardiac arrest patients. The use of this modality across the United States in this population is unknown.
Methods: The Nationwide Inpatient Sample (NIS) is a federal database capturing 20% of all US hospital admissions. A cohort of patients who suffered both in and out of hospital cardiac arrests from the 2006 to 2012 NIS datasets was created.
Results: The records of 55,208,382 hospitalizations were analyzed, of which 207,703 patients suffered a cardiac arrest. There were 2952 (1.42%) patients who also had an EEG. Patients who had an EEG compared to those who did not were: younger (62.2 years SD 16.6 vs 66.9 years SD 16.2, $p < 0.01$), were less likely to have insurance coverage (89.9% vs 91.6%, $p = 0.03$) and had significantly longer length of stay (8.6 days IQR 3.7–17.1 vs 4.1 days IQR 1.0–10.5, $p < 0.01$). Patients treated at urban teaching hospitals were more likely to receive an EEG than patients treated at urban non-teaching and rural hospitals ($p < 0.01$). The rate of EEG in survivors of cardiac arrest increased from 1.03% in 2006 to 2.16% in 2012, a relative increase of 110% ($p < 0.02$). The median time to performance of an EEG was 1.6 days IQR 0.33–4.53 days.
Conclusion: EEG is performed on approximately 2% of patients who suffer cardiac arrest in the United States. The treatment hospital and patient characteristics of those who received an EEG different from those who did not.

Introduction

Cardiac arrest affects more than 500,000 individuals in the US each year.[1] Up to 40% of patients who suffer cardiac arrest will survive the initial event, however a large portion of these patients are left with neurologic dysfunction.[2–5] Approximately 50% of patients admitted to intensive care units (ICU) with coma after cardiac arrest have poor neurologic outcome from anoxic encephalopathy.[6]

Electroencephalography (EEG) measures electrical potential differences in synaptic neuronal activity using scalp electrodes, providing information on cortical functioning of the brain.[7] Cortical synaptic activity is particularly sensitive to hypoxia, making EEG an ideal monitoring modality for anoxic encephalopathy.[8] Recent studies have shown that EEG is reliable in predicting the severity of encephalopathy and poor outcome in cardiac arrest survivors. In addition, early use of EEG has also been shown to be useful in predicting a good neurological outome.[9–12] Furthermore, up to one third of cardiac arrest patients in ICU have clinical or non-convulsive seizures detected by continuous EEG monitoring.[13]

According to surveys of neuro-intensivists, up to 78% of patients who suffer cardiac arrest treated at specialized centers undergo routine EEG monitoring.[14] There has been no nationwide analysis of the utilization of EEG in patients who survive cardiac arrest. We

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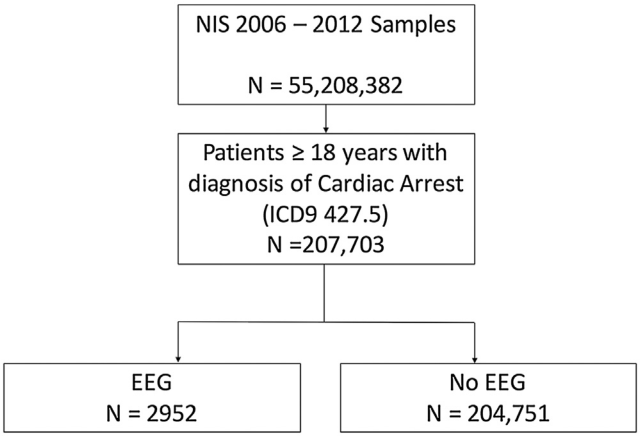

Fig. 1. Patient selection flow diagram.

hypothesize that the real world incidence of EEG in cardiac arrest survivors will be lower than the rates observed in survey studies, as well there may be patient and hospital characteristics influencing EEG performance. We therefore attempted to characterize the national usage of EEG in this population utilizing the Nationwide Inpatient Sample (NIS).

Methods

We report our study in accordance with the STrengthening the Reporting of OBservational studies in Epidemiology (STROBE) statement.[15] We used a retrospective de-identified dataset; a waiver of consent was granted from the University of British Columbia Institutional Review Board (H15-01943).

Study population

For this analysis the NIS was utilised as a data source. The NIS is a federal all payer database created by the Agency for Health Care Quality and Research (AHRQ) which captures approximately 20% of all US inpatient hospitalizations.[16] Utilizing a complex survey design, the NIS is powered to calculate national estimations of the delivery of care representing 95% of all US inpatient care.

Patients ≥18 years of age with a diagnosis of cardiac arrest (ICD9 code 427.5) from the 2006 to 2012 NIS samples were included in the analysis. The use of EEG was captured by isolating patients with ICD9 procedure codes for electroencephalogram (89.14) and video/radio-telemetered electroencephalographic monitoring (89.19). The timing of EEG monitoring in relation to time of admission was also obtained. A patient selection flow diagram is displayed in Fig. 1.

Patient level variables obtained from the dataset included: age, gender, length of stay (LOS), in-hospital mortality, zip-code income quartile and insurance status (covered vs not). Hospital level variables isolated from the NIS were: size (small, medium, large as defined by the AHRQ[16]), teaching status (yes vs no), location (rural vs urban) and region of country (Northeast, Midwest, South and West).

Seizures were defined using ICD9 codes for epilepsy and convulsions, which have been independently validated for the study of seizures.[17] The presence of seizures was defined as a patient having codes for epilepsy (345.0 x–345.5 x and 345.7 x–345.9 x) or other convulsions (780.39), similar to other published literature.[18]

Statistical analysis

All analysis was preformed using SAS v9.4 (Cary, NC, USA) employing appropriate complex survey procedures and weights. Normally distributed data were analyzed using the T test, for non-normally distributed data the Wilcoxon Rank Sum test was used. Chi-square analysis was utilized for ordinal and nominal data. Linear regression analysis was used for trend analysis. All tests were performed with a two-sided alpha error of 0.05. In compliance with the AHRQ data use agreement, cells with less than 10 patients are obscured to prevent identification of individual patients.[19] Proper adjustments for the re-design of the NIS in 2012 were included in our analysis.[20,21] Missing data was excluded from analysis, however this represented less than 1% of data.

A multivariate logistic regression model was created modeling the outcome of performing an EEG. The variables included in the model were chosen a priori and included: age, gender, race, insurance coverage, zip code income quartile, hospital region, hospital size, hospital teaching status, presence of myoclonus and the presence of seizures.

Results

The records of 55,208,382 hospitalizations from the 2006 to 2012 NIS samples were analyzed. There were 207,703 patients who suffered a cardiac arrest, of which 2952 (1.42%) also had an EEG (Table 1). Patients who had an EEG compared to those who did not were: younger (62.2 years SD 16.6 vs 66.9 years SD 16.2, $p < 0.01$), were less likely to have insurance coverage (89.9% vs 91.6%, $p = 0.03$) and had significantly longer LOS (8.6 days IQR 3.7–17.1 vs 4.1 days IQR 1.0–10.5, $p < 0.01$). There was no observed association of EEG performance vs not on female gender (44.0% vs 45.1%, $p = 0.24$) or in-hospital mortality (60.7% vs 60.9%, $p = 0.84$). Socioeconomic status was associated with EEG performance, with patients living in zip-codes with the highest income quartile having the most access to EEG ($p < 0.01$). The race of patients was also unequally distributed amongst those who received an EEG, with higher levels of ethnic minorities receiving an EEG ($p < 0.01$). Myoclonus was a more common secondary diagnosis in patients who underwent EEG compared to those that did not (4.4% vs 0.9%, $p < 0.01$). Seizures were also more common in those patients that had an EEG performed (31.3% vs 8.7%, $p < 0.01$).

Patients treated at urban teaching hospitals were more likely to receive an EEG than patients treated at urban non-teaching and rural hospitals ($p < 0.01$, Table 1). Similarly, patients treated at hospitals in the Northeast and West were more likely to receive EEG's compared to patients treated in the Midwest and South of the country ($p < 0.01$). There was a trend for increased utilization of EEGs as hospital size increased, however this did not reach statistical significance ($p = 0.09$).

The rate of EEG in survivors of cardiac arrest increased from 1.03% in 2006 to 2.16% in 2012, representing a 1.13% absolute and a 110% relative increase ($p < 0.01$, Fig. 2). The median time to performance of an EEG was 1.6 days IQR 0.33–4.53 days. The median time to EEG in patients who died in-hospital was 1.0 days IQR 0–3 days. The median length of stay for patients who had an EEG and died in hospital was 6 days IQR 3–12 days.

The results of the multivariate logistic regression analysis predicting performance of an EEG are displayed in Table 2. After for controlling for all variables in the model, access to EEG was lower for older patients (OR 0.96 per 5 year increase, 95% CI 0.95–0.97, $p < 0.01$) as well as those located in all regions of the country compared to the Northeast (Midwest OR 0.45, 95% CI 0.39–0.51, $p < 0.01$; South OR 0.42, 95% CI 0.37–0.47, $p < 0.01$; and West OR 0.78, 95% CI 0.69–0.88, $p < 0.01$). Access to EEG was higher for all ethnic