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Feasibility of bispectral index monitoring to guide early post-resuscitation cardiac arrest triage☆,☆☆

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ABSTRACT

Introduction: Triage after resuscitation from cardiac arrest is hindered by reliable early estimation of brain injury. We evaluated the performance of a triage model based on early bispectral index (BIS) findings and cardiac risk classes.

Methods: Retrospective evaluation of serial patients resuscitated from cardiac arrest, unable to follow commands, and undergoing hypothermia. Patients were assigned to a cardiac risk group: STEMI, VT/VF shock, VT/VF no shock, or PEA/asystole, and to a neurological dysfunction group, based on the BIS score following first neuromuscular blockade (BISi), and classified as BISi > 20, BISi 10–20, or BISi < 10. Cause of death was described as neurological or circulatory.

Results: BISi in 171 patients was measured at 267(±177) min after resuscitation and 35(±1.7)°C. BISi < 10 suffered 82% neurological-cause and 91% overall mortality, BISi 10–20 35% neurological and 55% overall mortality, and BISi > 20 12% neurological and 36% overall mortality. 33 patients presented with STEMI, 15 VT/VF-shock, 41 VT/VF-no shock, and 80 PEA/asystole. Among BISi > 20 patients, 75% with STEMI underwent urgent cardiac catheterization (cath) and 94% had good outcome. When BISi > 20 with VT/VF and shock, urgent cath was infrequent (33%), and 4 deaths (44%) were uniformly of circulatory etiology. Of 56 VT/VF patients without STEMI, 24 were BISi > 20 but did not undergo urgent cath – 5(20.8%) of these had circulatory-etiology death. Circulatory-etiology death also occurred in 26.5% BIS > 20 patients with PEA/asystole. When BISi < 10, a neurological etiology death dominated independent of cardiac risk group.

Conclusions: Neurocardiac triage based on very early processed EEG (BIS) is feasible, and may identify patients appropriate for individualized post-resuscitation care. This and other triage models warrant further study.

1. Introduction

Outcomes of patients surviving in- and out-of-hospital cardiac arrest have improved with routine application of therapeutic temperature management and evidence-based post-resuscitation care guidelines.[1,2] These guidelines offer several concrete recommendations, including therapeutic hypothermia to 32–34 °C for 12–24 h in survivors of VT/VF arrest, and urgent coronary angiography and PCI as appropriate for patients with STEMI at the time of presentation. Most of the other care is discretionary, however, and there is evidence of great variability in practices.[3]

One reason for this variability is the wide range of injuries suffered by hospitalized cardiac arrest survivors related to the severity and type of neurological and cardiac injuries at the time of hospital presentation, when any combination of mild, moderate, and severe brain injury, seizures, STEMI, acute coronary syndrome, pulmonary embolism, metabolic acidosis, shock, and cardiomyopathy may coexist. Despite this variation in patient condition and context, triage schemes remain rudimentary. For example,

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2010 AHA Guidelines suggest urgent coronary angiography for all OHCA survivors with STEMI, even those with severe brain injury.[1] Urgent coronary angiography for OHCA survivors with VT/VF arrest remains controversial despite evidence of benefit, and many investigators and practitioners have demanded a more sophisticated assessment paradigm.[4–9]

Asphyxial rat models of brain injury following cardiac arrest suggest that processed EEG performed as early as 60 min after resuscitation predict outcome with a high degree of sensitivity and specificity.[10–14] In humans, we have previously shown that simple and commercially available processed EEG (the bispectral index) under a standardized sedation and neuromuscular blockade algorithm accurately predicts outcome at a mean of 4.5 h after resuscitation.[15,16] Believing that post-resuscitation CA care should be individualized to consider the relative risk/benefit profile of various treatment strategies for individual patients, we developed a possible risk stratification model, characterizing CA survivors based on commonly accepted cardiac risk groups, and an assessment of the severity of brain injury by processed EEG.[15] We then populated the model with a large, retrospective cohort, to see if it reliably classified patients according to their ultimate risk of neurological or cardiac etiology death, and might therefore be used to triage patients prospectively to a treatment regimen tailored to their injuries.

2. Materials and methods

This was a retrospective study involving serial patients admitted to the intensive care unit of a single United States center after in-hospital or out-of-hospital cardiopulmonary arrest between September, 2008 and May, 2012. Patients were included if over 18 years of age and a complete data set was available. Patients that died on hospital days 1–2 were excluded due to the difficulty of determining the cause of death in this subgroup, and the high frequency of psychosocial issues, such as the role of advanced age and DNR status in determining outcome.[17] De-identified demographic, clinical, treatment, and outcomes data are collected prospectively into an IRB-supported database built around the International Cardiac Arrest Registry (INTCAR) platform. Processed EEG data are routinely uploaded from the bedside bispectral index monitors (Covidien Medical, Boston, MA, models A2000 and VISTA). All patients are treated under a standardized post-resuscitation therapeutic hypothermia protocol, which has been previously described[18,19] and involves rapid surface cooling to 33 °C using a commercially available servo-regulated surface cooling device, 20 mcg/kg/min infusion of propofol, 25 mcg/h infusion of fentanyl, and intermittent bolus-dose vecuronium to initiate the cooling process and then in response to visible shivering.[20,21] All patients are monitored with the bispectral index continuously during the hypothermia protocol to verify the adequacy of sedation,[22] and with continuous EEG to detect seizure activity.

STEMI was defined as ST elevations >1 mm in 2 or more contiguous leads. Shock was defined as requiring vasopressor support to maintain systolic blood pressure >90 mmHg during the first hour of hospitalization. Left ventricular function was based on the first measurement, typically within 12 h of presentation. Clinicians described the cause of death: When patients became brain dead or died after withdrawal of life support due to perceived neurological futility, the etiology of death was described as neurological etiology. If the patient died of shock, re-arrest, refractory arrhythmia, or progressive lactic acidosis and multiorgan system failure, the cause of death was described as circulatory. All inpatient deaths met these criteria.

At our center, when patients do not awaken in the first days after rewarming, board certified neurologists are consulted to remark on prognosis. This prognosis is typically delivered based on serial examinations off analgesia and sedation, continuous EEG findings, MRI typically performed between days 3 and 5 post-arrest, and serum neuron-specific enolase levels obtained at 24, 48, and 72 h. Although, in light of recent criticisms of the 2006 AAN Practice Parameters[23,24] none of these modalities is considered infallible, we believe that in concert they frequently paint a picture of mild, moderate, or grave brain injury, with a corresponding high-to-low likelihood of functional recovery. Occasionally, somatosensory evoked potentials are then obtained, for confirmation of severe injury. Families use this information, in conference with attending neurology and critical care specialists, to determine whether discontinuation of life support measures is advisable, or prolonged supportive care is appropriate. Such conferences are tailored to individual family needs, and a dogmatic approach to interpreting prognostic data is discouraged. The timing of these meetings is not uniform, but delay ≥72 h after rewarming is recommended. The BIS monitor is removed after 48 h of temperature management, and although not blinded early on, is not available to consulting neurologists and is not part of prognostication. Indeed, the authors have strongly discouraged this experimental modality be used to influence bedside discussions of prognosis in out unit, and its primary clinical utility is to titrate sedation during neuromuscular blockade.[19]

Post-anoxic seizures and frequent periodic discharges are routinely treated with antiepileptic and suppressive agents, but they are also thought to reflect a more significant injury – especially if arising from a suppressed or burst-suppressed background,[24,25] and may therefore influence prognostication.

The BISi is defined as the mean bispectral index plateau value recorded during 10 min following the administration of the first dose of neuromuscular blockade.[15] Neuromuscular blockade is necessary to eliminate muscle artifact that confounds the BIS reading, and the measurement is typically performed after arrival in the ICU, at which point cooling pads are placed, the BIS monitor applied, sedation and analgesia infused, and a bolus dose of 0.1 mg/kg vecuronium administered to augment the cooling process.

The practice standard in our institution includes urgent cardiac catheterization for most CA survivors found to have ST-elevation myocardial infarction, but the most appropriate therapy is ultimately determined by the attending interventional cardiologist, and varies somewhat. Other cardiac arrest survivors, including those with a presumed cardiac cause of the arrest, rarely undergo urgent coronary angiography and PCI (defined as occurring prior to neurological assessment or awakening), but among patients who demonstrate neurological recovery, most undergo angiography on a delayed basis. We believe this approximates standard care in our region, and most areas of the United States, though some hospitals have adopted a more aggressive approach.[26,27]

Based on commonly employed cardiac risk strata and previously observed associations between processed EEG findings and neurological outcomes,[15] a simple grid for risk stratification was developed (see Table 2 below). Patients in the database were classified according to the grid, and within each category the following treatment and outcomes considered: survival, death due to neurological etiology, death due to circulatory failure, early coronary angiography, and early percutaneous coronary intervention.

3. Results

One hundred and seventy one patients met inclusion criteria. Demographics, number of comorbid medical conditions, characteristics of the arrest, presence of factors such as STEMI, cardiomyopathy, and shock, severity of neurological dysfunction as described

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