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Color density spectral array of bilateral bispectral index system: Electroencephalographic correlate in comatose patients with nonconvulsive status epilepticus

Miguel A. Hernández-Hernández [a,c,*], José L. Fernández-Torre [b,c,d]

[a] Department of Intensive Medicine, Marqués de Valdecilla University Hospital, Santander, Cantabria, Spain
[b] Department of Clinical Neurophysiology, Marqués de Valdecilla University Hospital, Santander, Cantabria, Spain
[c] Biomedical Research Institute (IDIVAL), Santander, Spain
[d] Department of Physiology and Pharmacology, University of Cantabria (UNICAN), Santander, Cantabria, Spain

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ABSTRACT

Purpose: to describe the characteristics of the color density spectral array (CDSA) of bilateral bispectral index (b-BIS) monitoring system in patients with comatose nonconvulsive status epilepticus (NCSE). We hypothesized that CDSA could be helpful for monitoring NCSE in critically subjects if continuous EEG (cEEG) is not available.
Methods: we retrospectively analyzed comatose patients admitted to our neurological intensive care unit (NICU) from 2011 to 2014 with a diagnosis of definitive NCSE that underwent b-BIS monitoring for at least 24 h to guide anesthetic sedation. Clinical, electroencephalography and neuroimaging findings were analyzed. Moreover, all parameters from the b-BIS data including the CDSA were reviewed during periods of NCSE (NCSE pattern) and profound sedation (sedation pattern).
Results: 15 NCSE patients were included. The delay from the diagnosis of NCSE to the onset of b-BIS monitoring was 8 (0.5–31) h and total time of b-BIS monitoring 7.8 ± 6.5 days. CDSA during NCSE pattern was characterized by continuous or intermittent red and dark red tones, spectral edge frequency (SEF) in the delta-theta range, with or without asymmetry and BIS number trend with significant variability. In contrast, CDSA during sedation revealed predominance of orange, yellow, green and occasionally blue tones, SEF in the alpha-beta range, absence of asymmetry and stability of BIS number.
Conclusions: b-BIS monitoring system and, in particular, CDSA used by nonexpert NICU personnel may be helpful to follow-up episodes of NCSE, to detect recurrences of nonconvulsive seizures (NCSzs), and to monitor profound anesthetic therapy in comatose patients when cEEG is not available.

1. Introduction

Status epilepticus (SE) is a common neurological emergency characterized by continuous or recurrent seizures without full recovery of consciousness between seizures, which may result in death or permanent neurological sequelae [1]. The most frequent seizures type in comatose patients with acute brain injury (ABI) admitted to the neurological intensive care unit (NICU) are nonconvulsive (NCSzs) and, a definitive diagnosis of nonconvulsive SE (NCSE) can only be strictly established with electroencephalograhy (EEG) [2]. Unfortunately, although the use of continuous EEG (cEEG) monitoring for critically ill patients has grown over the past decades, there are important limitations that explain its scarce availability [3,4].

Meanwhile, different digital EEG trend analysis methods such as amplitude integrated EEG (aEEG) and color density spectral array (CDSA) have been developed to facilitate interpretation of prolonged EEG recording and recognition of seizures. These quantitative EEG (qEEG) display tools have been incorporated into modern EEG machines. In addition, other alternative devices such as the bispectral index (BIS) monitor, which also includes a CDSA in the newest version, seem to be helpful in the management of selected cases of SE [5–8].

The aim of this study was to describe the characteristics of the CDSA of bilateral BIS (b-BIS) monitoring system in comatose patients with NCSE and during the anesthetic control of seizures

* Corresponding author at: Department of Intensive Medicine. Marqués de Valdecilla University Hospital, Avda Valdecilla 25, 39008 Santander, Cantabria, Spain. Tel.: +34 942202906; fax: +34 942203543.
E-mail address: mahernandez@humv.es (M.A. Hernández-Hernández).

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and, to report the differences between both states. Our hypothesis was that CDSA could be helpful for monitoring NCSE in critically subjects if cEEG is not available.

2. Methods

2.1. Study population

We conducted a retrospective descriptive analysis of adult patients with diagnosis of *comatose NCSE* admitted between January 2011 and December 2014 to our 12-bed NICU at Marqués de Valdecilla University Hospital in Santander, a region located in the north of Spain. The files of all patients with an ICD-10 discharge diagnosis of SE (convulsive or nonconvulsive) from a computerized database of our hospital were reviewed. Clinical information was subsequently extracted through retrospective review of case records for all eligible patients using a standardized data collection form.

Patients were eligible if they had a diagnosis of definitive NCSE and underwent b-BIS monitoring for at least 24 h to guide anesthetic sedation as part of their clinical care. During the study period, neurophysiologists on call and cEEG monitoring were not available in our hospital.

2.2. Electroencephalography (EEG) and definition of comatose NCSE

EEG recordings were performed with standard scalp electrodes placed according to the international 10–20 system during at least 30 min and following local protocols for NICU patients. In general terms, NCSE may be defined as a pleomorphic and heterogenous epileptic condition, lasting more than 30 min, in which continuous or recurrent electrographic seizure activity was responsible for diverse clinical symptoms including altered mental state, behavioral and perception abnormalities, vegetative disturbances or reduced level of consciousness [9,10]. For the diagnosis of *comatose NCSE* we used the criteria proposed by Young and colleagues [11], and subsequently modified by Chong and Hirsch [12] and Drislane and Kaplan [13]. In all cases, major convulsive manifestations were absent. All EEGs in *comatose NCSE* patients were assessed by a senior neurophysiologist (JLF-T) and found to fit into three patterns: (i) Generalized, (ii) Focal, partial or lateralized, and (iii) Focal secondarily generalized (FSG). An asymmetry of background activity of 50% or more was regarded as clinically significant.

2.3. Bilateral bispectral index (b-BIS) monitoring

We used the newest b-BIS Vista™ monitor (Aspect Medical Systems Inc., Norwood, MA) version 3.00 to coupled to BIS bilateral sensor with pre-gelled 6-electrode array placed on the forehead and temple which allows registration 4 EEG channels that correlate approximately to the FPz and FP1/2 and F7/F8 leads of international 10/20 system electrode placement. The electrodes are referenced by an additional electrode over the eyebrow. Suitable electrode impedance (<5 kΩ) was confirmed using the manufacture's automatic checking routine and BIS sensor was changed as necessary [7,14]. The system calculates BIS number and other variables, such as electromyographic (EMG) activity, suppression rate (SR) and sign quality index (SQI), for the left and right sides of the brain, and reports them to the monitor for display.

The CDSA or spectrogram is a new variable of the b-BIS system obtained in real time through fast Fourier transform to display a three dimensional picture of EEG power over time at various frequencies. The CDSA trend is 3-dimensional: frequency with a range from 0 to 30 Hz (x-axis), time (y-axis) and the amplitude of the power spectrum (z-axis) is encoded in different colors, from blue-low or minimal power, to red-high or maximal power [15,16]. CDSA is recorded continuously and the system shows the last 30 min in the screen of the monitor. Additionally, the device is able to convert up to 24 h of CDSA data into a PDF format for exporting [17].

CDSA display includes the Spectral Edge Frequency (SEF) and Asymmetry Indicator (ASYM). SEF is showed (in Hz) as a white line superimposed on the graph where 95% of the total power lies on one side of the line (toward the inside of the graph) and 5% lies on the other side. ASYM is draw in the center of the CDSA display and is an EEG power-based parameter that quantifies hemispheric differences in relative total power of the EEG between the left and right side (graph indicates the side with relative greater power). The ASYM scale begins at 20% at the center line and runs left or right to 100%. An asymmetry of background activity of 50% or more was regarded as clinically significant.

2.4. NCSE management in the NICU

Although there is no standard protocol for the management of NCSE in our institution, all patients with NCSE were treated in a similar way. When EEG anomalies suggestive of NCSE were seen in the EEG of a patient, a bolus of intravenous anesthetics (benzodiazepines or propofol) was injected during the recording in order to evaluate the clinical and electroencephalographic effect. Following confirmation of NCSE diagnosis, antiepileptic drugs (AEDs) were administered (such as phenytoin or levetiracetam) and continuous infusion of propofol or midazolam was started. The AED use might vary among individual prescribers. After 24–48 h, sedation was stopped and a second scalp EEG carried out to evaluate the AED response. Etiology of NCSE was established when possible and AEDs were adjusted until NCSE control was achieved by clinical and serial EEGs. The onset of NCSE was considered as being the moment at which the first EEG confirmed the presence of ongoing seizures. The end-point of NCSE was determined to be when EEG changes regressed. Therefore, NCSE control was regarded when a follow-up EEG showed seizure resolution with or without changes in the level of consciousness. In all patients, the termination of the episode of NCSE was confirmed with EEG.

In the last four years, we used the b-BIS monitoring system to control the depth of anesthesia and detect the reappearance of NCSzs as part of our care in all comatose patients with NCSE diagnosed by routine EEG. We employed this system since we did not have cEEG. To achieve this, we maintained the b-BIS sensor during scalp EEGs in order to compare EEG findings simultaneously between both devices and to correlate them with CDSA.

Subsequently, the CDSA of b-BIS that was recorded during the periods categorized as NCSE (NCSE pattern) and after the abolition of epileptiform activity following the administration of anesthetics (sedation pattern) to analyze the differences of the CDSA during both states. CDSA was exported each 24 h and reviewed by physician team to assist in decision-making.

2.5. Data collection and analysis

The following information was collected: age, sex, etiology, indication for the EEG, clinical characteristics, the type of epileptiform discharges i.e. localization, power, frequency and morphology, number of scalp EEGs, AEDs, time to resolution of NCSE and clinical outcome. The time of onset and total time of b-BIS monitoring were also analyzed. CDSA data exported of b-BIS system were collected.

Based on this information, CDSA was reviewed retrospectively in each patient in order to identify periods with evidence of NCSE