Clinical Neurophysiology 128 (2017) 1000–1007

Contents lists available at ScienceDirect

Clinical Neurophysiology

journal homepage: www.elsevier.com/locate/clinph

Applicability of NeuroTrend as a bedside monitor in the neuro ICU

J. Herta [a,*], J. Koren [b], F. Fürbass [c], A. Zöchmeister [a], M. Hartmann [c], A. Hosmann [a], C. Baumgartner [b,d], A. Gruber [a]

[a] Department of Neurosurgery, Medical University of Vienna, Vienna, Austria
[b] Karl Landsteiner Institute for Clinical Epilepsy Research and Cognitive Neurology, 2nd Neurological Department, General Hospital Hietzing with Neurological Center Rosenhuegel, Vienna, Austria
[c] AIT Austrian Institute of Technology GmbH, Digital Safety & Security Department, Vienna, Austria
[d] Department of Epileptology and Clinical Neurophysiology, Sigmund Freud University, Vienna, Austria

ARTICLE INFO

Article history:
Accepted 2 April 2017
Available online 11 April 2017

Keywords:
Epileptic seizure detection
Nursing
Interrater agreement
Continuous EEG
Intensive care unit
Screening device
Monitoring
Periodic discharge
Rhythmic and periodic patterns

HIGHLIGHTS

- Proposal and guidance on how a computer algorithm may be used by ICU staff as a cEEG bedside monitor.
- High interrater agreement among nurses for EEG patterns that may indicate subclinical seizures.
- Large amount of prospectively recorded, randomized long-term video EEG data from two neuro ICUs.

ABSTRACT

Objective: To assess whether ICU caregivers can correctly read and interpret continuous EEG (cEEG) data displayed with the computer algorithm NeuroTrend (NT) with the main attention on seizure detection and determination of sedation depth.

Methods: 120 screenshots of NT (480 h of cEEG) were rated by 18 briefly trained nurses and biomedical analysts. Multirater agreements (MRA) as well as interrater agreements (IRA) compared to an expert opinion (EXO) were calculated for items such as pattern type, pattern location, interruption of recording, seizure suspicion, consistency of frequency, seizure tendency and level of sedation.

Results: MRA as well as IRA were almost perfect (80–100%) for interruption of recording, spike-and-waves, rhythmic delta activity and burst suppression. A substantial agreement (60–80%) was found for electrographic seizure patterns, periodic discharges and seizure suspicion. Except for pattern localization (70.83–92.26%), items requiring a precondition and especially those who needed interpretation like consistency of frequency (47.47–79.15%) or level of sedation (41.10%) showed lower agreements.

Conclusions: The present study demonstrates that NT might be a useful bedside monitor in cases of subclinical seizures. Determination of correct sedation depth by ICU caregivers requires a more detailed training.

Significance: Computer algorithms may reduce the workload of cEEG analysis in ICU patients.

1. Introduction

Continuous electroencephalography (cEEG) is used in the intensive care unit (ICU) to detect subclinical seizures and to monitor sedation depth in cases of refractory seizures or elevated intracranial pressure (Eisenberg et al., 1988; Friedman et al., 2009; Sutter et al., 2013). Previous studies showed that subclinical seizures occur more often than anticipated in the ICU (Kaplan, 1999) and frequently develop at an early stage of acute brain injury (Claassen et al., 2004). Since mortality increases exponentially with seizure duration in critical care patients, proper application and instant interpretation of cEEG is crucial in this setting (Young

---

Abbreviations: AC1, Gwet's multirater agreement coefficient of first-order; AIT, Austrian Institute of Technology; aEEG, amplitude integrated electroencephalography; BMA, biomedical analyst; BS, burst suppression; CCET, American Clinical Neurophysiology Society's Standardized Critical Care EEG Terminology; cEEG, continuous electroencephalography; ESP, electrographic seizure pattern; EXO, expert opinion; FIRDA, frontal intermittent rhythmic delta activity; GCS, Glasgow coma scale; ICU, intensive care unit; IRA, interrater agreement; MRA, multirater agreement; NT, NeuroTrend; PD, periodic discharge; qEEG, quantitative electroencephalography; RAA, rhythmic activity in the alpha range, "rhythmic alpha activity"; RDA, rhythmic delta activity; RDA+S, rhythmic delta activity plus seizures; RTA, rhythmic activity in the alpha range, "rhythmic theta activity"; SIRPIDs, stimulus-induced rhythmic, periodic, or ictal discharges; SW, spike wave.

* Corresponding author at: Department of Neurosurgery, Medical University of Vienna, Währinger Gürtel 18-20, 1090 Vienna, Austria. Fax: +43 01 40400 45660.

E-mail address: johannes.herta@meduniwien.ac.at (J. Herta).

http://dx.doi.org/10.1016/j.clinph.2017.04.002
1388-2457/

et al., 1996; Vespa et al., 1999). Its use has been associated with a favorable outcome in the critically ill (Ney et al., 2013). But cEEG monitoring is not available in the majority of hospitals as it requires a lot of resources.

To minimize the diagnostic effort of visually screening hours of cEEG the Austrian Institute of Technology (AIT) has developed a computer algorithm called NeuroTrend (NT) with a strong ability to visualize rhythmic and periodic patterns in a time compressed fashion (Fürbass et al., 2015, 2016). A possible field of application lies in the use of NT as a bedside monitor. However, in contrast to other ICU monitors, an automatic alarm system for seizures would be ineffective, as false alarms would be too frequent in an environment that contains a plurality of possible EEG artefacts. In addition, NT data needs interpretation as it also displays trend data of patterns that are not clearly ictal. Therefore, trained nurses, taking care of the same patient over several hours would be best suited to use and interpret the computer results.

The present study investigated whether briefly trained ICU caregivers can read and interpret NT cEEG data correctly. To test this hypothesis, 15 ICU nurses and 3 biomedical analysts (BMA) not familiar with EEG, had to evaluate NT cEEG data from patients with acute brain injury. The evaluations were then compared between the respondents as well as with an expert opinion (EXO) and tested for their consistency. The main parameters tested for consistency were: (1) Identification of seizures occurrence and seizure progression (2) Assessment of the sedation depth.

2. Methods

2.1. Dataset

A dataset of 83 prospectively recorded continuous video-EEGs (6733 h, mean 73 h) from a neurological (Neurological Center Rosenhuegel) and a neurosurgical ICU (General Hospital Vienna) was used. All recordings were obtained from patients older than 18 years with a median age of 58.5 years. EEGs were recorded using a Micromed EEG system (SystemPLUS Evolution 1.04.95, Micromed S.p.A., Veneto, Italy) with a sampling rate of 256 Hz, placing 21 electrodes according to the international 10–20 system. Only video-EEGs with a duration of more than 24 h and a sufficient EEG signal quality over the whole recording period were used in this study. Patients were selected using the NeuroTrend (NT) Analysis Database. This database was established in 2011 with its main focus of investigating rhythmic and periodic EEG patterns of ‘ictal-interictal uncertainty’ as well as subclinical seizures and status epilepticus (Koren et al., 2015). All cEEGs registered in the database were reviewed by board certified neurophysiologists and screened for electrographic seizure patterns (ESP), spike wave (SW), rhythmic delta activity (RDA), periodic discharges (PD), burst suppression (BS) patterns and patterns mimicking artefacts as described elsewhere (Herta et al., 2015). EEG changes in frequency, prevalence, localization and morphology were reevaluated every 24 h according to the guidelines of the American Clinical Neurophysiology Society’s Standardized Critical Care EEG Terminology (CCET) (Hirsch et al., 2013). Additional information included treatment protocols, patient characteristics, certain neurologic scores and follow up data (Glasgow Outcome Score after six month). From this database 20 patients were randomly selected with a predefined split into the following six groups: PD ($n = 3$), ESP ($n = 3$), SW ($n = 3$), RDA ($n = 3$), BS ($n = 3$) and none of the above-mentioned patterns ($n = 5$). If a patient showed more than one pattern type he or she could be randomized into multiple groups but overall could not be selected more than once.

2.2. NeuroTrend

Included cEEGs were analyzed by the computer algorithm NT. This algorithm detects and visualizes rhythmic and periodic EEG patterns with a strong emphasis on data and time compression as well as artefact rejection (Hartmann et al., 2014; Fürbass et al., 2015, 2016). A color code displays the following patterns: periodic discharges (PD), rhythmic delta activity (RDA), rhythmic delta activity plus superimposed sharp waves or spikes (RDA + S), rhythmic activity in the theta range (RTA), rhythmic activity in the alpha range (RAA) and spike wave (SW). Pattern localization, pattern frequencies, frequency bands (beta, alpha, theta and delta range) and amplitude integrated EEG (aEEG) are calculated and displayed on a graphical user interface. The definition of rhythmic and periodic EEG patterns follows the guidelines of the CCET adding unequivocal electrographic seizures including generalized spike-wave discharges at 3 Hz or faster, evolving discharges that reach frequencies of more than 4 Hz as well as BS patterns (Hirsch et al., 2013). A validation of NT was recently published elsewhere (Herta et al., 2015). NT is part of the encevis software package. Version V1.3 of encevis was used in this study (http://www.encevis.com).

2.3. NT training and data preparation

Nurses and BMAs (in the following referred to as “respondents”) from a neurosurgical ICU were asked to volunteer for the study. A total of 18 respondents, including 3 BMAs and 15 nurses, then compiled a questionnaire where they were asked about work experience, experience with EEG, computer skills, experience in playing computer games and presence or absence of color blindness. All personal data were anonymized for further analysis. All respondents underwent a brief educational course of approximately one hour. Features of NTs graphical user interface and the study design were explained. Samples of cEEG and NT data were presented. The presentation files as well as a short rating manual were handed out to the respondents (available as Supplementary material).

Shortly thereafter each respondent was asked to rate the preselected NT data. The rating manual could be used during the evaluation process. During the assessment, the time needed to evaluate the NT data of 20 patients was measured. NT data were presented to the respondents by an editable Microsoft® PowerPoint slideshow (Fig. 1). A brief patient history was given, including information about admission diagnosis, operative procedures undertaken and their time course, seizures prior to EEG, anesthetics and antiepileptic drugs administered, clinical features that may indicate subclinical seizures (Husain et al., 2003) and Glasgow Coma Scale (GCS) at cEEG start. Subsequently, results of NT analysis were presented in a mask that allowed simultaneous ratings of each slide. Slides displayed 6 consecutive NT screenshots for each patient with a length of 4-h each, giving in total 120 screenshots or 480 h of cEEG.

2.4. NeuroTrend review scheme

Rating possibilities were grouped into 4 categories and could be selected by check boxes. In category one the patterns recognized by NT (PD, RDA, RDA + S, RTA, RAA, SW) had to be identified (Fig. 1a). The selection of multiple patterns for each 4-h segment was possible. For each pattern the principal location had to be defined. If the pattern was not clearly localized to the left or right hemisphere, generalized had to be selected. Furthermore, for each pattern the consistency of frequency had to be indicated (Fig. 1b). A consistent frequency was assumed if the frequency remained the same or increased/decreased continuously over a longer recording period of at least 30 min.