Epilepsy & Behavior 85 (2018) 173–176

Contents lists available at ScienceDirect

Epilepsy & Behavior

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

Brief Communication

Tolerability of a comprehensive cardiorespiratory monitoring protocol in an epilepsy monitoring unit

Brian K. Gehlbach [a,b,1], Rup K. Sainju [b,1], Deanne K. Tadlock [b], Deidre N. Dragon [b], Mark A. Granner [b], George B. Richerson [b,c,d,*]

[a] Department of Internal Medicine, University of Iowa Carver College of Medicine, 200 Hawkins Drive, Iowa City, IA 52242, USA
[b] Department of Neurology, University of Iowa Carver College of Medicine, 200 Hawkins Drive, Iowa City, IA 52242, USA
[c] Department of Molecular Physiology and Biophysics, University of Iowa Carver College of Medicine, 200 Hawkins Drive, Iowa City, IA 52242, USA
[d] Veterans Affairs Medical Center, 601 Hwy 6 West, Iowa City, IA 52246, USA

ARTICLE INFO

Article history:
Received 6 March 2018
Revised 3 June 2018
Accepted 4 June 2018
Available online xxxx

Keywords:
Epilepsy
Video-EEG monitoring
Cardiorespiratory monitoring
Tolerability
Sudden unexpected death in epilepsy

ABSTRACT

Background: Recent reports of fatal or near-fatal events in epilepsy monitoring units (EMUs) and an increasing awareness of the effects of seizures on breathing have stimulated interest in cardiorespiratory monitoring for patients undergoing video-electroencephalography (EEG) recording. Patient and provider acceptance of these extra recording devices has not previously been studied and may represent a barrier to widespread adoption.
Methods: We queried EMU subjects regarding their experiences with a monitoring protocol that included the continuous measurement of oral/nasal airflow, respiratory effort (chest and abdominal respiratory inductance plethysmography), oxygen saturation, and transcutaneous CO_2. Surveys were returned by 71.4% (100/140) of eligible subjects.
Results: Overall, 73% of participants reported being moderately to highly satisfied with the monitoring, and 82% reported moderate to strong agreement that advance knowledge of the monitoring would not have changed their decision to proceed with the video-EEG study. Except for nasal airflow, none of the additional monitoring devices caused more discomfort than EEG electrodes.
Conclusion: Patient acceptance of an EMU comprehensive cardiorespiratory monitoring protocol is high. The information obtained from "multimodality recording" should help clinicians and investigators understand the effect of seizures on both cardiac and respiratory physiology, may enhance safety in the EMU, and may aid in the identification of biomarkers for sudden unexpected death in epilepsy (SUDEP).

1. Introduction

The modern epilepsy monitoring unit (EMU) was made possible by the digitalization of video-electroencephalography (EEG) and by advances in automated signal processing. These advances have occurred largely within the past 20 years, marking the EMU as a relative newcomer in the creation of dedicated inpatient units focused on the rapid identification of acute clinical changes. Accordingly, while coronary care units have been around for over 50 years, the approach to monitoring inpatients with epilepsy has evolved over a relatively short period of time. Core monitoring components have typically involved dedicated nursing staff and EEG seizure monitoring technicians as well as real-time computerized seizure detection algorithms. Electrocardiographic (ECG) signals are frequently recorded as part of the EEG record [1], and cardiac telemetry is employed by some EMUs. Despite an increasing awareness of the effects of seizures on breathing [2, 3] and human and animal data suggesting that periictal hypoventilation/apnea is the cause of some cases of sudden unexpected death in epilepsy (SUDEP) [4–6], the systematic monitoring of respiration has been neither routine nor recommended [7–9].

Recent reports of people with epilepsy (PWE) suffering fatal or near-fatal events while being cared for in an EMU [6, 10] have stimulated interest in cardiorespiratory monitoring. Analysis of the events reported in the MORTEMUS study demonstrates that terminal apnea precedes terminal asystole in such cases [6]. Thus, the early identification of periictal hypoventilation may afford an opportunity for intervention prior to arrest. The so-called "multimodality" monitoring may also increase the diagnostic yield of video-EEG monitoring in cases where periictal cardiorespiratory phenomena constitute the only clinical sign of seizure [11]. Patient acceptance of dedicated cardiorespiratory monitoring during long-term video-EEG recording has not been previously

* Corresponding author at: The Roy J Carver Chair in Neuroscience, University of Iowa, 200 Hawkins Drive, 2151 RCP, Iowa City, IA 52242, USA.
E-mail addresses: brian-gehlbach@uiowa.edu, (B.K. Gehlbach), rup-sainju@uiowa.edu, (R.K. Sainju), deanne-tadlock@uiowa.edu, (D.K. Tadlock), deidre-nitschke-dragon@uiowa.edu, (D.N. Dragon), mark-granner@uiowa.edu, (M.A. Granner), george-richerson@uiowa.edu (G.B. Richerson).
[1] Contributed equally to the work.

https://doi.org/10.1016/j.yebeh.2018.06.006
1525-5050/

studied. Indeed, the perception that such measures may be tolerated poorly could serve as a barrier to implementation [12].

We studied patient tolerance of a comprehensive cardiorespiratory monitoring protocol involving ECG and the measurement of airflow (using an oral/nasal thermistor and nasal pressure transducer), respiratory effort (via respiratory inductance plethysmography, RIP), capillary oxygen saturation (SpO_2), and transcutaneous CO_2 ($tcCO_2$). We hypothesized that additional cardiorespiratory monitoring would be as well tolerated as EEG not only in patients with epilepsy but also in those patients ultimately diagnosed with nonepileptic spells. This report describes overall patient satisfaction with this protocol and suggests strategies for implementation.

2. Materials and methods

The University of Iowa Comprehensive Epilepsy Program is accredited as a level 4 program by the National Association of Epilepsy Centers. The program's adult EMU is a 9-bed unit located within the main hospital and staffed by a core group of nurses, EEG technologists, seizure-monitoring technicians, a neurology resident, and an epileptologist. Safety protocols include real-time 24-hour automated seizure detection and visual monitoring, ECG recording, and a fall prevention protocol. Telemetry and pulse oximetry are utilized at the discretion of the admitting physician.

The data reported in this paper were acquired as part of a larger, ongoing study investigating mechanisms of periictal respiratory depression in patients with epilepsy. Subjects were typically approached by the study team within 12 h after admission to the EMU and, if enrolled, underwent continuous respiratory monitoring from this point on until the conclusion of video-EEG monitoring. Oral/nasal airflow was measured using a nasal pressure transducer (BiNAPS, Salter Labs) and oral/nasal thermistor (ThermiSense, Salter Labs). Chest and abdominal excursions were measured using respiratory inductance plethysmography (zRIP, Pro-Tech Services). The SenTec Digital Monitoring System (SenTec AG, Therwil, Switzerland) was used to measure SpO_2 and $tcCO_2$, with the sensor applied to the cheek. All data were saved and time-synchronized with the video-EEG recording. The SenTec was programmed to alarm at the bedside when values for SpO_2, $tcCO_2$, or heart rate were out of range.

Subjects completed a written questionnaire provided by EMU staff after respiratory monitoring was completed. This questionnaire assessed a) level of comfort with each component of monitoring, b) overall satisfaction with monitoring, c) interference with sleep and daily activity due to monitoring, and d) likelihood of proceeding with the video-EEG study, had the subjects been provided advance information regarding the additional monitoring procedures. Subjects were also provided with an opportunity to report their experience or comments as free text. This study was approved by the University of Iowa Institutional Review Board, and all subjects provided written consent.

2.1. Clinical variables

Medical records were reviewed to obtain clinical information. Variables included for analyses were age, gender, body mass index (BMI), duration of video-EEG monitoring, duration of respiratory monitoring, history of obstructive sleep apnea (OSA), prior long-term (≥24 h) inpatient video-EEG monitoring, prior sleep study, the recording of seizures or spells during the video-EEG study, and final diagnosis of epilepsy vs nonepileptic spells.

2.2. Statistics

The SPSS software (IBM Analytics, Somers, NY) was used for statistical analyses. Student's *t*-test (two-tailed) was used to evaluate normally distributed variables, and Mann–Whitney *U* test was used for comparing median differences of non-Gaussian distributed variables, with alpha = 0.05. Chi-square (χ^2) test was used to compare proportions. Spearman's rho correlation coefficient test (two-tailed with alpha = 0.05) was used for univariate analyses to examine the relationship between clinical variables. The Bonferroni correction was used to adjust for multiple comparisons.

3. Results

3.1. Subject characteristics and protocol adherence

Table 1 summarizes the characteristics of the study subjects. One hundred of 140 (71.4%) eligible respondents completed the survey. Of this, 71% (71/100) received a discharge diagnosis of epilepsy while 29% (29/100) were diagnosed with nonepileptic spells. All participants wore EEG and ECG electrodes continuously throughout the study. Nine subjects (9%) did not wear a nasal pressure transducer or oronasal thermistor, one subject (1%) did not wear a respiratory inductance plethysmograph because of recent thoracic surgery, and 6 (6%) subjects did not undergo $tcCO_2$ monitoring because of lack of equipment availability or patient preference.

Thirty-one subjects had previously diagnosed OSA. Four additional subjects were identified by respiratory monitoring as having a high likelihood of OSA and were referred for polysomnography for confirmation and treatment.

No serious adverse events were recorded. One subject developed a local reaction to an ECG electrode.

3.2. Analysis of survey questionnaire

Eighty-eight of 100 (88%) subjects completed all the survey questions while the remainder did not answer one or more questions.

3.2.1. Level of comfort with different monitoring components

Fig. 1 shows levels of comfort as reported by the participants for each component of the monitoring. The percentage of subjects who reported no or mild discomfort for each component was 73.7% for EEG, 84.8% for ECG, 45.5% for nasal airflow, 71.7% for RIP, and 74.7% for $tcCO_2$ monitoring. These rates were not different (p = NS, Table 2) between patients with and without epilepsy. When compared with EEG electrodes, a significantly smaller proportion of subjects reported no or mild discomfort with airflow monitoring (73.7% vs 45.5%, Bonferroni adjusted p = 0.004) while other components were comparable (p = NS). In univariate analyses, level of discomfort with airflow monitoring was independent of age, epilepsy diagnosis, duration of EMU stay, length of respiratory monitoring, gender, BMI, prior video-EEG, and prior sleep study (all with p value greater than the Bonferroni adjusted significance level of 0.00625). Two variables—history of prior video-EEG and duration of EMU stay—were significantly different between patients with or without epilepsy and were therefore selected for further analysis to determine their effect on patients' comfort or satisfaction with the monitoring protocol. These variables showed no significant associations with any outcome (data not shown).

Sixty percent of subjects generally agreed (with variable strength of agreement) that comprehensive monitoring did not interfere with their sleep, and 63% agreed that it did not interfere with daily activity. These rates were not significantly different between subjects with or without epilepsy (data not shown).

3.2.2. Level of satisfaction with the monitoring

Seventy-three percent of the participants reported being moderately to highly satisfied with the comprehensive monitoring protocol. Univariate analyses showed level of satisfaction to be unrelated to diagnosis of epilepsy, age, gender, duration of video-EEG monitoring, duration of respiratory monitoring, BMI, seizures or spells captured during the study, history of prior video-EEG, and history of prior polysomnography (all with p = NS).