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Short communication

Detecting nocturnal convulsions: Efficacy of the MP5 monitor

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ABSTRACT

Although the cause of sudden unexplained death in epilepsy patients (SUDEP) is unknown, evidence implicates respiratory compromise. Most cases occur while the patient is in bed and unsupervised. We investigated the efficacy of the Medpage bed seizure monitor to detect generalized tonic-clonic seizures. Patients with a history of tonic-clonic seizures were enrolled on a video-EEG unit. The MP5 device was placed between the mattress and bed base between midnight and 8:00 a.m. 64 subjects were enrolled (1528 h). Five of eight tonic-clonic seizures were detected. There were 269 false positive alarms (146 h with false positive alarms). The sensitivity and specificity of the alarm were 62.5% and 90.4%, respectively. The negative predictive value of 99.8% illustrates the potential for this device to provide additional security for patients with tonic-clonic seizures, however individual calibration would likely be necessary to improve the positive predictive value of 3.3%, which requires further validation.

1. Introduction

Standardized mortality ratios in patients with epilepsy are 2–3 times higher than the general population. Sudden unexplained death in epilepsy (SUDEP) accounts for the majority of epilepsy-related deaths.[1,2] Although the etiology of SUDEP remains elusive, risk factors include a history of primary or secondary generalized seizures.[1,3–5]

The observation that most unwitnessed SUDEP cases occur while the patient is in bed suggests respiratory compromise during the ictal or post-ictal phase.[6] This is further supported by the observation that supervision appears to protect against SUDEP.

The Medpage bed seizure monitor, model MP5, was designed to detect nocturnal seizures. The device consists of a sensor (internal microphone) enclosed in a plastic casing that is placed between the mattress and box spring. The sensor is tuned to detect tapping noises and bed spring noises. The signals are analyzed for durations, frequency and intensity. The MP5 console can adjust the external microphone sensitivity, bed sensor sensitivity and motion detection delay settings. The sensor system can be adjusted for sensitivity to movement to calibrate for mattress thickness and the weight of the patient. The delay to motion detection can also be adjusted to increase delay and allow for brief periods of movement associated with frequent turning in bed. The range of delay is from 3 to 20 s. The monitor alarms following a detection above the set thresholds to alert family members to the presence of a seizure, allowing them to render any aid necessary in the ictal or post-ictal settings. We investigated the sensitivity and specificity of the device.

2. Methods

Subjects were recruited on the inpatient video electroencephalography (VEEG) unit. Subjects, ages 13–65 years, were admitted for presurgical evaluation, medication adjustments or characterization of seizures. Only subjects with primary or secondarily generalized seizures were enrolled. Following informed consent, the MP5 device was placed between the mattress and bed base. Subjects were monitored between the hours of 00:00 (midnight) and 08:00 by the nursing staff.

A total of six MP5 devices were utilized in this study. The monitoring console was placed at the bedside. The sensitivity and detection delay are controlled via two separate dials without graduation markings. Sensitivity was set at 33% below the maximum setting and the detection delay was set approximately 5% below the maximum. These standard settings were marked on all machines and were utilized for all patients. The external microphone sensor was disabled for this study. The wireless alarm receiver was placed at the nurses' station next to the patient's video monitor. The nursing staff would simultaneously monitor the patient's VEEG and MP5 alarms. If the MP5 alarm activated, the staff would record the time and the activity noted on the video EEG monitor onto the MP5 data sheet. All alarm periods were reviewed by an epileptologist for evidence of a seizure on the VEEG. VEEG

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was reviewed the following morning by the clinical team of epileptologists to identify all seizures that occurred overnight.

For data analysis, all monitoring periods were broken down into the total number of hours monitored and categorized as either true positive (a seizure occurred and was detected), true negative (no seizures detected and none occurred), false positive (a seizure was detected but none occurred) and false negative (a seizure occurred and no detection was reported).

3. Results

Data recorded from the MP5 monitors was compared to the data recorded from video EEG monitoring. A total of 64 patients were enrolled in the study; one patient was withdrawn from study because monitoring revealed that the patient did not have epilepsy, four were withdrawn because of crosstalk between simultaneously utilized monitors and eight were withdrawn because of technical issues.

There were 1528 total hours of monitoring. The monitoring results for each patient are shown in Table 1. A total of eight seizures with tonic-clonic activity were captured, of which five were positively detected. There were a total of 269 false positive alarms, often occurring in clusters resulting in a total of 146 h of monitoring with at least one false positive alarm. The calculated sensitivity and specificity of the alarm was 62.5% and 90.4%, respectively. The positive predictive value was found to be 3.3% and the negative predictive value was 99.8%.

Table 1
Individual patient monitoring results

Patient number	Total hours monitored	Total hours with one or more false alarms	Total hours with no alarms, no seizures	GTCs detected	GTCS undetected
1	0	0	0	0	0
2	0	0	0	0	0
3	0	0	0	0	0
4	0	0	0	0	0
5	40	6	34	0	0
6	48	1	47	0	0
7	32	13	19	0	0
8	0	0	0	0	0
9	56	15	41	0	0
10	24	0	24	0	0
11	16	0	16	0	0
12	0	0	0	0	0
13	32	1	31	0	0
14	40	5	35	0	0
15	0	0	0	0	0
16	0	0	0	0	0
17	8	0	8	0	0
18	16	6	10	0	0
19	32	2	30	0	0
20	0	0	0	0	0
21	24	4	18	2	0
22	40	4	35	1	0
23	40	12	28	0	0
24	0	0	0	0	0
25	0	0	0	0	0
26	24	8	16	0	0
27	0	0	0	0	0
28	16	0	16	0	0
29	40	5	35	0	0
30	32	1	31	0	0
31	40	0	40	0	0
32	8	0	8	0	0
33	0	0	0	0	0
34	24	1	23	0	0
35	0	0	0	0	0
36	8	0	8	0	0
37	8	0	8	0	0
38	48	5	43	0	0
39	14	3	11	0	0
40	8	2	6	0	0
41	13	0	13	0	0
42	56	1	55	0	0
43	46	2	44	0	0
44	46	6	40	0	0
45	32	1	31	0	0
46	80	0	80	0	0
47	40	1	39	0	0
48	32	0	32	0	0
49	36	3	33	0	0
50	32	4	27	0	1
51	32	0	32	0	0
52	56	2	54	0	0
53	24	0	24	0	0
54	8	0	8	0	0
55	48	3	45	0	0

Table 1 (*Continued*)

Patient number	Total hours monitored	Total hours with one or more false alarms	Total hours with no alarms, no seizures	GTCs detected	GTCS undetected
56	32	2	29	1	0
57	24	4	20	0	0
58	32	3	28	0	1
59	48	9	39	0	0
60	8	0	8	0	0
61	8	1	7	0	0
62	24	3	19	1	1
63	29	1	28	0	0
64	24	6	18	0	0
Total	1528	146	1374	5	3

For each patient, the total number of hours monitored with the MP5 device is shown. The number of seizures (detected or undetected) is shown. The number of hours in which at least one false positive detection was reported as well as the number of hours with no detections are shown. The totals for all categories are shown, from which the sensitivity, specificity, positive predictive value and negative predictive value are calculated.

4. Discussion

Although this study demonstrates an overall strong negative predictive value, there are limitations to this study within the inpatient setting. For maximal sensitivity and specificity, calibration of the sensors would be necessary; in this study standardized settings were utilized for all subjects. In each individual subject, depending on the person's height and weight, this could lead to either increased false positive or false negative results. Ideally, this calibration could be done over the course of a couple nights to optimize the settings for an individual.

A second consideration in the high negative predictive value is the statistical analysis based upon each monitoring hour. This was chosen as it reflects a practical metric for both safety (detections) and quality of life (disruptions throughout the night). The disadvantage is that it leads to a very high number of true negatives, which would be dramatically reduced if, for instance, detections per night were utilized.

Although methods of early seizure detection for purposes of treatment or prevention of seizures remain active areas of investigation, these systems typically focus on scalp or intracranial EEG, limiting their applicability to the general population with seizures who may be at risk of injury or SUDEP. Several investigators have reported utilizing a combination of electrocardiographic (EKG) changes to identify seizures in adults[7–9] and neonates.[10–13] For neonates, Greene et al. noted that, for some patients, an increase in heart rate may be the only clinical manifestation of neonatal seizures.[11] Given the differences in both clinical and electrographic presentation of neonatal seizures, these findings may not be generalizable to an older pediatric or adult population. Ho and colleagues studied the use of implantable loop recorders to detect generalized tonic-clonic seizures.[9] Although typically utilized to detect cardiac dysrhythmias, the authors here analyzed recordings specifically to detect generalized tonic-clonic seizures (GTCs). Twelve GTCs were detected in six out of 14 patients. The researchers suggest using this detection device as a diagnostic tool, rather than as a preventative measure. Zijlmans et al. identified an increase of at least 10 beats/min in heart rate in 73% of seizures.[7] Although these studies demonstrate promise for seizure detection with EKG monitoring, to our knowledge, no external, non-invasive detection device has been employed for use in epilepsy treatment.

The MP5 device tested here focuses on detecting sounds caused by bed movement due to tonic-clonic seizures, as opposed to EEG or EKG methods of seizure detection. Motion or fall detection systems have begun to be tested for medical purposes and show initial promise. Wu and Xue designed a portable pre-impact fall detector with inertial sensors to detect falls prior to impact with the ground.[14] They developed an algorithm that was able to detect all falls at least 70 ms before impact. All falls in 24 subjects were detected with no false alarms after the sensor threshold was adapted to each individual subject. Because of the fall risk associated with certain seizure types, this technology may be of specific benefit in prevent injuries associated with seizures. Similarly, accelerometry was evaluated for detection of nocturnal events in seven patients with seizures.[15] They were able to achieve a sensitivity of 100% of motor activity identified by experts with a positive predictive value of 43–89%.

Despite the limitations of studying patients in a standardized, inpatient setting, we believe this study suggests a role for the MP5 device in patients with a history of tonic-clonic seizures. Further study utilizing individually calibrated devices, ideally in a home setting with continuous monitoring for seizures, would better characterize the ''real world'' efficacy of the MP5 monitor.

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