EPILEPSY CURRENTS

Current Literature

In Clinical Science

Real-Time Non-EEG Convulsive Seizure Detection Devices: They Work; Now What?

Automated Real-Time Detection Of Tonic–Clonic Seizures Using a Wearable EMG Device.

Beniczky S, Conradsen I, Henning O, Fabricius M, Wolf P. *Neurology* 2018;90:e428–e434.

OBJECTIVE: To determine the accuracy of automated detection of generalized tonic-clonic seizures (GTCS) using a wearable surface EMG device. METHODS: We prospectively tested the technical performance and diagnostic accuracy of real-time seizure detection using a wearable surface EMG device. The seizure detection algorithm and the cutoff values were prespecified. A total of 71 patients, referred to long-term video-EEG monitoring, on suspicion of GTCS, were recruited in 3 centers. Seizure detection was real-time and fully automated. The reference standard was the evaluation of video-EEG recordings by trained experts, who were blinded to data from the device. Reading the seizure logs from the device was done blinded to all other data. RESULTS: The mean recording time per patient was 53.18 hours. Total recording time was 3735.5 hours, and device deficiency time was 193 hours (4.9% of the total time the device was turned on). No adverse events occurred. The sensitivity of the wearable device was 93.8% (30 out of 32 GTCS were detected). Median seizure detection latency was 9 seconds (range −4 to 48 seconds). False alarm rate was 0.67/d. CONCLUSIONS: The performance of the wearable EMG device fulfilled the requirements of patients: it detected GTCS with a sensitivity exceeding 90% and detection latency within 30 seconds. CLASSIFICATION OF EVIDENCE: This study provides Class II evidence that for people with a history of GTCS, a wearable EMG device.

Commentary

However devastating sudden unexpected death in epilepsy (SUDEP), there are alluring factors that suggest that prevention is only just out of reach. Despite the frequency of generalized tonic–clonic (GTC) seizures that are provoked, SUDEP is rare in the epilepsy monitoring unit (1). It is believed that quick intervention from nurses in reviving and repositioning is critical. In fact, mere supervision at night was significantly associated with a decreased risk of SUDEP (2, 3). Perhaps even the most rudimentary home intervention is sufficient, if only GTC seizures can be detected quickly.

In the current paper, Beniczky et al. present a study using an arm-worn EMG device to detect GTC seizures. In a study of relatively moderate size consisting of 32 GTC seizures in 20 patients, they reported a detection sensitivity of 93.8% (30 of 32 seizures) with low latency (median 9 sec, max 48 sec), and a false alarm rate (FAR) of 0.67/day. Most significantly, they reported no adverse events at all. The study has several strengths. The study design was prospective, an important step in validating the previous retrospective work with EMG-based devices (4); seizure detection algorithms typically tend to do better on retrospective data where overfitting can become problematic. The algorithm was simple and straightforward, the importance of which is demonstrated in the fact that 1) it allowed implementation of a "generic" version for all patients without requiring individual tuning; 2) the device is capable of real-time analysis and, though turned off for this study, generating real-time alarms.

There is a comparable prospective American trial by Halford et al. (5) with similar patient characteristics, population size, and recording device. They reported substantial variability in detection sensitivity based on placement of the recording device. Once ideally placed, they detected 29 of 29 GTCs with a latency of 7.7 sec, and false alarm rate of 1.44/day. More significantly, they reported adverse events in 28%, leading to withdrawal in 9% of patients, mostly due to skin irritation from the electrode patch. It is not clear why there was such a marked discrepancy, but may in part be explained by the type of adhesive utilized.

A second method based on electrodermal activity and accelerometer deserves mention (6). The major advantage of this device as compared to EMG-based ones is that it is much more practically wrist-worn. Although prospective studies have not yet been published, it appears to have similar sensitivity with potentially somewhat lower false alarm rates (7). More significantly, it gained FDA approval as a medical device in the United States earlier this year.

Some differences aside, we now have a reasonable estimate regarding the performance of these devices, raising several questions that need to be addressed:

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Will These Seizure Detection Devices Function Well in Real-Life Outpatient Settings?

The device is tested in a highly controlled inpatient setting. It is applied by the investigators, not the patient or family, ensuring optimal contact and positioning. Halford's study had demonstrated how potentially sensitive the device may be to positioning errors. The battery is changed three times a day, something that is hardly realistic in a real-world setting. The device was on the patient, on average, for only 50 hours. In the provided photographs, the device is quite sizable, and it seems hardly likely that the device could be used on a consistent basis, even if used only at nighttime. Surely, further miniaturization will improve this issue. From an ergonomics perspective, a wrist-worn device would be far more palatable for uninterrupted long-term use.

The problem of FAR perhaps presents the most vexing challenge to these class of devices, both in terms of true alarm to false alarm ratios, as well as the absolute number of false alarms. Frequent uncontrolled GTCs comprise a small number of the most severely ill patients. In most patients, GTC seizures are rather rare events. As such, the higher the mass adoption rate, the less frequent the opportunity to deliver true positive signals. The FAR, of course, will not diminish; thus, the population signal-to-noise ratio will decline as these alarm devices are adopted more widely, likely leading to alarm fatigue. In terms of absolute numbers of false alarms, even in a device with excellent performance characteristics such as this one, patients and their caretakers will be forced to deal with several false alarms every week. This may be tolerable over the long term to the most dedicated patients and caregivers but will likely be unacceptable to most, particularly if immediate action in response to an alarm is required. Perhaps improved algorithm design and intelligent computing will decrease the FAR, further ameliorated if these devices are used only at night when the FAR is low. Although the risk of SUDEP is highest during the night, it is not exclusively a nocturnal phenomenon.

Usage of these devices will likely also incur significant cost beyond just the acquisition of the device. Given the inevitable FAR, successful use and monitoring likely will require some type of external monitoring service, incurring ongoing fees. One may also be concerned with the other implication of these devices. Would failure to offer or inform of these devices constitute negligence on the physician's part, especially when the regular discussion of SUDEP has only relatively recently been advocated? Can such devices be introduced without promoting a brand? Moreover, there will likely be a large amount of guilt on the part of the family who chooses not to utilize a device, especially if a loved one succumbs to SUDEP.

Although the current alarming devices are designed to alert family members, the generated data will almost certainly filter over to the treating physician. The generated data would be of substantial value if habitual, disabling seizures were quantified, but data with clinically easily recognized convulsions, intermixed with reams of alarms that (more often than not) are false, may not be particularly useful and just cause information burden. None of the current devices has any utility in detecting focal seizures, the most common disabling seizures in patients with epilepsy.

Will These Devices Prevent SUDEP?

All of the previous concerns would be tolerable if these devices actually lowered the risk of SUDEP. The rate of SUDEP is low, so it is unlikely that any kind of controlled trial is feasible. Answers will have to be derived from long-term follow-up epidemiological studies.

Assuming the existence of an ideal device, always functioning without failure, sufficiently tolerable for the patient to wear it continuously, and producing no false alarms, we will likely find that GTC seizure rates are underestimated by a certain number of patients and families. Widespread adoption of these devices may result in more intense treatment of seizures, with greater willingness on the part of the neurologist to try another anti epileptic drug (AED). This in itself may potentially decrease the rate of SUDEP. Analysis of randomized placebo-controlled adjunctive AED trials have demonstrated that additional drug trials, at least in the short term, may decrease the risk of SUDEP (8). More importantly, demonstrating an accurate high GTC seizure frequency may motivate a patient to be more compliant with the medication regimen—though this is hardly the main reason for noncompliance for many patients. The undesired consequence may also be overtreatment of seizures, resulting in more side effects and lower quality of life, using adjunctive medications that, in the long run, may not confer any long-term benefits toward seizure freedom.

In the patient whose GTC seizures remain uncontrolled, it is unclear whether even an ideal device would be able to prevent SUDEP; certainly, it would likely be far less useful in adults than children. Epilepsy patients, once they leave their parents, are less likely to be married and more likely to live alone (9). Although it is not known what the critical window for resuscitation is, it is uncertain that anyone not living with the patient would reach the patient within that time period. There is already one reported SUDEP in a patient wearing a wrist-worn seizure detection device that appeared to function as designed. Despite an attendant reaching the patient within 15 minutes of notification, he was found prone and pulseless. Respiratory cessation appeared to occur in less than 5 minutes after seizure cessation (10). Will there even be enough time for a parent to wake up and run to a convulsing child's room?

Nonetheless, it is critical to continue to promote technological innovation and device development in this field. Our smartphones and wrist- worn devices track and monitor us with accuracy that would have been unimaginable even a generation ago. The arrival of these detection devices, like all technological advances, will feel premature and its adoption chaotic, for good reason. Nonetheless, for epileptologists who treat patients with medically uncontrolled seizures and for families who may lose loved ones to SUDEP, no potential option can come soon enough.

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