Are Seizure Detection Devices Ready for Prime Time?

Standards for testing and clinical validation of seizure detection
Beniczky S, Ryvlin P. Epilepsia. 2018;59(S1):9-13. doi:10.1111/epi.14049

To increase the quality of studies on seizure detection devices, we propose standards for testing and clinical validation of such devices. We identified 4 key features that are important for studies on seizure detection devices: subjects, recordings, data analysis and alarms, and reference standard. For each of these features, we list the specific aspects that need to be addressed in the studies, and depending on these, studies are classified into 5 phases (0-4). We propose a set of outcome measures that need to be reported, and we propose standards for reporting the results. These standards will help in designing and reporting studies on seizure detection devices, they will give readers clear information on the level of evidence provided by the studies, and they will help regulatory bodies in assessing the quality of the validation studies. These standards are flexible, allowing classification of the studies into one of the 5 phases. We propose actions that can facilitate development of novel methods and devices.

User-based evaluation of applicability and usability of a wearable accelerometer device for detecting bilateral tonic-clonic seizures: a field study
Meritam P, Ryvlin P, Beniczky S. Epilepsia. 2018;59(S1):48-52. doi:10.1111/epi.14051

Clinical validation studies of seizure detection devices conducted in epilepsy monitoring units (EMUs) can be biased by the artificial environment. We report a field (phase 4) study of a wearable accelerometer device (Epi-Care) that has previously been validated in EMUs for detecting bilateral tonic–clonic seizures (BTCS). Seventy-one patients using the device (or their caregivers) completed the modified Post-Study System Usability Questionnaire. Median time patients had been using the device was 15 months (range = 24 days to 6 years). In 10% of cases, patients stopped using the device due to reasons related to the device. The median sensitivity (90%) and false alarm rate (0.1/day) were similar to what had been determined in EMUs. Patients and caregivers were overall satisfied with the device (median = 5.5 on the 7-point Likert scale), considered the technical aspects satisfactory, and considered the device comfortable and efficient. Adverse effects occurred in 11% but were only mild: skin irritation at the wrist and interference with home electronic appliances. In 55%, the device influenced the number of seizures logged into the seizure diary, and in 40%, it contributed to fewer seizure-related injuries. This field study demonstrates the applicability and usability of the wearable accelerometer device for detecting BTCS.

Wearable devices for sudden unexpected death in epilepsy prevention
Ryvlin P, Ciumas C, Wisniewski I, Beniczky S. Epilepsia. 2018;59(S1):61-66. doi:10.1111/epi.14054

Sudden unexpected death in epilepsy (SUDEP) is most often associated with the occurrence of generalized tonic–clonic seizures (GTCS), a seizure type that can now be detected with high sensitivity and specificity by wearable or bed devices. The recent development in such devices and their performance offer multiple opportunities to tackle SUDEP and its prevention. Reliable GTCS detection might help physicians optimize antiepileptic treatment, which could in turn reduce the risk of SUDEP. Generalized tonic–clonic seizures–triggered alarms can lead to immediate intervention by caregivers that are also likely to decrease the odd of SUDEP. The biosignals used to detect GTCS might provide novel SUDEP biomarkers, in particular, by informing on several important characteristics of the ictal and postictal periods (type of GTCS, duration of tonic phase, rotation in the prone position, presence and duration of postictal immobility and bradycardia, rise in electrodermal activity). Other biosensors not yet used for detecting GTCS might provide complementary information, such as the presence and intensity of ictal/postictal hypoxemia. The above biomarkers, if strongly predictive, could help identify patients at very high risk of SUDEP, enabling better assessment of individual risk, as well as selection of appropriate patients for clinical studies aiming at preventing SUDEP. The same biosignals could also be used as ancillary biomarkers to test the impact of various interventions before moving to highly challenging randomized controlled trials with SUDEP as a primary outcome.
Achieving the goal of accurate seizure quantification at each clinic visit has long been problematic. Patients and families may fail to keep a seizure calendar or forget to bring it to clinic. They may not recognize seizures when the patient is alone and has no recalled aura or reliable postictal symptoms or signs. Optimal management of epilepsy therapy depends on accuracy of seizure counts, and any tools that can lead to quick first aid for seizures may reduce morbidity and mortality, at least theoretically. Effective devices may give peace of mind to caregivers so they can give the patient and caregivers time alone when needed for their quality of life and independence.

The following papers in a June 2018 Epilepsia supplement address the testing and potential value of wearable seizure detection devices for convulsive seizures.

Beniczky and Ryvlin discuss quality issues for validation of seizure detection devices. They discuss creation of standards for regulatory bodies since there are now several approaches to device development. A 5-phase process is proposed, similar to clinical drug trials, with initial studies to develop a seizure detection method, studies for proof of principle using real seizure data in 1 to 10 cases, studies in a larger number of cases and seizures after the evaluators are trained to identify events, a larger confirmation study with testable outcome measures done prospectively, and finally field studies to get more cases and longer observation times.

The authors point out that most studies with wearable devices to detect seizures were tested in an epilepsy monitoring unit setting but refer to one home study addressed below. Outcome measures to evaluate should include device recording/not recording times, safety, sensitivity, false alarms, latency to detect events, adherence, and quality of life. Clearly, a comparison with a patient- or family-generated seizure calendar is needed in this assessment.

Though not mentioned, any device that shows the time of day for events and event duration would be helpful, but the authors do point out that some nonmotor seizure types may not be detected. It seems likely that convulsive seizures would be detected with electromyography detection.

In the second paper, Meritam, Ryvlin, and Beniczky discuss practical applications for a wrist-worn accelerometer for detection of BTCS in 71 outpatients or institutionalized patients using the device from 24 days to 6 years. The device sends an alarm to a mobile phone or portable control unit so caregivers are alerted. Questionnaires for the patient or caregivers were used to assess usability, actual time used, user satisfaction, information quality, and reasons for halting use of the device.

Six patients discontinued participation in the study because of inability to follow-up and 7 discontinued for device reasons: 4 due to excessive false alarms, 2 with inability to use the device, and 1 with a broken device. Most patients and caregivers rated the device highly for satisfaction, effectiveness, clear alarms, error messages, and relative lack of side effects. Also noted were improvements in seizure calendar documentation because of recognition of previously undetected seizures. Some patients reported fewer seizure-related injuries, though establishing safety benefits probably requires longer term observations and a control group. False alarms could be related to other physical activities involving vigorous wrist movements such as brushing the teeth. Mild adverse events such as skin irritation and interference with electronic appliances occurred in 11%. Clearly, the wrist-worn accelerometer device is useful for the majority of patients with BTCS once the patient and caregiver learn to use it.

The last of the papers from Ryvlin et al suggests that seizure detection devices could reduce the probability of SUDEP. As the ultimate severe complication of a seizure, impending SUDEP requires a rapid response from caregivers if there is hope of intervening to prevent SUDEP. Still, not all cases of SUDEP may be preventable, as SUDEP may occur even in the setting of rapid basic cardiac life support. Additionally, some cases of SUDEP may occur following a nonconvulsive focal seizure that may go undetected by motion detecting devices. However, when suffocation or asphyxia is going to result in SUDEP, quick first aid would very likely save a life since an impaired airway is usually easy to correct. Seizure-related accidents, such as falls, burns, or other injury, could be recognized and treated sooner, potentially leading to a better outcome. Connecting oximetry and heart rate detectors to a seizure detection device as more sophisticated detectors are developed could add more value in identifying patients with prolonged postictal states likely to be associated with of postictal generalized electroencephalogram suppression that is a SUDEP risk factor.

Validation that seizure detection devices can reduce the risk of SUDEP could take many patient-years of observation, even when using historical controls. Another method of validation could involve comparing SUDEP rates when patients are wearing or not wearing the device. Currently, these ideas are speculative but common sense suggests that it will work. It will be important that noninvasive seizure detection devices are affordable, easy to use, informative, and reliable.

So, are seizure detection devices ready for prime time? Yes and no. Some patients and families may find value with today’s devices, whether validated or not by the Food and Drug Administration. Anything that assists patients and families to have accurate seizure counts will be a benefit to a physician at the office visit. It is likely that seizure detectors will improve over time with additional functions to monitor the health of patients. Inclusion of video in areas of the home might be feasible if the detached components can be linked to improve interpretation of the data. Review of data generated would need to be very simple and quick. Time spent would probably lead to appropriate billing codes and reimbursement so that physicians would have incentives to review data. To say that seizure detection devices reduce SUDEP will require long-term studies in large numbers of patients. If these devices lead to more effective treatment to control seizures, a drop in the SUDEP rate would be likely.

By Paul C. Van Ness