



Case Report

Long-term accelerometry-triggered video monitoring and detection of tonic–clonic and clonic seizures in a home environment: Pilot study



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ABSTRACT

Purpose: The aim of our study was to test the efficacy of the VARIA system (video, accelerometry, and radar-induced activity recording) and validation of accelerometry-based detection algorithms for nocturnal tonic–clonic and clonic seizures developed by our team.

Methods: We present the results of two patients with tonic–clonic and clonic seizures, measured for about one month in a home environment with four wireless accelerometers (ACM) attached to wrists and ankles. The algorithms were developed using wired ACM data synchronized with the gold standard video-/electroencephalography (EEG) and then run offline on the wireless ACM signals. Detection of seizures was compared with semicontinuous monitoring by professional caregivers (keeping an eye on multiple patients).

Results: The best result for the two patients was obtained with the semipatient-specific algorithm which was developed using all patients with tonic–clonic and clonic seizures in our database with wired ACM. It gave a mean sensitivity of 66.87% and false detection rate of 1.16 per night. This included 13 extra seizures detected (31%) compared with professional caregivers' observations.

Conclusion: While the algorithms were previously validated in a controlled video/EEG monitoring unit with wired sensors, we now show the first results of long-term, wireless testing in a home environment.

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1. Introduction

Epilepsy is a condition in which seizures often occur unprovoked and without warning. Mainly for safety reasons, many patients and their families are looking for a seizure detection system that is efficient, comfortable, and easy to use. This implies that such a system should have a high detection sensitivity (detect as many seizures as possible) and low false alarm rate; it should be unobtrusive, wireless, and in case of daytime use practically unnoticeable; and it should allow long-term use in a home situation without the presence of professionals.

Alarming for safety reasons or reassurance is already used in fall detectors for the elderly, babyphones (reacting to sound or movement), and glucose monitors for persons with diabetes [1,2]. In addition to being used for alarming, a detection system could allow offline storage or online streaming of selected data, allowing follow-up on treatment efficacy or summoning emergency support, respectively.

Our team is interested in the long-term observation of patients with epilepsy and detection of their seizures [3,4]. The focus lies on those convulsive seizures that can be dangerous because of their intensity (possible injuries), duration, or serious consequences such as brain damage, autonomic dysregulation, or suffocation. More specifically, we currently aim at the detection of nocturnal tonic–clonic and clonic seizures with patients remaining in one place, their bed, mainly because of the need for supervision at night and because seizures often occur during sleep.

As sensors need to be as unobtrusive as possible but still effective, small wireless accelerometers (measuring the acceleration of movement) are used and attached to the wrists and ankles of the patient.

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The goal of this study was to test the efficacy of the VARIA (video, accelerometry, and radar-induced activity recording) system and algorithms for tonic–clonic and clonic seizures compared with that of semicontinuous monitoring by professional caregivers (keeping an eye on multiple patients), as well as the independence, robustness, comfort, and user-friendliness of the system. We therefore measure long term in a home environment without uncomfortable and stigmatizing electroencephalography (EEG) electrodes rather than in a video/EEG monitoring unit, and the system therefore needs to be able to store the data and to allow visual verification of detected events. This is why a camera is added to the accelerometer system.

2. Methods

2.1. Patients

Two patients were measured for one month in their rooms in an epilepsy center in Flanders, Belgium. As they returned home for the weekends and as the caregivers needed to get acquainted with the recording system, they were measured for a mean of 12 nights per patient.

Patient 1 is an 8-year-old girl with epilepsy *e.c.i.* and different types of seizures that typically last no more than 3 min: tonic–clonic seizures with or without faltering respiration, tonic seizures, and clonic seizures. All three occur symmetrically as well as asymmetrically. She also exhibits myoclonic jerks manifesting as (head) nods or facial contractions with eye deviation. Seizures are noticed based on semicontinuous video monitoring and when a scream or breathing problem is heard.

Patient 2 is a 9-year-old boy with lesional epilepsy due to herpes encephalitis, who is kept in bed with a restraining belt around the waist. He suffers from tonic–clonic seizures of various duration, tonic, clonic, and myoclonic seizures and (series of) spasms. The caregivers use a babyphone and semicontinuous video monitoring to keep an eye on him.

Approval by the Medical Ethical Commission of the Antwerp University Hospital, Belgium and signed informed consent forms from all parents were obtained prior to inclusion in the study, which was performed in accordance with the 1964 Declaration of Helsinki.

2.2. Measurement

The system uses video, accelerometry (ACM), and radar-induced activity recording and is therefore named VARIA. It consists of an AXIS M1011 camera (Axis Communications AB, Sweden) and a Hygrosens RAD-MOD motion sensor based on the radar principle (B + B Thermo-Technik GmbH, Germany). The camera and radar are attached to a tripod that is placed close to the patient's bed. The radar is added for detection of movements in the direction of the sensor and for measurement through sheets. Radar technology is also used for detection of falling, wandering, sitting, or getting up [5], so we expect it to detect large and slow epileptic and nonepileptic movements, also those caused by other persons in the room. Four Shimmer sensors with integrated three-axis ACM (Shimmer, Ireland), streaming wireless (Bluetooth) communication standards, are adjusted to allow recording of more than 10 h before batteries need recharging and are put in elastic bracelets worn around wrists and ankles. A laptop with a software application developed in LabVIEW (National Instruments Corporation, US) stores all movement data recorded by either camera, radar, or ACM (Fig. 1).

The technical aspects of the recording system will be published in more detail by Bonroy et al. and are briefly described in the Supplementary material.

2.3. Analysis

The algorithms developed by Milosevic et al. [6] for tonic–clonic and clonic seizures based on a large database of video/electroencephalography (EEG) data were used. Results of a patient-specific (algorithm trained

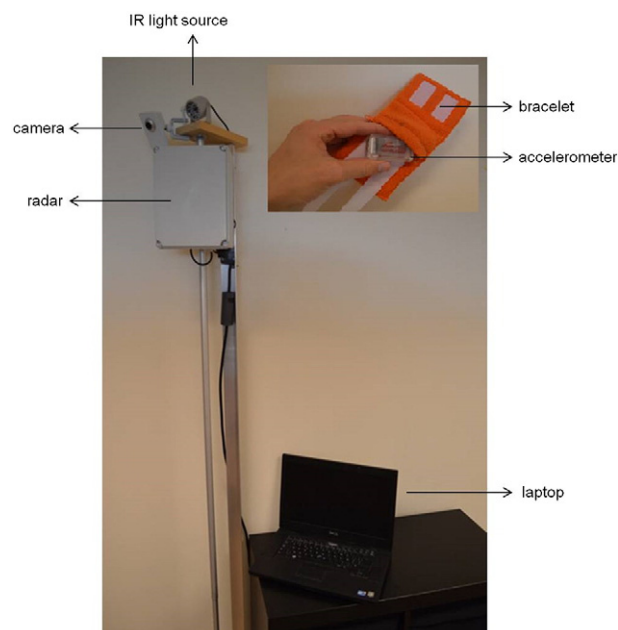


Fig. 1. Setup of VARIA system: video, accelerometry, and radar-induced activity recording. Camera and radar are attached to the tripod, accelerometers are worn in elastic bracelets around wrists and ankles, and a laptop receives and stores all movement data recorded by any of the three modalities.

only on data of the patient itself), a nonpatient-specific (algorithm trained on data not including those of the patient itself), and a semipatient-specific (algorithm trained on data also including those of the patient itself) approach were compared with the notes of professional caregivers. For a full description on how to implement these methodologies in practice, please see the Supplementary material.

Professional caregivers were asked to write down all seizures the patients had, with time and description in a form of a clinical report. They recognize epileptic seizures (one month training and yearly tuition), are awake during the whole night, know the patients, and are semicontinuously watching on average four patients with active epilepsy in front of a video screen, only leaving if one of them or one of the other (maximum) twelve patients need care.

The events detected with the algorithms were visually inspected by a pediatric video/EEG specialist and a pediatric neurologist using the screening tool which is a graphical user interface developed in MATLAB® (Mathworks Inc., US) (Fig. 2). The screening tool displays information on the number of movement events and on their duration. The ACM signals, a distribution graph, and the video images are depicted for each event. Also, radar and video signals are shown, as well as the fraction (percentage) of movement within the event. The graph at the lower left corner sets out amplitude of all events based on ACM signals and length of all events based on the three detection modalities. In other words, it shows the intensity and duration of the movement.

After the application of each of the three developed seizure detection algorithms and during postprocessing, the following logical reasoning was used:

- Rule 1: A margin of error of 5 min has been taken into account for the seizure reporting. As the caregiver might write down the seizure after having attended to the patient, we assume the seizure may have been noticed 5 min before or after the actual time in the notes.
- Rule 2: Only seizures longer than 10 s are considered as possibly dangerous and therefore candidates for the alarm system, hence shorter seizures are not counted when calculating detection performance.

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