Radiofrequency-based Wireless and Contactless Sensors for Detection of Seizures and Risk Factors of SUDEP

Hernan Nicolas Lemus MD[1], Hao He, PhD[2], Yuan Yuan, PhD[2], Steven Tobochnik MD[1], Emily Lapinskas[1], Dina Katabi PhD[2], Jong Woo Lee MD, PhD[1]

[1]Brigham and Women's Hospital, Epilepsy Division, Department of Neurology

[2]Department of Electrical Engineering and Computer Science, Massachusetts Institute of Technology

Introduction

There is a need for devices that accurately detect seizures and monitor respiratory patterns, particularly to identify peri-ictal apnea during convulsions. Rapid detection of bilateral tonic-clonic seizures (BTCS) and peri-ictal respiratory dysfunction may allow for intervention to prevent SUDEP.

Aim

A wireless motion-detection device developed at the Massachusetts Institute of Technology utilizes a novel low radiofrequency (RF) emission/sensing to isolate a patient's movement with unprecedented sensitivity and spatial resolution. We sought to determine if this wireless motion detection may detect convulsive seizures and peri-ictal apnea, two major risk factors of sudden unexpected death in epilepsy (SUDEP).

Methods

- Subjects: Adults ≥18 years admitted to the epilepsy monitoring unit (EMU) for medically refractory epilepsy or for spell characterization.
- Wireless motion-detection device: RF-based devices have been installed in each EMU room and appropriately calibrated. Representative motion heat map diagram, displaying time (X-axis), distance from device (Y-axis), and movement (color coded) are shown in Figure 1.
- Respiratory data: Respiratory inductive plethysmography (RIP) belts were used to assess the respiration changes such as apnea and tachypnea during and after the convulsion.
- EEG analysis: Seizures were classified according to the latest International League Against Epilepsy criteria from video-EEGs. Only BTCS were included.

Results

- A total of 78 patients underwent simultaneous video-EEG and RF recording, and 9 patients were connected to RIP belts. A total of ten convulsions were captured on video-EEG.
- The device revealed RF signal changes in 10/11 (91%) convulsions from 8 patients and identified the onset of the motor activity with a specific unique RF pattern (figure 1).
- Interictal respiratory patterns from the RF-device correlated accurately to the RIP-based patterns (figure 2).

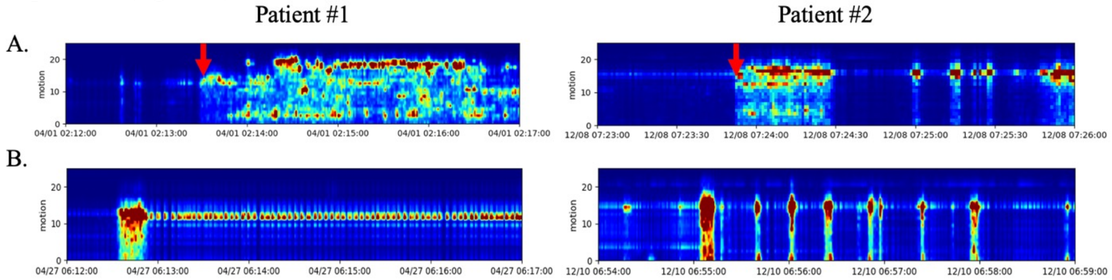

Figure 1. Representative RF patterns identified by the RF-device in patients admitted to the EMU.
A. Ictal RF patterns: Heat map representing a three to five-minute window for each patient and the movement-based RF signals during a convulsive seizure; red arrowheads represent the onset of the motor activity. X-axis represent the time in minutes and Y-axis represent the distance from the device in meters.
B. Interictal RF patterns: Heat map representing a five-minute window for the patients shown in A and the movement-based RF signals when the patient is lying in bed. X-axis represent the time in minutes and Y-axis represent the distance from the device in meters.

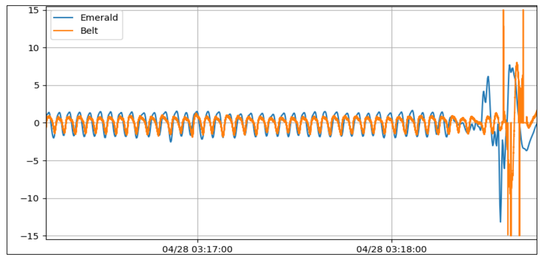

Figure 2. Specific respiration RF patterns identified by the RIP and wireless motion in a single patient admitted to the EMU. Respiratory pattern during a convulsion as seen by RF device (blue) and RIP belt (orange).

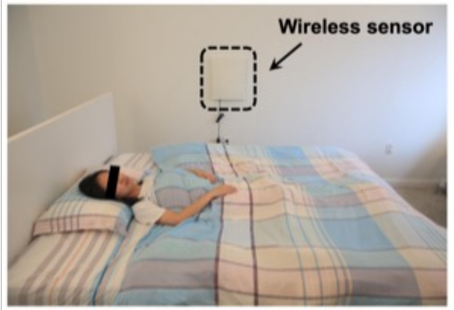

Figure 3. Wireless motion detection device installed in a patient's room. Black square represents the location of the device.

Discussion

- Current wearable technologies developed to detect seizures have limitations such as the presence of wires, bulky size, discomfort, and need for support, which may prevent their proper use.
- The RF-device (figure 3) was able to accurately identify convulsions with unique RF heat map signatures that discriminate from non-specific motor activity.
- The RF-device was able to detect respiratory effort interictally, though movement artifacts prevented the isolation of ictal respiratory patterns.
- There is a need for wireless devices that allow continuous monitoring of convulsive seizures in any location, particularly at the patient's residence.
- This project will form the basis for the development of a fully automated machine learning algorithm for the detection of BTCS.

Acknowledgments

The authors thank The Endowed A.J. Trustey Epilepsy Research Fund.