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A Home-based Epileptic Seizure Detection System Using Wearable and Non-contact Sensors

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***Abstract*— To address the issue of daily monitoring epileptics, we designed this multi-sensor seizure detection system, which contains a bracelet and a non-contact night monitor. The bracelet has an electromyography (EMG) sensor, a 3-dimensional accelerometer (ACM), and a 3-dimensional gyroscope. The non-contact night monitor contains a Doppler radar sensor. This designed approach proved a sensitive and convenient monitoring method for epileptics with convulsive seizures, especially those who had more seizures at night while releasing their caregivers from accompanying the patients all day long. Moreover, this study also provided a new recording method for medical clinical diagnosis.**

***Clinical relevance* — This proposed system could accurately estimate respiration, heartbeat rate, heart rate variability (HRV), and movement information to detect and alarm seizures.**

I. INTRODUCTION

There are more than nine million epileptics in China, and this number is growing at a rate of 0.4 million per year. The sudden death rate of patients with epilepsy is 2-4 times that of normal people, which is also known as sudden unexpected death in epilepsy (SUDEP). There are mainly two kinds of epileptic seizures: convulsive seizures and non-convulsive seizures, of which the first one contributes to most seizure-associated accidents, including injuries, asphyxia, and SUDEP. Epileptic seizures, especially seizures at night, are at risk of being missed by the patient's caregivers. Using monitoring system or devices in their daily life could help avoid SUDEP. To extend, our proposed system could help record the symptoms before, during and after seizures, which would provide a suitable home-based recording and diagnosing method.

II. METHOD

In our previous work [1], a bracelet with a three-dimensional (3-D) ACM and a 3-D ANG was designed. We designed a two-layer ensemble classification model to detect convulsive seizures. However, only convulsive seizures can be detected by motor sensors because some seizures are not clearly visible in ACM and ANG signals. We added the measurement of the EMG signal and other signals, such as respiration rates in this study to include more types of seizures detection. EMG does not measure any movement directly, but it illustrates muscle tones in tonic contractions, so using both ACM and EMG sensors could include tonic seizure type into our proposed seizure detection system. The incidence of tachycardia before seizures is about one-third of epileptic seizures, so detecting heart rate changes could help avoid SUDEP. For night monitoring, we took the subject's comfort into consideration and designed a non-contact radar to collect respiration, heartbeat rate, and some indicators of HRV [2]. The non-contact radar device contains PCB board with a radar sensor, while a ASP circuit, a 24-bit ADC, a Bluetooth module (CSR HC05) and the dc–dc converter circuit are integrated in another single PCB board (6 cm × 7 cm). These two PCBs as the radar sensor has compact size. The subject's body surface reflects signals which dominate the radar measurements of cardiopulmonary activities. Then, the heart rate and respiration information would be extracted by processing the echo signal.

III. RESULTS

The bracelet could detect convulsive seizures with a sensitivity of 75.92% for whole day detection and a sensitivity of 88.01% for night detection. The non-contact radar monitor is tested on both simulated targets and human subjects. In simulated target experiments, the baseband signal-to-noise ratio (SNR) reached 73.27 dB, which is high enough for heartbeat detection. The mean squared error of demodulated signal is 0.35%, indicating high demodulation linearity. In human subject experiments, the relative error of extracted beat-to-beat intervals ranges from 2.53% to 4.83% compared with electrocardiography (ECG) R-R peak intervals. The accurate analysis for heart rate provided by this radar sensor reached the accuracy of 100% for p = 2% and higher than 97% for p = 1%.

IV. DISCUSSION & CONCLUSION

In this study, a method of the epileptic seizures daily monitoring system based on multi-sensors was proposed. Our proposed devices and algorithms could detect abnormal heart rate changes and movements caused by seizures to avoid SUDEP.

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REFERENCES

[1] H. Wei, Z. Zhao, Y. Wang, H. Zhang, F. Lin, Noncontact accurate measurement of cardiopulmonary activity using a compact quadrature doppler radar sensor, IEEE T BIO-MED ENG, 61 (3) (2014) 725–735.

[2] C. Dong, L. Chen, T. Ye, X. Long, R. M. Aarts, J. Van Dijk, C. Shang, X. Liao, Y. Wang, Home-based detection of epileptic seizures using a bracelet with motor sensors, in: 2021 10th International IEEE/EMBS Conference on Neural Engineering (NER), IEEE, Virtually, 2021.