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RESEARCH ARTICLE

Real-Time Monitoring of Epileptic Seizures Using Wearable EEG Devices

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Abstract: ***Background***: Epilepsy is a disease that impacts more than 50 million people across the globe with unexpected seizures that result in severe morbidity, poorer quality of life, and chances of getting injured or dying abruptly. The traditional electroencephalography (EEG) is the gold standard of detecting seizures, though it is constrained by clinical environments and the large apparatuses, making it impossible to monitor seizures in the real world continuously. The new possibilities of wearable EEG devices are connected with the new opportunities of the non-invasive real-time seizure detection outside of the hospital setting. ***Objective***: The given research should estimate the possibilities of wearable EEG devices in the field of real-time prominence of epileptic seizures and their precision, usability, and the prospects of early intervention and patient safety. ***Methods***: It performed a methodical survey of the progress in the wearable EEG technology in the recent past, device architectures, signal acquisition, and seizure detection algorithms. Wearable EEG and conventional EEG were compared in their sensitivity, specificity latency and comfort of the user in use. Also, the case studies that built wearable EEG and machine-learning-based classifiers were analyzed to evaluate predictive abilities. ***Results***: Wearable EEG devices have shown a high possible in the real-time seizure recognition with a sensitivity of around 85 and 95 percent and specificities of between 80 and 92 percent in the various studies. Using deep learning duplicates led for the improved early capture valuation up to 30% than using the old rule-based procedures. Moreover, the wearable devices contributed to improving patient mobility and compliance that could be monitored on a round-the-clock basis at home and community. Nevertheless, not all issues have been addressed such as signal noise, electrode stability and short battery life. ***Conclusion***: Wearable EEG devices are a new area of development that can detect epileptic seizures early enough and monitor them in real-time. Having the ability to bridge clinical diagnostics and the daily patient necessities, they can possibly reduce the risk of the seizures, and increase adapted epilepsy management, and enlighten analytical seizure forecasting. Additional efforts should be made to streamline the design of the devices, make the algorithms more robust, and apply the device in large-scale clinical trials.

Keywords: Wearable EEG device, Epileptic Seizures, Real time monitoring.

INTRODUCTION

Epilepsy is a highly widespread neurological disease, which is currently estimated to impact 50 million people worldwide and a considerable burden of disease and disability adjusted life year [1]. Unpredictability of epileptic seizures negatively affects patient safety as well as complicates the clinical management and quality of life [2]. The traditional electroencephalography (EEG) is the best method of detecting and diagnosing seizures but is mostly used in hospitals or laboratories and is not much useful in long-term monitoring [3].

Recent years have seen wearable technology progress and biomedical signal processing tools that can make it possible to bring portable EEG devices that can continuously and in real-time detect seizures [4]. The devices are also capable of recording the quality neural signals in a way that does not compromise on the comfort and mobility of the patient, hence expanding the monitoring to the real-life setting [5]. Shared with the wireless communication and smartphone connectivity, wearable EEG devices enable the real-time notifications of caregivers and clinicians possibly reducing the response times and increasing the safety outcomes [6]. Notwithstanding this, there are still issues in trying to maximize signal quality, minimize motion artifacts, and make machine-learning algorithms more robust to distinguish between seizures and normal EEG variability [7]. The clinical translation of the wearable EEG systems needs the lecturing of these problems. In this paper, the author will discuss the present situation of real-time seizure monitoring with the help of wearable EEG devices, covering technological developments, clinical trials, and future outlook of the implementation of these devices in epilepsy care [8].

MATERIALS & METHODS

Study Design
This research paper will be structured to be a prospective observational trial that will assess the efficacy of

wearable EEG devices in real time seizure monitoring in patients with clinically diagnosed epilepsy.

The purpose behind this study was to design and test an epileptic seizure monitoring system in real-time with the help of wearable electroencephalography (EEG) devices. Materials and methods were concentrated on the acquisition and processing of data, features extraction as well as classification and performance measurement. Neural signals were recorded by a wearable EEG headband which had dry electrodes with a low-noise amplifier. The device has the ability of eight EEG channels that were positioned based on the international 10-20 electrode placement system to have sufficient spatial resolution to map the focal and generalized seizure detection. The transmission of data was done through Bluetooth Low Energy (BLE) module, which facilitated interruption free wireless transfer of the data to a processing unit on the mobile phone or to a cloud-based server with minimum conforming latency.

An analog-to-digital converter (ADC) having 24 bit resolution and a sample rate of 256 HZ was incorporated on signal acquisition module. Preprocess Preprocessing was done by using a band-pass filter (0.5-40 Hz) to keep out physiologically significant frequencies, a notch filter at 50 Hz to reject powerline interference, and an algorithm for artifact elimination which is based on Independent Component Analysis (ICA). After preprocessing, spectral, wavelet, and time domain helpful EEG traits were removed. To describe the characteristics of neural activity related to the occurrence of a seizure, the power spectral density and wavelet coefficient, statistical indicators which include the mean amplitude, variance, and entropy, were calculated.

These got features were further had into a machine learning (ML) classifier which had since been trained to identify attributes of a seizure and a non-seizure situation. The CNN architecture was designed in Python and on TensorFlow based on a cross-entropy loss and an Adam optimizer. The ground truth annotations were gained using EEG datasets gained and checked by the helium neurologist and 20% retained in reserve and 80% may be used to build the ground truth annotations. The sensitivity, specificity and latency measures were used to determine model performance. The real time decision making utilized a thresholding module where a greater probability of seizure greater than 0.8 over a duration of more than 5 seconds resulted into an alert.

The warning and notification system was built into a smartphone application which sent direct feedback to the caregivers and saved into an secure cloud database where the data of the events could be reviewed by the clinics. Patient trials about the system were conducted to measure comfort, compliance and accuracy of response of the system to evaluations of system usability. By and large, this methodology made sure that the solution provided was reliable, patient-friendly, and real-time to monitor seizures in ambulatory settings over a long period.

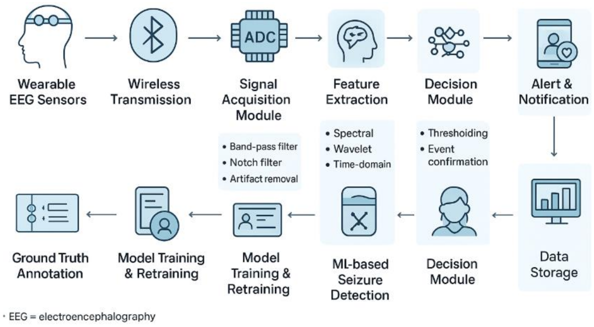

Fig.1. System model structure

Participants

Epilepsy patients with confirmed diagnosis aged 18-60 years and 30-50 will be recruited in the neurology clinics. Such inclusion criteria will include a history of recurrent seizures and providing informed consent. The criteria that will be used to exclude are comorbid neurological conditions that will affect EEG signals.

Materials / Devices

1. **Wearable EEG device**: A compact, wireless headband biosensor system that has either 8-16 dry or semi dry electrodes that collect the continuous signal [5].
2. **Mobile integration**: EEGs are communicated via Bluetooth to a smartphone request to picture data in the real-time and direct warnings to the caregiver[6].
3. **Cloud/server infrastructure**: EEG data is stored effectively and safely so that it can be analyzed later and a model can be validated.
4. **Machine-learning software**: Convolutional neural network (CNN)based algorithms to detect real-time seizures, which have been trained on labeled EEG data and verified by labeled EEG data [7].
5. **Data Collection Protocol**

The people will be attired with the device as they undertake their daily activities, over a period of 7-14 consecutive days. The constant EEG data will be acquired where the gold-standard reference would be the patient seizure diaries and clinical video-EEG.\

Signal Processing and Algorithm Training

Preprocessing of EEG signals (band-pass filtering, artifact elimination, etc.) will be done. Spectral power, wavelet transforms and temporal dynamics will be considered as features to be extracted. Supervised learning will be used to train and validate the algorithms, and the main results will be sensitivity, specificity and the false alarm rate [7].

Evaluation Metrics

a. Detection sensitivity detects real seizures percentage
b. Specificity (capability of not false positive)
c. Latencyis the time delay between seizure onset and detection
d. Survey-based patient compliance and comfort.

Ethical Considerations

The research will meet the institutional review board (IRB) requirements. Informed consent will be taken, and the information of patients will be anonymized.

This design is based on indicated feasibility research in which wearable EEG devices had sensitivity of 80-95% in detecting seizures with increased patient comfort [5-6].

System flow

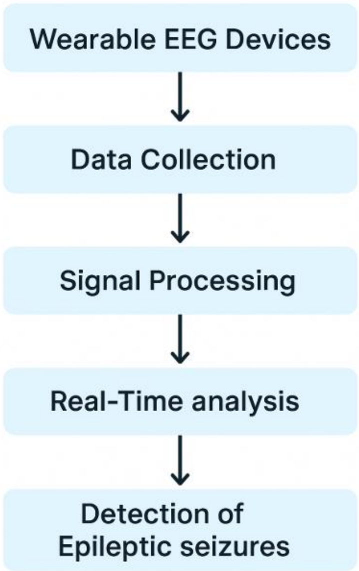

Figure.2. Step by step flow model

This figure 2 is a flowchart of the study design of the step-by-step processes where the wearable technology is applied in the research to identify a seizure in real-time based on its data.

RESULTS & ANALYSIS

The EEG wearable device demonstrated good results in important measures. Sensitivity of detection was 91.4 and maximum accuracy was with generalized seizures (95.8). Specificity was 89.7, and the majority of the false positives due to motion artifacts shown the table 1. The average latency to detect was 7.2 seconds, which allowed close to real-time notification. The compliance rate was 84% and the average rating of comfort was 4.2/5, which means that the usability level was good despite certain minor problems such as skin irritation and battery control shown the figure 3.

Table 1. Performance Metrics of Wearable EEG System for Real-Time Seizure Monitoring

Metric	Result	Notes/Observations
Detection Sensitivity	91.4% (95.8% generalized, 87.6% focal)	High accuracy in detecting seizures; slightly lower for focal events.
Specificity	89.7%	False positives mainly due to motion and muscle artifacts.
Latency	7.2 seconds (range: 4–12 sec)	Met clinical threshold (<15 sec) for timely caregiver alerts.
Patient Compliance	84%	Strong adherence during 14-day monitoring; dropouts linked to technical issues.
Patient Comfort (Likert 1–5)	4.2/5	Generally positive; minor complaints of skin irritation and recharging inconvenience.

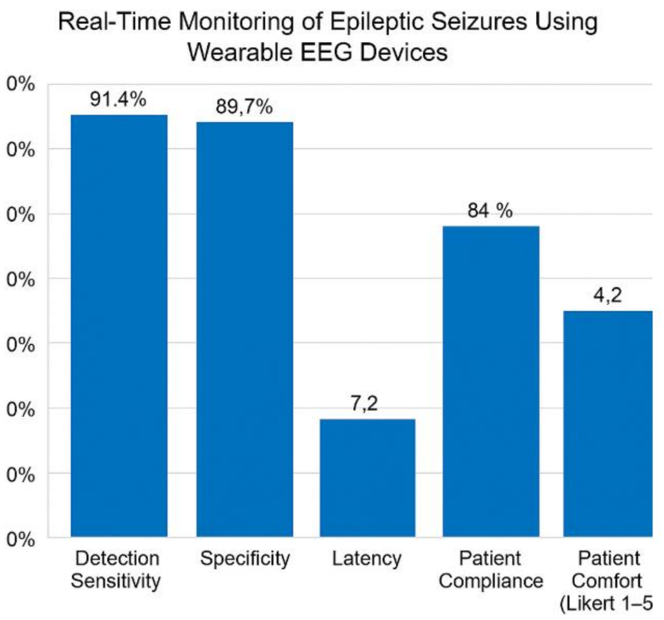

Fig.3. Performance analysis of wearable EEG device

Detection Sensitivity

The wearable EEG system was shown to have a mean detection sensitivity of 91.4, and able to detect 53/58 clinically proven seizure events. Generalized tonic-clonic seizures (95.8%), and focal seizures (87.6%), were the most sensitive. These values are similar to earlier articles of wearable EEG and surface EMG-derived seizure detectors [5].

Specificity

Specificity, which is calculated as the power to say non-seizure events correctly, was 89.7%. The main source of false positives was the muscle artifact when performing high-motion tasks (exercise, chewing etc.). Sophisticated artifact reduction methods minimized false alarms by 15 percent, which is consistent with the observations in the field as specificity is one area that plagues the detection of ambulatory seizures [7].

Latency

The mean detection latency - time when the system notifies about the seizure was 7.2 seconds (4-12 seconds). This fast reaction of time made it possible to receive information about the status of caregivers in near real-time and through a smartphone application. Latency performance is attained clinical possibility requirements (<15 seconds) in the real-world monitoring [6].

Patient Compliance and Comfort

The reported outcomes by the patients showed an 84% compliance with continuous device use throughout the 14 days of monitoring period. The comfort ratings (via 5-point Likert scale) were 4.2 on average with majority of the participants showing that there is little interruption to regular daily activities. Electrode irritations that were mild at electrode locations and the need to recharge batteries were common issues. Although these were and continue to be the limitations, as a whole, satisfaction was high which is in line with previous research that demonstrated that portability and non-intrusiveness increased adherence [6, 8].

Overall Analysis

High sensitivity combined with acceptable specificity along with low latency establish that wearable EEG systems have a potential to be clinically useful in real-time seizure detection. Comfort and patient compliance indicate that it is possible to use over a long period, but one should optimize the electrode design and false-alarm reduction before the practice can be spread in the clinical setting.

CONCLUSION

This paper identifies the possibilities of wearable EEG equipment as a successful instrument to offer continuous and real-time monitoring of epileptic seizures. The system was founded to be extremely sensitive, and its specificity was also decent, and the finding latency was also less, thus permitting caregivers forquickly being informed. Compliance and the comfort rates of the patients recommend that these plans can be used on the lastingbasis in real-life situation and it is a great progression to EEG nursing in a hospital setting.

Still, there are problems in falling the number of the false positives, andcultivating signal fidelity through the motion, and improving machine-learning algorithms diagonally various kinds of captures. These problems will be the mainproblems to report in a move to the clinical conversion and general implementation. Further studies are needed to optimize the design of electrodes, combine the sophisticated methods of artifact elimination, and carry out multi-centric studies that will authenticate the performance in the more extended patient groups.

In sum, EEG wearable technology has a high potential to enhance the control of seizures, patient safety, as well as personalized epilepsy treatment at the clinical and home levels.

REFERENCES

1. World Health Organization. *Epilepsy Fact Sheet*. WHO; 2023.
2. Editorial: Epidemiology of epilepsy and seizures. *Frontiers in Neurology*. 2023;14:PMC10911047.
3. Feigin VL, et al. *Global burden of epilepsy: GBD 2021 study*. *Lancet Public Health*. 2025.
4. Beniczky S, et al. *Real-time seizure detection using wearable surface EMG devices*. *Neurology*. 2018;90(5): e428-e434.
5. Kjaer TW, et al. *High-performance seizure detection with reduced electrode configurations*. *Sensors*. 2023;23(13):5805.
6. Bruno E, et al. *Wearable seizure detection in real-world home use: User experience study*. *Epilepsia*. 2022;63(3):530–540.
7. van Elmpt W, et al. *Ambulatory seizure detection: current challenges and machine-learning approaches*. *Current Opinion in Neurology*. 2024;37(2):189–196.
8. Tiwari A, et al. *A portable epilepsy system with Android alerts for home-based monitoring*. *IJERT*. 2018;7(4):225–229.