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Review article

Technology-enabled seizure detection and reporting: The epilepsy network project

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ABSTRACT

The traditional models of epilepsy care provision have not changed substantially in more than a century, despite rapid advances in computing, technology and materials science. One consequence of these advances has been the near universal prevalence of smartphones. Wearable devices with a complex sensor arrays are an emerging technology. These devices provide a coalescence of digital computing and communication tools that offer a new way to detect, report and communicate about seizures. The pilot of a smartphone-based application for patients and cares allowing real-time reporting of seizures securely to the relevant epilepsy care team is described. Wrist-worn devices were evaluated for their ability to detect epileptic seizures. Relevant information, such as seizure notifications and live alerts for notification of emergency attendance or admission to the hospital, are sent securely to the epilepsy care team in real time. Tailored specialist advice following notification is provided along traditional lines. Compared to the year preceding the pilot, the interval between seizure occurrence in the community and notification of the specialist team reduced, with faster response times in terms of advice. There was a 30% reduction in admissions for patients with epilepsy and 10% reduction in length of stay. Patients using the technology report an increased feeling of empowerment. This model of care has several challenges and requires modification of existing working practices if benefits for patients are to be fully realised. The benefits and challenges of technology-enabled care in are discussed from the perspective of the experience from development to clinical deployment.

1. Introduction and rationale for development

The Dorset Epilepsy Service (DES) provides support to people with epilepsy (PwE) across Dorset. This service is staffed by two adult specialist nurses and on consultant neurologist with an interest in epilepsy. A telephone and email advice line for the epilepsy service was established in 2009. The limited capacity for outpatient review of PwE, combined with the variable uptake of the support provided started a reimagining of how the service in Dorset could be provided for PwE. The concept was of a patient smartphone application linked to the clinical record at core, with wearable devices connecting to the patient application to supplement the patient submitted data. A longer-term aim is to radically change the current process of outpatient review of epilepsy by the development of a co-authored record with patient-triggered follow-up. A consortium involving Poole Hospital, the University of Kent, Graphnet Health and Shearwater Systems was awarded a grant by Innovate UK, with the development work starting in March 2015.

2. Mechanisms of action

Retail and medically approved wearable devices for epilepsy were surveyed at the beginning of the project. Devices with an open application programming interface (API) were shortlisted. These devices were then compared against a set of criteria including range of sensors and access to the raw sensor data. The Microsoft Band/Band 2 was selected based on these assessment criteria and tests of data collection using a normal control group. PwE admitted for video EEG at Poole Hospital as part of their care were consented to simultaneous data collection with the wearable device. Data from the wearable device captured around the time of seizures confirmed by video EEG was used to build a seizure classifier.

A smartphone application was designed and built with input from PwE and published to the Apple (iTunes) and Google (Play) application stores. This smartphone application provided links to a personal health record (PHR) running in the cloud (Microsoft Azure). The wearable device connects via low-power Bluetooth connections the smartphone and transmits sensor array data to the PHR. The PHR is configured to share data with a secure clinical data repository (CDR), also in the cloud (Microsoft Azure). The CDR connects with the electronic health record (EHR) using a secure, end-end encrypted, messaging application with a push-subscribe model (Careflow Connect), delivering real-time patient triggered alerts to the epilepsy care team. The technical architecture is shown in Fig. 1.

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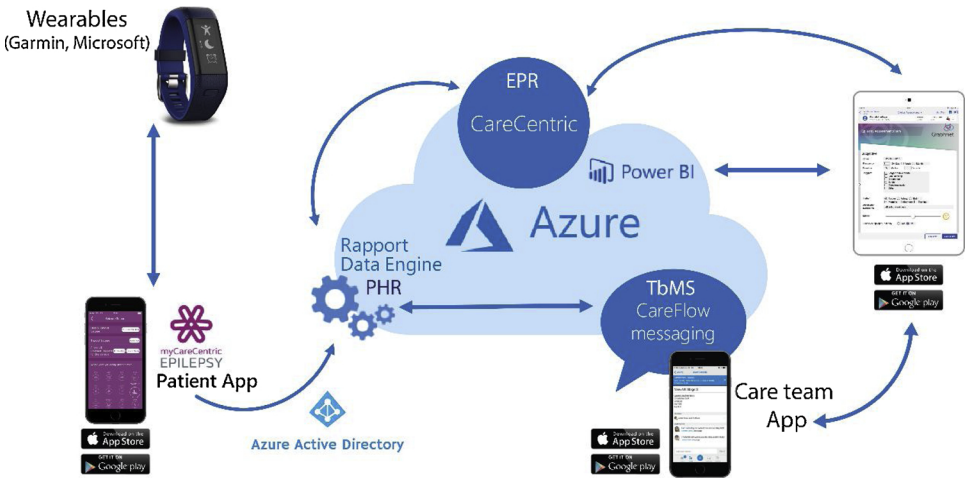

Fig. 1. Technical architecture.

A selection of PwE known to the epilepsy team were consented and identified in the Poole Hospital patient administration system (PAS). Real-time alerts are automatically generated following admission to the emergency department (ED) or to Poole Hospital. The epilepsy team receive notification and review the reason for admission using clinical information from the EHR, supplemented by telephone calls or visits to the relevant location.

3. Results

Data sets from the wearable were obtained during in-patient recordings of PwE undergoing video EEG as part of their routine epilepsy work-up. Data from around the time of the electrographic seizures was used to build an automated classifier for detection. This seizure classifier was able to detect 83% of the generalised tonic-clonic seizures which had simultaneous wearable data sets with no false positives. Detailed analysis of the predominant sensor contributions to the identification of seizures was used to then power cycle the wearable in order to optimise battery life of the device.

316 PwE (164 female; 152 male; mean age 42.9) with drug-refractory epilepsy were monitored for admissions to Poole Hospital over one-year. Alerts marking admissions from this group averaged less than 1 per day. The number of admissions decreased over the first six months of the study period from 33 per month at the start, plateauing at around 20 admissions per month over the last 6 months of the pilot (mean 20.7 compared to 30.2). Review of the monitored admissions suggested that the length of stay for those admitted was reduced by 10% (mean 3.2 days compared to 3.6 days).

In addition, 61 PwE were recruited to a pilot study of the smartphone application over the same period. 54 of these were additionally provided with a wearable device. 63% of PwE recruited to the pilot had experienced more than one seizure per year for at least 3 years. All were on conventional anticonvulsant medication. An average of 5 seizure alerts were generated in each 24-hour period. The time taken for the epilepsy team to respond to each alert was reduced by between 24 and 48 h, compared to similar notifications arising through the existing email advice line. The rate of seizure reporting between outpatient clinic appointments increased in the study group by up to 50% compared to per-pilot advice line contacts (Fig. 2).

4. Tolerability and safety

The wearable device was well tolerated, and no allergic reactions were reported. Several devices were broken due to damage sustained during epileptic seizures. A number of wearable devices developed problems with maintaining a full battery charge. Some users reported discomfort with prolonged wear. Bluetooth connection problems were reported with iOS devices, due to an issue with the iOS control of smartphone applications entering sleep mode.

The smartphone application received broadly positive feedback. An embedded user suggestion feature was used to provide feedback which was incorporated into subsequent updates of the application. Some users had to be provided with clinical support to re-register the application with the clinical systems following replacement of their smartphone.

The admission alerts led to some form of intervention from the epilepsy team in under half of cases. The majority of these were ensuring that the regular anticonvulsant medication for the individual was prescribed and given. Medication changes to the regular anticonvulsants prescription was made in less than 20%. A minority of cases required more than one intervention.

5. Planned studies

We are currently undertaking an NIHR-sponsored trial of the smartphone, wearable and clinical platform focussing on the user experience, as part of the SCALS programme run by the University of Oxford. We intend to expand the use of the platform to earlier in disease presentation (Page et al., 2018). Methods of ensuring longer-term retention and follow-up are being explored, including for PwE moving between care settings and locations.

Incorporation of other retail wearables is ongoing, with integration of Garmin devices into the platform already completed. Work on the completion of bidirectional notifications between clinical systems and the patient-held smartphone is underway. Further development of automated visualisation and analysis of the mixed, complex data sets generate through the platform is underway. Classification of other seizure types remains an area of interest but will require substantially larger data sets than have been collected to date. Future wearable devices with a greater range of sensors or more sensitive monitors may

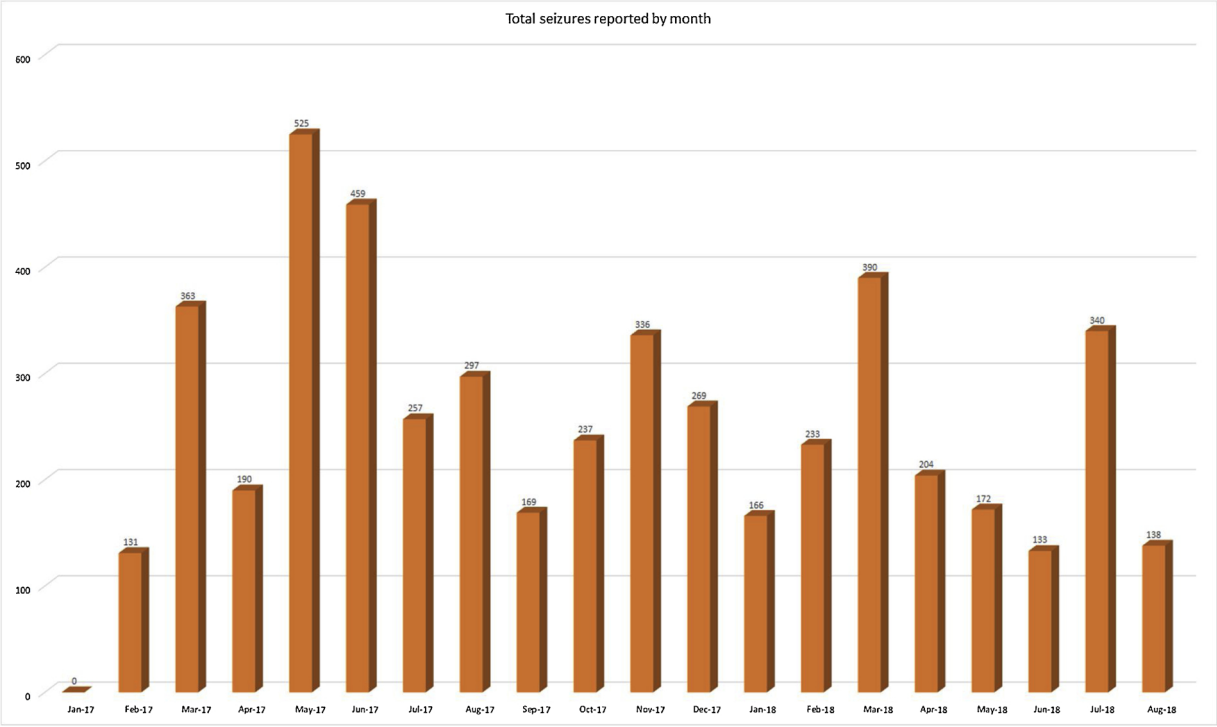

Fig. 2. Reported seizures using solution by month.

facilitate this. It is likely that some seizure types will remain challenging to detect with a wrist-worn wearable device if there is no peripheral change in movement pattern or physiology during the seizure.

Collaboration with the EpSMon (Epilepsy Self Monitoring) team is underway to provide notifications of SUDEP risk and alert thresholding based on seizure severity. An open API that allows registration of third party applications against the clinical systems with import of patient authored data has been completed as part of this work.

Wider dissemination of the epilepsy platform is being discussed with potential collaborating centres in the United Kingdom. The platform has already been used to develop similar applications for heart failure, cancer and migraine.

References

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