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Summary of
CONGRESS ABSTRACTS

Wearable sensors in epilepsy and Parkinson's disease: A focus group study

Johansson D*[1], Ozanne A*[2], Alt Murphy M[1], Bergquist F[1] and Malmgren K[1]
1. Institute of Neuroscience and Physiology, Sahlgrenska Academy, University of Gothenburg, Gothenburg, Sweden.
2. Institute of Health and Care Sciences, Sahlgrenska Academy, University of Gothenburg, Gothenburg, Sweden.

Background:
Wearable sensors that measure movement and physiological variables are attractive for clinical evaluation of neurological diseases like epilepsy and Parkinson's disease (PD). In the last year alone, there were almost one hundred publications on this topic with respect to the use of wearables in neurological disease monitoring. There is, however, still a lack of knowledge about patients' and health professionals' perceptions regarding the use of wearables in epilepsy and PD. The aim of this study was to explore perceptions regarding the use of wearable technology in disease monitoring and management as reported by individuals with epilepsy, and PD as well as health professionals working with these patient groups.

Materials & Methods:
Six patient groups (n=25) and two groups with health professionals (n=15) participated in a qualitative, descriptive study with focus-groups interviews. The manifest qualitative content analysis was used.

Results and Conclusions:
Four categories and nine subcategories emerged from the analysis. Participants saw possible benefits for improved treatment effect and valued this benefit more than possible inconvenience of wearing the sensors. They emphasized the importance of interactive information between patients and health professionals before, during and after recordings. However, they were concerned about problems such as unclear information, lack of personal integrity and inconclusive recordings. Discrete design and simplicity were considered as facilitators for improved usability.

Health professionals and patients expressed some conflicting expectations and preconceptions that may hinder the use of wearables. Everyone involved needs to feel well-informed and find an added value in using the device. Wearables need to be user-friendly and have an attractive design to be applicable in clinical settings, and therefore patients have a role in contributing to the design of their monitoring.

Non-EEG based seizure detection: necessity, availability, possibilities, requirements and challenges

Van de Vel Anouk[1], Cras Patrick[2] and Ceulemans Berten[1]
1. University Hospital of Antwerp – University of Antwerp, Pediatrics – Pediatric Neurology department, Edegem, Belgium
2. University Hospital of Antwerp – University of Antwerp, Neurology department, Edegem, Belgium

Background:
Many patients, parents and caregivers are searching a device alerting for epileptic seizures, to avoid further injuries or even SUDEP (Sudden Unexpected Death in Epilepsy) and to offer care. Our research focuses on non-EEG (electroencephalography) based seizure detection, not prediction, and its clinical aspects: necessity, availability, possibilities, requirements and challenges.

Materials & Methods:

1. A literature study and contacts with manufacturers have led to an overview of possible detection methods with (dis)advantages, available devices and state-of-art research.

2. With questionnaires to patients, family, caregivers and involved physicians, we verified the need and requirements for a seizure detection device.

Results and Conclusions:

1. Detection methods comprise measurement of heart rhythm, perspiration, sound, muscle tension, movement, oxygen saturation, respiration and blood pressure. Preferably movement (including many seizures) and autonomic changes (including dangerous seizures) should be combined in a multimodal device.

Validated studies for commercial devices are limited or contradictory, and user experiences often negative (discomfort, missed seizures, false alarms). Most of them are developed for adults and typical (severe, long, symmetrical) tonic-clonic seizures.

Comparison of research is difficult since groups are focusing on different seizure types, timing (day versus night) and patients (adult versus child).

2. Seizure detection is judged useful by 85% of questioned physicians and 65% of patients and family. A device for long term use should be comfortable and user friendly, and a 90% sensitivity and one false alarm per seizure (one per week when seizure free) seem acceptable.

3. Many difficulties and challenges need to be taken into account: selection of relevant seizures, sensor type, attachment site and useful features, inter- and intrapatient variability and ethical considerations.

All the above and our own clinical research based on accelerometry, electromyography and heart rhythm measurement have convinced us that a detection device can be suboptimal at purchase, as long as it is able to adapt to patient characteristics (weight, steady state heart rhythm), seizures (type, intensity, duration) and wishes: personalization is the future!

EpSMon – Safety in your pocket: patient self-empowerment saves lives

Dr Brendan McLean[1], Dr Rohit Shankar[2,3], Dr Craig Newman[4], Ms Samantha Ashby[5], Ms Jane Hanna[5]
1. Royal Cornwall Hospitals NHS Trust
2. Cornwall Partnership Foundation Trust
3. Exeter Medical School
4. Plymouth University
5. SUDEP Action

Background:
UK has 600,000 people with epilepsy (PWE), 30% being treatment resistant. In PWE 42% of the 1200 deaths/year is avoidable. NICE since 2004 strongly advocate discussion of mortality risk, but until recently only 4% PWE had a recorded discussion. When, how, what to discuss & assess risk is arbitrary, non-person centered with no structured evidenced mechanism.

Materials & Methods:
Using research & Quality Improvement methodology, EpSMon an evidenced based mobile app to empower risk self-monitoring was delivered. EpSMon is the electronic version of the evidenced based & clinically validated SUDEP & Seizure safety checklist (https://sudep.org/checklist). This is an easy reference tool developed by identifying current risk factors especially 'modifable' ones to complete in clinic to support clinical activity & person centred communication to enable self empowerment. It has over 10 peer reviewed publications highlighting its use and impact. The checklist was tested in various populations over 5 years and converted into EpSMon (www.epsmon.com), now free in the UK in both Android & Apple versions.

Results and Conclusions:
EpSMon launch was supported by 36 regional radio/TV, 26 newspapers & 43 organizations. EpSMon has been evaluated across eHealth, clinical and management communities. It has won ILAE UK expert led poster 2015 prize, USA SUDEP challenge 2016 (83 applicants/25 countries), BMJ Neurology

2016 and UK patient Safety Awards 2016. It is one of seven projects selected for NHS England's National Innovation Accelerator scheme 2017. A 2016 Cochrane review (CD011792) on SUDEP prevention highlights the importance of education/training and singles out EpSMon. The RCGP has recommended EpSMon to all 7,000 GP practices through e-module training for epilepsy management. EpSMon is part of national epilepsy commissioning toolkit. A NIHR review of emerging epilepsy technology has given the highest rating for EpSMon. There are 3000 regular users of EpSMon. Version 2 is due to be launched in the USA and the UK. EpSMon helps identify changing risk to allow PWE and clinicians to intervene, and focuses individuals on issues within their control. There is developing evidence of improving safety by indicators of ED admissions, clinicians, patients and carer feedback and death reduction.

Seizure detection with integrated sensor garments

K Malmgren[1], D Johansson[1], F Ohlsson[2] and J Wipenmyr[2]
1. Department of Clinical Neuroscience, Institute of Neuroscience and Physiology, Sahlgrenska Academy at Gothenburg University, Gothenburg, Sweden
2. Department of Sensor Systems, Research Institutes of Sweden, Acreo AB, Gothenburg, Sweden

Background
The aim is to develop a garment with integrated electronics and sensors with analysis algorithms to monitor patients with epilepsy, Parkinson's disease and stroke. Sensor functionalities will include monitoring of movements, heart rate, oxygen saturation and blood pressure. Sensors include electronic sensors and functional textile e g passive heart rate electrodes.

Materials & Methods
The garment must be comfortable to wear and robust enough to withstand normal use and machine wash. The possibility to individualize the garment, including configuration, aided by 3D-scanning and 3D-fitting software is investigated. The current prototype is based on an undershirt with three sensor units on forearms and chest and one central unit.

Analysis algorithms are based on machine learning methods. Several classification methods are evaluated in conjunction with different decision structures. The algorithms are intended to detect generalized tonic-clonic (GTCS) and hypermotor (HMS) seizures with high sensitivity and specificity.

Results
A first version of the garment is tested with promising results with respect to measurement of motion and pulse as well as system functionality and

washability. For the purpose of algorithm development, accelerometer data has been collected using commercial motion sensors. So far we have registered 34 GTCS in 11 patients and 38 HMS in 4 patients.

A detection algorithm focused on GTCS using machine learning methods has been developed using part of the recorded seizures. The best performance in terms of algorithm generalizability and robustness against high frequency non-seizure movements was obtained using non-linear classifiers able to capture a complex seizure manifestation.

Initial investigations of HMS indicate that certain features can statistically discriminate seizure from non-seizure activity. However, the variable motor manifestations appear to be difficult to automatically detect with high specificity in real patient data using group level models.

Conclusions
Challenges include practical aspects of the garment that need to be resolved to ensure reliable collection of high quality sensor data.The GTCS algorithms are being further evaluated and individualized algorithm development for HMS detection is currently investigated.

User based evaluation of applicability and usefulness of a wireless wrist accelerometer in registering bilateral tonic-clonic seizures

Pirgit Meritam[1], Sándor Beniczky[1,2]
1. Department of Clinical Neurophysiology, Danish Epilepsy Centre, Dianalund, Denmark
2. Department of Clinical Neurophysiology, Aarhus University Hospital, Aarhus, Denmark

Background:
Overview of seizure frequency is essential for optimizing treatment and assessing risk of seizure related injuries and SUDEP (sudden unexpected death in epilepsy), strongly associated to bilateral tonic-clonic seizures.

Accelerometric sensors with algorithms to identify the motor symptoms in epileptic seizures are among the many seizure detection devices developed for daily use. A wireless accelerometric wristwatch Epi-Care Free is commercially available, developed to detect bilateral tonic-clonic seizures.
We aimed to study if the applicability and gain of this device is recognized by everyday users.

Method:
112 persons using the Epi-Care Free device were asked to fill out a

questionnaire, modified after IBM´s Post Study System Usability Questionnaire (PSSUQ).

To each question, the participants gave one out of seven grades on Likert scale ranging from “I strongly disagree” to “I strongly agree”, and assessed the amount of seizures and false alarms.

Results and Conclusions:
61% of participants finished the questionnaire. The median age of patients was 26 years (range 7-72 years).

The questionnaire was answered by personnel, family members or patients (43%, 32%, 18% resp). The median time of usage was 1 year (range 24 days to 6 years).

73% agreed to being satisfied with using the device.

In 22 cases (32%) the patient had no seizures when using the device. 82% (38/46) agreed that the system is effective in detecting bilateral tonic-clonic seizures, whereas 11% disagreed. For 80% of patients 90-100% of seizures were detected. In 2 cases, none of the seizures were registered.

28% of users didn´t experience any false alarms, in 26,5% the false alarms were seldom, whereas in 26,5% the false alarms went off daily. The most common reason given were hand movements. 72% of users agreed that the rate of false alarms was acceptable, 16% disagreed.

33% (15/46) strongly disagreed that seizure related injuries decreased, 39% agreed to a variable degree.

46% agreed that the system had an influence on the number of seizures noted in the seizure calendar, 28% disagreed.

81% didn´t experience any side effects, 4 patients developed a skin rash.
As most users agreed the device is applicable and effective, we conclude that it contributes to decreasing the burden of caregivers in daily practice.

Automated video-based detection of convulsive seizures in a residential care setting

Evelien Geertsema[1], Thea Gutter[1], Ben Vledder[1], Johan Arends[2], Frans Leijten[3], Roland Thijs[1,4], Gerhard Visser[1] and Stiliyan Kalitzin[1,5]

1. Stichting Epilepsie Instellingen Nederland (SEIN), The Netherlands.
2. Epilepsy Center Kempenhaeghe, The Netherlands.
3. Brain Center Rudolf Magnus, University Medical Center Utrecht, The Netherlands.
4. Department of Neurology, Leiden University Medical Centre, Leiden, the Netherlands.
5. Image Sciences Institute, University Medical Center Utrecht, Utrecht, The Netherlands.

Background:
After convulsive seizures (CS), people with epilepsy are often in need of assistance, may need first aid and are at risk of SUDEP. Automated seizure detection systems can help alert caregivers, but wearable sensors are not always tolerated by children or mentally impaired people, and need regular charging. In a previous study, we presented an algorithm to detect CS in video registrations. The aim of the present study was to investigate detection performance in a residential care setting.

Materials & Methods:
Our algorithm calculates relative frequency content (2-6 Hz relative to 0-12 Hz) in the optical flow signal of videos. Two video databases were analysed retrospectively; a learning set to find a detection threshold and a test set to study detector performance. The start and end of CS and other seizures considered desirable to detect (long tonic, hypermotor, and other major seizures where care is needed) were annotated. The learning set contains video-EEG recordings of 50 subjects with 72 CS. The detection threshold was set to the value that acchieved 97% sensitivity in the learning set. The test set consisted of 24 nights (~251 hours) of 12 subjects in a residential care department, with 6 CS in 6 subjects. Detection sensitivity, latency and false detection rate per night (8 hours) were calculated. A seizure was detected when the algorithm output exceeded the threshold for 2 consecutive seconds.

Results:
With the detection threshold determined in the learning set, 5/6 CS were detected in the test set, resulting in 83% sensitivity. Four CS were detected within 10 seconds from the start of vibrations/clonic movements. Additionally, 0/3 tonic, 3/5 hypermotor, and 6/6 major seizures were detected. Median false detection rate was 0.83 per night. No false detections occurred in 10/24 nights. False detections were related to: Other, non-clinically urgent seizures (13%, e.g. myoclonic seizures), caregivers (10%), patient behavior (48%) and

video disturbances (29%, e.g. moving objects).

Conclusions:
Our algorithm could improve patient safety unobtrusively by automated detection CS in video. Most CS were detected with an acceptable latency and false detection rate in nightly video recordings in a residential care setting. The algorithm can also detect some non-convulsive seizures that require care to be given.

Ear-EEG for mobile long-term EEG monitoring of interictal and ictal events

Zibrandtsen, I[1], Kidmose, P[2], Kjær, T W[1]
1. Zealand's University Hospital, Dept. of Neurology, Roskilde
2. Aarhus University, Dept. of Biomedical Engineering

Background:
Temporal lobe epilepsy is the most common focal epilepsy in adults. Seizures commonly interfere with awareness and memory and may occur unpredictably. Combined, these factors likely add to difficulties in diagnosis and management. We propose that Ear-EEG - an EEG-recording device situated in the outer portion of the external acoustic meatus and intended for extended yet flexible use with minimal interference with activities of daily living - could help on all these counts. We explore the clinical utility of the ear-EEG in epilepsy by comparing it to simultaneous scalp EEG recordings.

Materials & Methods:
15 patients with suspected temporal lobe epilepsy (TLE) were recruited. Ear-EEG pieces were individually customized. Comparison was between 25 channel scalp EEG recorded in the hospital's epilepsy monitoring unit and 4+4 channel bilateral ear-EEG. Linear dependencies of signals were calculated and mapped. A visual analysis of seizure recognition was carried out by two neurophysiologists, who compared seizure epochs from both scalp-EEG and ear-EEG. Time-frequency analysis was performed in Matlab.

Results and Conclusions:
A total of 27 focal seizures were recorded, 3 of which culminated with secondary generalization. Visual analysis showed very comparable detection rates for the two methods: 14/14 and 23/24 detections for the two reviewers, respectively. Time series correlation varied between 0.4-0.9 between ear-electrodes and scalp electrodes and decreased with increasing distance away from the temporal region. Ear-EEG can resolve epileptiform morphology of ictal and ictal events in the temporal lobe. For some focal temporal lobe seizures, ictal activity can be equally well resolved in the time-frequency domain using ear-EEG as with scalp-EEG.

Ear-EEG is a promising candidate for a wearable very-long term monitoring EEG recording device that minimally interferes with activities of daily living.

Automated R-peak detection algorithm for patients with epilepsy using a portable electrocardiogram recorder: first step towards portable seizure detector.

Jesper Jeppesen[1], Anders Fuglsang-Frederiksen[1], Peter Johansen[2], Per Sidenius[3], Sándor Beniczky[1,4]
1. Department of Neurophysiology, Aarhus University Hospital, Denmark. 2. Department of Engineering, Aarhus University, Denmark. 3Department of Neurology, Aarhus University Hospital, Denmark. 4Department of Clinical Neurophysiology, Danish Epilepsy Centre, Dianalund, Denmark.

Background:
Earlier studies have shown that short term heart rate variability (HRV) analysis of ECG is a promising biomarker for detection of epileptic seizures. A precise and accurate automatic R-peak detection algorithm is a necessity in a real-time, continuous measurement of HRV, in a portable ECG device.

Materials & Methods:
We used the portable CE marked ePatch® heart monitor to record the ECG of 14 patients, who were enrolled in the video-EEG long term monitoring unit for clinical workup of epilepsy. Recordings of the first 7 patients (356 recording hours) were used as training set of data to optimize the R-peak detection algorithm and the recordings of the last 7 patients (467.6 recording hours) were used to test the performance of the algorithm. We aimed to modify and optimize an existing QRS-detection algorithm to a more precise R-peak detection algorithm to avoid the possible jitter Q- and S-peaks can create in the tachogram, which causes error in short-term HRV-analysis.

Results and Conclusions:
The proposed R-peak detection algorithm showed a high sensitivity (Se = 99.979%) and positive predictive value (P^+ = 99.976%), which was comparable with a previously published QRS-detection algorithm for the ePatch® ECG device, when testing the same dataset.

The novel R-peak detection algorithm designed to avoid jitter has very high sensitivity and specificity and thus is a suitable tool for a robust, fast, real-time HRV-analysis in patients with epilepsy. The R-peak detection algorithm is the first important step in creating a portable fully automatic real-time seizure detection for these patients.

Tonic seizure detection based on multimodal detection methods using the EpiSense sensor

J. van Sluis, MSc[1,2], J.P. van Dijk, PhD[1], M.J. Zwarts, MD, PhD[3]
1. Department of Clinical Physics, Kempenhaeghe Center for Epileptology, Heeze, the Netherlands
2. School of Medical Physics and Engineering, Eindhoven University of Technology, Eindhoven, the Netherlands
3. Department of Clinical Neurophysiology, Kempenhaeghe Center for Epileptology, Heeze, the Netherlands

Background:
Epileptic nocturnal seizure detection to date, has mainly been focused on developing detection methods based on heartrate (ECG/PPG), and accelerometry (ACM) measurement [1]. These detection methods are successful in detecting so-called clonic seizures, where ictal activity is characterized by rhythmic muscle contraction and an increase in heartrate. However, current detection methods fail to detect the tonic epileptic seizure or preceding tonic phase in tonic-clonic seizures.

Tonic seizures are characterized by a severe continuous contraction of muscles in the body, including the respiratory muscles [1]–[3]. Herewith, an increase in heartrate does not always occur and ACM based detection does not comply due to a lack of movement. Tonic seizures may lead to unconsciousness, post-ictal cardiorespiratory depression, and are associated with an increased risk of Sudden Unexpected Death in Epilepsy (SUDEP) [1], [3].

Tonic seizures are most hazardous during nighttime, when supervision is minimal. Due to the possible detrimental outcomes, patients' caretakers and/or close relatives are anxious to go to sleep because of the fear of losing their loved ones without notice. To reduce the risk of SUDEP and to be able to provide immediate medical care when necessary, a tonic seizure detection method with a high sensitivity and a high positive predictive value is needed. The detection method needs to be able to generate a real-time alarm so that the environment can intervene when necessary as soon as possible.

An ongoing project at Kempenhaeghe Center for Epileptology in the Netherlands, the EpiSense project, specifically focuses on the detection of nocturnal tonic seizures. The addition of EMG measurement to existing detection methods based on ECG and ACM measurement is expected to enable tonic seizure detection at night.

Materials and Methods:
For this project, the EpiSense sensor has been developed in which the three measurement modalities EMG, ECG and ACM are combined in a single ultra-low power wearable detection device worn around the upper arm using a size-adjustable strap. This sensor is synchronized with the local network time

which provides a time stamp for the measurements. In addition, the local network time synchronization enables simultaneous video monitoring (gold standard) for comparison of the data and validation of epileptic seizures.

The sensor's performance (sensitivity and positive predictive value) will be determined based on comparison with the video recordings. The measured data can be logged for at least five nights and this data is stored on a micro SD card in the sensor. The recorded data can be retrieved from the SD card after a full week of measurements.

During trial measurements, the upper arm sensor band measures synchronous EMG, ECG, and ACM using a total of five electrodes. Two electrodes are used for EMG measurement, two electrodes are used for ECG measurement, and the remaining electrode is used as a ground electrode. The accelerometer is built in in the sensor body.

The bipolar EMG signal is derived from the left deltoid muscle where EMG signal measurement is most pronounced [4]. The two electrodes are placed approximately 2 cm apart from each other on the coronal plane on the lateral deltoid muscle belly.

One ECG lead runs from the sensor located on the upper arm across the chest slightly right from the sternum to measure heart rate whilst minimizing artefacts through muscle activity. The other ECG lead runs from the sensor to the lower ribs on the left chest. By positioning the ECG leads as described above, the heart rate is measured in lead-II position. The final electrode, the ground electrode, is placed on the lateral side of the elbow joint. Figure 1 shows the EpiSense sensor with the five measurement leads as described above.

Figure 1: the EpiSense sensor with its five electrodes: the upper two leads are for measuring EMG activity, the lower two leads depicted in the centre part are for measuring ECG activity, and the lower lead located most left is used as a reference.

The size adjustable strap is not included in this figure, but can be attached to the openings on both sides of the sensor.

ACM measurement is used to identify the patient's body posture to minimize false-positive alarms. I.e., when the patient for example needs to use the bathroom during nighttime, ACM measurement will ensure movement artefacts registered by the sensor and thus will not evoke an alarm. ECG measurement has been taken into account for the possibility to detect an increase in heart rate which may occur during a nocturnal tonic seizure, but for monitoring the vital functions of the patient as well.
To check whether the electrodes are properly attached and whether the measured signal is of sufficient quality, in this research setting, visual assessment of the real-time signal can be done through an Android software application. The sensor connects with the software app via Bluetooth connection via a double tap on the sensor body.

The sensor is applied around the patient's upper arm before bed and the recording is initiated via a series of double taps as well. The measurements during this trial are only conducted at night, and 'a night' is defined as the period during which the patient is in bed.

Results and Conclusions:
Based on the acquired EMG signal, a real-time tonic seizure detection algorithm is developed. The first approach of the detection algorithm is based on a continuous increase of muscle activity over a period of time, which occurs during tonic muscle contraction. Hereby a moving window is applied to real-time check the signal's mean and standard deviation. When signal values rise continuously with a predetermined rate over a predetermined period of time, an alarm will be generated. Specific characteristics of the tonic seizure such as continuous muscle activity (no rhythmicity as is seen during clonic seizures), and a horizontal body posture are taken into account to maximize sensitivity and positive predictive value of tonic seizure detection.

Another detection approach that we are experimenting with is tonic seizure detection based on an increase in the frequency spectrum during tonic seizures [2]. During regular muscle activity and even simulated tonic seizures, frequency spectra remain below 100 Hz. During tonic epileptic seizures, the median frequency is observed to shift towards the right (towards higher frequencies) [2]. This feature of epileptic seizures combined with the characteristic of continuous activity may be the most reliable method to detect tonic seizures.

At this point in time, no outcomes regarding the performance of the sensor can be provided yet, but will be obtained in the next couple of months.
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QNeuro – cloud-based medical assistance and decision support system for effective treatment and assistance of epilepsy patients

Piotr Zwoliński, Mariusz Chmielewski
Co-authors: Jacek Mazurek, Joanna Jędrzejczak, Beata Majkowska-Zwolińska, Tomasz Mazurczak, Marcin Roszkowski, Szymon Niemcewicz, Marcin Kukiełka

The paper will present developed methods and software mechanisms of QNeuro, a medical assistance and decision support system for effective treatment of epilepsy patients. System is integrating and combining eHealth, telemedicine and medical diagnostics support system in order to provide an effective Internet platform for patient and neurologist support. The work contains the vision and elaborated functionalities of QNeuro, supporting remote care of epilepsy patients and access to medical diagnostics and treatment knowledge base. QNeuro is a SOA cloud-based system providing the latest web and telemedicine technologies that support the diagnostics, treatment and supervision of patients suffering from epilepsy.

Selected implementation technologies compose a technology stack which delivers stateful user interfaces, diagnostics and treatment processes, remote EEG and VEEG patient monitoring, GSM and chat based communication supplemented with machine learning and inference mechanisms. The system delivers tailored functionalities for patients, neurologists, consultants organizing electronic patient – medical staff communication, assistance and medical consultation. The patient portal provides mechanisms for epilepsy monitoring, recording episodes, assisting pharmacological therapy, managing documentation, scheduling visits and contacting consultations. QNeuro is also a specialised analytical tool that provides a quantitative assessment of the therapy effectiveness, including medication and documentation management. System offers an innovative approach to organise the processes and content providing visually attractive run on any device interface tailored to patient's and doctor's needs. The physitian's portal is a tool facilitating an effective

virtual medical office supporting scheduling visits, disease history inspection, therapy development and evaluation and finances management.

The tool automates many patient care processes, allowing effective diagnosis, remote EEG, VEEG examination and treatment monitoring. The essential functionalities of the system are delivered through epiEngine subsystem which is a collection of authoritative analytical services delivering diagnosis of the disease and proposing adequate and effective therapy, both pharmaceutical and alternative. The services utilise rule base reasoning techniques supplemented with machine learning algorithms. Mechanism provide means of patient case evaluation and classification in order to properly diagnose the patient and recommend treatment based on expert knowledge stored in the system. System will be initially calibrated with adequate expert knowledge supplemented with validated cases recorded within the system usage.

QNeuro will also provide a set of dedicated diagnostic devices for homeEEG and homeVEG that will provide an ecosystem of financially accessible, remote, simple to use diagnostic equipment. Assigned homeEEG functions will provide the first home EEG solution capable of performing EEG and VEEG examinations, remotely in patient's home.

The system is currently being developed and integrated, and its implementation is planned for 2019. The system is intended to support and provide new types of telemedicine care - primarily to patients with chronic and drug-resistant epilepsy. The system will eliminate the existing medical and non-medical problems and will facilitate diagnosis and treatment processes supporting patients and medical staff.

The inevitable new era of digital medicine introduces the need to create new - digital and cyber-based - platforms for the care of patients with chronic diseases. QNeuro cloud-based system is designed and developed to be unique, innovative and comprehensive medical care tool for epilepsy patients.

QNeuro project is co-financed by the European Regional Development Fund under the Operational Program Intelligent Development for the years 2014-2020 under the sub-measure 1.1.2 OP IR Research and Development related to the pilot-demonstration project in the competition 2 / 1.1.2 / 2015 PO IR

Obstacles in the implementation of wearable seizure detection techniques in a residential care facility

Nicole Rommens[1], Evelien Geertsema[1] and Gerhard Visser[1]
1. Stichting Epilepsie Instellingen Nederland (SEIN)

Background:
A growing market of seizure detection techniques increases the possibilities for monitoring seizures. In residential care facilities people with epilepsy are mostly monitored with fixed sensors, like video, audio monitoring or bed motion sensors. This leaves people unmonitored during the day, which can result in adverse events to be recognized late. This study investigates the feasibility of implementing wearable seizure detection techniques in a residential care facility to enable day-time monitoring.

Materials & Methods:
The Embrace and Epi-care Mobile were tested at the residential care facility of SEIN. The Embrace is based on movement, electrodermal activity and temperature changes, while the Epi-care Mobile is based on movement. Seven residents with tonic-clonic seizures (TCs) were included. Some of these residents were mentally impaired. Both sensors were worn day and night, with a dedicated phone, for two to four weeks. When a sensor detected a seizure, nurse staff was automatically called by the dedicated phone. Seizures, classifications and interventions were reported by nurses.

Results and Conclusion:
Results were very subject dependent. While most subjects were satisfied, two quit preliminary due to a high false positive rate and an increase in contact moments. One subject experienced movement limitations because of the sensor. Performance to detect TCs differed considerably between subjects; sensitivity ranged from 0% to 100%, false positive rate ranged from 0.07 to 4.86 per day.

The systems needed to be charged often (once a day) and long (over an hour), which was burdensome. The alarm systems were not readily suited for use in a care facility workflow. Connection and system functioning was not verified continuously, rendering seizure monitoring unreliable. Not all subjects tolerated wearing a sensor and always having a phone with them.
Wearable seizure detection techniques may support caregivers in the detection of dangerous seizures during the day. Before implementation in residential care facilities, different challenges need to be overcome like detection performance, ensuring continuous function of the system and implementation in current workflow. These techniques aren't suitable for all patients and personalized solutions are necessary.

Feasibility of home video telemetry polysomnography for assessing sleep related neurological disorders

Muthinji, P.[1,2], Mullatti, N.[1] , Amin, D.[1], Brunnhuber, F.[1], Turner, L.[2], and Stores, R.[2]
1. King's College Hospital, London, UK
2. University of Portsmouth, Portsmouth, UK

Background:
Mobile home recording devices must provide an accurate account of an individual's behavioral and physiological characteristics, be acceptable to the patients and be economically viable. The feasibility of recording synchronized multiple-parametric bio signals synchronized audio-visual recording in assessing sleep related neurological disorders in the home environment is unclear. The purpose of this study was to explore whether Home Video Telemetry Polysomnography (HVTP) can be performed successfully in people's own homes among patients referred to King's College Hospital telemetry unit to be investigated for sleep related neurological disorders.

Materials & Methods:
A mixed method with three strands was adopted. Two quantitative strands dealt with data quality and cost aspects, and one qualitative strand dealt with acceptability. A 30-channel recording was synchroinsed with audio-visual signal. A numerical score point quality grading system developed by the researcher to assess sufficiency and readability of the recorded signals was used.

Results and Conclusions:
Twenty-one patients underwent two nights of the study. The findings show that data was sufficient in for sleep analysis in 97.6%. The neurophysiological signal for sleep staging scored six points or more out of nine in 95.1% of the studies. Cardiorespiratory signal quality scored two or more out of three points in 97.6% for electrocardiogram and 85.4% for respiratory signals. Signal quality for the extended montage signals scored six points or more out of nine in 95.1% of the studies. Video quality scored nine points or more out of fifteens in 95.1%, and audio signal scored four points or more out of five in 80.5%.

The average cost was £617.25 compared to £998.49 for similar procedures within our hospital setting. The study was acceptable to patients with burden of parasomnia, environmental and financial considerations emerging as main drivers. This indicates that Home Video Telemetry Polysomnography is technically feasible, acceptable and is economically viable.

An automatic multimodal seizure detection algorithm for evaluation of ambulatory EEG recordings

F. Fürbass[1], R. Hopfengärtner[2], C. Baumgartner[3], and T. Kluge[1]
1. Center for Health & Bioresources, AIT Austrian Institute of Technology GmbH, Vienna, Austria
2. Epilepsy Center, Department of Neurology, University Hospital Erlangen, Germany
3. Department of Neurology, General Hospital Hietzing with Neurological Center Rosenhuegel, Vienna, Austria

Background:
Ambulatory EEG recordings are a cost-effective alternative to inpatient video-EEG. The feasibility to distinguish non-epileptic and epileptic events of patients using ambulatory EEG was shown previously (Dash et al, Epilept Disord 2012). Automatic evaluation of recorded EEG/ECG/EMG signals by computer algorithms will greatly reduce evaluation time by providing time points of seizures.

Materials & Methods:
Automatic seizure detection methods based on EEG, EMG, and ECG signals were developed. For each modality, seizure specific features of the current time point are compared to past values to detect an increasing seizure likelihood and for seizure classification. An increasing rhythmic signal amplitude of EEG signals with high absolute amplitude compared to an average EEG spectrum triggered detections. EMG signals were extracted by bandpass filtering of EEG signals. The Line Length of EMG signals was compared to baseline and a steady increasing of tonic activity for more than 5 seconds was required for detections of seizure. For ECG signals an elevated heart rate above 100 beats per minute with a high cardiac sympathetic index of 100 beats (CSI100) triggered detections. To assess detection performance EEG/ECG recordings of 92 patients from two epilepsy monitoring units including 494 seizures were used. Sensitivity and false detection rate were evaluated for each signal modality and for reduced electrode montages.

Results and Conclusions:
All focal seizures evolving to bilateral tonic-clonic (BTCS, n=50) and 89% of focal seizures (FS, n=139) were detected. Average sensitivity in temporal lobe epilepsy (TLE) patients was 94% and 74% in extratemporal lobe epilepsy (XTLE) patients. Overall detection sensitivity was 86%. Average false detection rate was 12.8 false detections in 24 hours (FD/24h) for TLE and 22 FD/24h in XTLE patients. Utilization of 8 frontal and temporal electrodes reduced average sensitivity by only 5% to a sensitivity of 81%. Our results show that evaluation of different signal modalities based on reduced electrode montages result in high detection sensitivities. Short detection delay and low calculation times of the algorithm will allow ad-hoc processing of data streams from mobile devices.

Transformational Power of an Integrated HVT Service Model An Impact Analysis

Franz Brunnhuber[1], Devyani Amin[1], Sushma Goyal[1,3], Zaloa Agirre[1,3], Mark Richardson[1,2]
1. King's College Hospital, London, UK
2. King's College London, UK
3. Evelina Children's Hospital, London, UK

Background:
Inpatient Video-EEG Telemetry called EMU (epilepsy monitoring units) has been the gold standard for seizure classification and presurgical evaluation. At KCH, one of the major epilepsy surgery center in the UK 80% of patients have been admitted for diagnostic VT (seizure classification) and 20% for presurgical evaluation (involving drug reduction with scalp recordings or intracranial recordings. Due to ever increasing waiting times, we started to develop a Home video telemetry service for seizure classification from 2007 which became an established service from 2011. We were able to demonstrate that the quality of the home recording matches the gold standard and brings a number of advantages to both patients and hospitals. In this paper we want to analyse and review the impact of this service model over the last 10 years.

Materials:
Using the parameters below we analyse the impact of our integrated HVT service from 2007 to 2017 (1) ratio of inpatient diagnostic VT vs diagnostic HVT, (2) reduction of inpatient VT beds, (3) bed days saved, (4) change in working practice, (5) new services developed through the HVT infrastructure, (6) No of LD patient at home vs in the hospital, (7) Home connections, 8 (Seizure review with family), (9) Ecology - skin lesions and NES, (10) financial impact

Results:
From 2007 until March 2017 over 750 patients have been recorded in the home environment of which over 20 were polysomnographies (HVT-P). In our presentation we will present data for the above parameter 1 - 10).

Conclusions:
We can clearly demonstrate that the development of HVT as a supervised out of hospital engendered a measurable transformation at King's including a better patient care for the most vulnerable, a significant number of hospital bed days saved, spawning new services and a engendering an ecological understanding of seizures and epilepsy.

Clinical evaluation of the Brain Sentinel® GTC Seizure Detection and Warning System

José E. Cavazos[1], Mike Girouard[1], Damon P. Cardenas[1], and Luke Whitmire[1]
1. Brain Sentinel, San Antonio, TX, USA

Background:
Globally there are approximately 50 million people living with epilepsy. The prevalence of epilepsy patients with frequent generalized tonic-clonic seizures (GTCS) is unknown, but is probably 10-20% of patients with intractable epilepsy and these are the patients who are most at risk for injuries, sudden unexpected death in epilepsy (SUDEP), and mortality from any cause. Status epilepticus (SE) often begins as a GTCS. Early identification of the GTCS and intervention promises to decrease morbidity and mortality in cases of SE and SUDEP. Brain Sentinel® has developed a sEMG based device intended to detect GTCS. In addition to providing early identification of GTCS, the system also processes recorded sEMG allowing physicians to identify other types of events.

Materials & Methods:
A total of 11 NAEC level IV centers prospectively enrolled199 patients admitted for video-EEG who had history of having a GTC seizure. They underwent vEEG monitoring according to standard clinical care and were monitored using the Brain Sentinel device to assess its clinical effectiveness. vEEG monitoring was reviewed independently by at least 3 board certified epileptologists for seizure classification. sEMG data was processed to identify GTCS across a variety of threshold settings. Frequency analysis of GTCS and psychogenic nonepileptic spells (PNES) was completed with wavelet transformation of single channel sEMG data, captured at 1 kHz.

Results and Conclusions:
Based on vEEG, 24 subjects (17 adults & 7 children) experienced 29 GTCS, while properly wearing the device. The device detected 100% of these GTCS within and average of 7.7 s. 10 PNES were also identified. Frequency analysis of the sEMG shows significant differences between GTCS and PNES. This device may help caregivers implement seizure action plans sooner and provides longitudinal data to physicians that they may use to better diagnose and treat patients. Quicker administration of rescue medications may reduce the incidence of SE and SUDEP. Outpatient sEMG monitoring may help identify PNES patients sooner and reduce time to proper treatment.

Ultra-long-term recordings of brain and heart

Kjaer, TW

New technology now allows for unobtrusive recording for months and years of a range of physiological parameters including electroencephalogram (EEG) and electrocardiogram (ECG). Traditionally EEG-recordings are limited to hours-days rarely more than a week. In cardiology the loop-recorder has been developed to detect and save abnormal rhythms, but whith out storing intermediate data. We currently work on three different ways to obtain continuous data on the ultra-long-time range of months to years. The talk will discuss three different technical platforms with various advantages and disadvantages.

Ear-EEG comprises of up to 15 electrodes placed in an ear-plug in one or both ears. There is a central canal allowing for passage of sound. EEG is recorded in a matchbox-sized amplifier fixed to body or clothing. Simultaneous ear-EEG and standard-EEG reveals high correlation between signals in the range from 2-25 Hz. At lower and higher frequencies noise tend to appear. The ear-EEG platform has found to be useful in sleep and epilepsy.

EEG-24/7-subQ is an implantable chip placed under the skin behind the ear with a 11 cm long 3-lead electrode pointing in any relevant direction in the subcutaneous space. This device is implanted in a 10-15 min procedure and after healing of the skin there is no skin penetration. Power is supplied from an external 13 mm - antenna placed over the chip, which also receives the EEG signal. Data in the range from 0.1 - 25 Hz is available in high quality and highly correlated to standard EEG. The electrode can be placed almost anywhere on the skull, but when placed the position is fixed. This allows for monitoring well defined foci - even if small. The EEG-24/7-subQ solution has successfully been used to detect epileptic interictal and ictal discharges, hypoglycemia and sleep.

Multimodal in-the-wild platform is on its way in our clinic. The great advantage of this platform is that it allows for simultaneous registration from a range of sensors collecting both the clinical end the electroencephalographic data characterizing epileptic seizures.

These platforms allow for better monitoring of episodic events both with the purpose of optimizing prophylactic treatment of sleep disorders, epilepsy and diabetes and to build alarm systems. The data collected will also be used to perform prediction of episodes based on EEG and ECG.

It is hypothesized that the empowerment associated with use of these devices is relevant not only in various types of patients but also in normals who want to control when to stay alert, have a good sleep and may be even when they perform better at certain tasks like learning and memory.

Real-time seizure detection performance with Embrace alert system: One year real-life setting case study

Giulia Regalia[1], Chiara Caborni[1], Matteo Migliorini[1], Francesco Onorati[1], Rosalind W. Picard[1,2]
1. Empatica Inc, Milan, Italy
2. MIT Media Lab, Massachusetts Institute of Technology, Cambridge, Massachusetts, U.S.A

Background:
Automated mobile seizure detection devices can prompt caregivers to intervene and provide objective seizure counts in daily life. However, their performance outside epilepsy monitoring units (EMUs) is largely unknown. The Embrace system is the first commercially available multimodal system combining accelerometer and electrodermal activity to detect and alert to convulsive seizures (CSs). An automated machine-learning classifier was trained using video-EEG labeled EMU data (Regalia et al 2015, AES; Onorati et al 2016, Epilepsy Pipeline) and optimized using data from outpatient settings (Onorati et al 2016, Epilepsy Congress). In a longitudinal study with real-time detection (1 patient, 3 months), Embrace reached 92% sensitivity (Se) and less than 0.5 false alarms (FA) per day (Picard et al 2016, AES). Here, we monitor another patient for nearly 1 year, and report the results.

Materials & Methods:
A patient (age 15y) with Dravet Syndrome wore the Embrace smartwatch, which sent CS alerts to a smartphone for generating calls to caregivers, and logged the calls and alerts time in an online database. The patient was never left alone and the patient's caregivers were asked to meticulously report each CS. Two data experts independently inspected all the data to further verify the accuracy of caregivers' self-reports. Se was computed as the percentage of CSs that automatically triggered an alert. FAs were counted by subtracting the number of correctly recognized CSs from the total alerts.

Results and Conclusions:
Over a period of 11.3 months (341 days), the patient wore Embrace 5,968 hours (17.5±3.5 hours per day) and experienced 46 CSs. The watch generated 96 alerts, of which 45 were CSs (Se=98%), all successfully transmitted to the phone (mean delay=13 sec) and to the online database (mean delay=16 sec). The 51 FAs occurred between 6AM and 9PM, providing a FA rate of 0.14 per day worn. In 315 out of 341 days (92%) there were no FAs. The performances of Embrace for this patient are thus in the same range as previous results obtained in best-case clinical settings. Similar longitudinal analysis on a more heterogeneous patients' population is being performed to assess Embrace's validity in a greater variety of daily life settings.

Seizure detection using a wearable device

Dr. Rajlakshmi Borthakur & Pramod Krishnan

Objective:
The utility of TJay device in identifying seizures of frontal and temporal lobe origin in comparison with standard video EEG recording.
Material and Methods: One patient each with frontal and temporal lobe epilepsy were studied with the TJay device using electrodermal activity (EDA) and heart rate variability (HRV) parameters during prolonged Video EEG study and the results were compared.

TJay is a wearable device with embedded sensors for the effective management of epilepsy using predictive analytics and machine learning. TJay has been recognized by the Department of Science and Technology, Govt. of India, among others, as one of the top innovations in India. We are the winners of the Intel DST Innovate for Digital India Challenge, which is an initiative spearheaded by Prime Minister Mr. Narendra Modi. TJay is capable of capturing electrical signals transmitted by the body, ensuring proper collection of data and timely notification of alerts.

Results:
Three complex partial seizures of left temporal lobe origin were recorded from one patient. All seizures were hypomotor with only behavioural changes and were identified on TJay device by specific EDA and HRV changes. In the patient with frontal lobe epilepsy 8 seizures were recorded in sleep on Video EEG and TJay device, which were hypermotor. In additional, TJay device recorded 3 seizures with similar EDA and HRV signatures that were missed by standard Video EEG. The true seizure burden recorded by TJay device was significantly higher than that noted on Video EEG. In both patients, physiological and voluntary activities were clearly discriminated from seizures by specific EDA and HRV features.

Conclusion:
TJay device can consistently detect nocturnal seizures of frontal origin and complex partial seizures of temporal lobe origin, including those not identified on video EEG. It can help in assessing the true seizure burden and direct titration of therapy.

Secure streaming setup for wearable sensor data for clinical studies

S. Böttcher[1], A. Brandt[1], F. Nobilia[2] , M. Kerz[2], R. Dobson[2], A. Folarin[2], J. Borgdorff[3], J. Kurps[3], M. Moinat[3], N. Mahasivam[3], D. Veerbeck[4], H. Campos [5], M. Begale[6], E. Bruno[2], M. Richardson[2], A. Schulze-Bonhage[1] and M. Dümpelmann[1]

1. Epilepsy Center, Medical Center – University of Freiburg, Faculty of Medicine, University of Freiburg, Germany
2. Institute of Psychiatry, Psychology & Neuroscience, King's College London, London, UK
3. The Hyve, Utrecht, The Netherlands
4. Janssen Pharmaceutica NV, Beerse, Belgium
5. Goldenarm, Brooklyn, NY, United States
6. Vibrent Health, Fairfax, VA, United States
The RADAR-CNS Consortium (http://www.radar-cns.org/partners)

Background:
Vendors of wearable devices, with sensors which have the potential to detect epileptic seizures, often supply applications which transfer the data of the sensors directly to a cloud run by the vendor. The transfer of such data to external commercial IT infrastructures can pose data safety problems for the evaluation of the sensor data in clinical studies, regardless of the level of security provided by the offered infrastructure. Here a setup developed by the RADAR-CNS consortium is presented which uses a secure open source streaming environment suitable for a clinical environment and allows for synchronization of wearable data with other physiological data streams.

Materials & Methods:
Signals from several wearable devices worn on the wrist or upper arm with sensors for motion, pulse wave, electrodermal response and temperature are streamed data via Bluetooth to a small, commercially available, single board computer running Android. On the computer an application developed inside the RADAR-CNS consortium gathers the sensor data and streams the data via network to a server. IO pins on the computer board allow the generation of electrical trigger signals which can be captured by the video EEG system, allowing an exact synchronization between the sensor data from the wearables to EEG and video data. On the server the data is handled by an open source stream processing platform and several RADAR-CNS-developed components. The complete platform is easily deployable as software containers in common server environments.

Results and Conclusions:
The described framework is set up at two clinical sites, the Clinical Neurophysiology Department King's College London and Epilepsy Center, Medical Center – University of Freiburg in their respective video EEG monitoring units and passed long term recording tests. It could successfully be

shown that cloud based solutions provided by the vendors of wearables can be replaced by components which are secure and under complete control of the RADAR-CNS study group.

From a patient-independent to a patient-specific seizure detection algorithm using limited heart rate data

Thomas De Cooman[1], Carolina Varon[1], Wim Van Paesschen[2] and Sabine Van Huffel[1]
1. Department of Electrical Engineering (ESAT), KU Leuven, Belgium & imec, Belgium
2. Department of Neurology, UZ Leuven, Belgium

Background:
Previous studies showed that most seizures include strong ictal heart rate changes, making heart rate a useful modality to detect seizures in a home environment. Patient-independent seizure detection algorithms however showed mediocre performance due to the large inter-patient variability in heart rate characteristics. Ideally, an algorithm is made specifically per patient, but in practice insufficient annotated patient-specific data is available in order to train a robust patient-specific classifier. Therefore the aim of this study is to evaluate whether a patient-specific heart rate based seizure detector can be trained with a limited amount of patient-specific data, so that for example annotated data from the diagnostic or presurgical evaluations in the hospitals can be used for this purpose.

Materials & Methods:
Transfer learning allows to train classifiers from a limited amount of data if a reference classifier is available. In this study, a state-of-the-art patient-independent support vector machine classifier is used as a reference. The patient-specific algorithms are then obtained using this transfer learning approach, for which 20 to 48 hours of annotated data is used for training in this study. The method is evaluated on 6 temporal lobe epilepsy patients during more than 258 hours of day and night data, containing in total 74 complex partial and secondary generalized seizures.

Results and Conclusions:
The patient-independent algorithm detected 90.5% of the seizures, but also resulted in on average 2.57 false alarms per hour. By using the patient-specific algorithms obtained through transfer learning, the false alarm rate dropped to 1.26 per hour, but also the sensitivity dropped slightly to 86.5%. This small drop in sensitivity was caused by atypical or short seizures. The results show that the algorithm can already adapt to patient-specific characteristics by using annotated data from only 1 or 2 days, leading to 50% less false alarms compared to the patient-independent classifier.

Comparison between scalp EEG and EEG recorded behind ears for development of wearable epileptic seizure detection system

Y. Gu[1,2], E. Cleeren[3], W. Van Paesschen[3], S. Van Huffel[1,2] and B. Hunyadi[1,2]
1. KU Leuven, Department of Electrical Engineering (ESAT), STADIUS Center for Dynamical Systems, Signal Processing and Data Analytics, Leuven, Belgium
2. Imec, Leuven, Belgium
3. KU Leuven, University Hospital, Department of Neurosciences, Leuven, Belgium

Background:
This study is part of a project aiming to develop a wearable seizure detection system. EEG is a well-established technique in epilepsy monitoring and diagnosis. However, current EEG systems are not designed for long-term anbulatory recordings in the home setting. For this purpose, we investigate the potential to record epileptiform EEG from electrodes worn behind ears and compare the data quality with traditional scalp EEG.

Materials & Methods:
Patients with refractory focal epilepsy underwent long-term videoEEG recordings as part of a pre-surgical evaluation using a 21-channel scalp EEG system plus 2 extra electrodes placed behind each ear. Comparison between the two electrodes behind each ear and between the left and right ears formed 4 channels behind ears. The dataset consists of several 24-hour recordings of 5 patients. Different artifacts were visually inspected and compared, while spectral coherence was used to measure the degree of similarity between channels behind ears and all other channels.

Results and Conclusions:
In general, artifacts from ocular movements were suppressed at recordings behind ears. However, it was not the case for muscle artifacts. During seizures, the coherence for LeftCenter-RightCenter, LeftTop-RightTop, LeftTop-LeftCenter and RightTop-RightCenter with their highest matched scalp EEG channel were on average 0.86, 0.83, 0.80 and 0.82, respectively. We conclude that electrodes behind the ears can reliably record epileptiform activity, therefore, are suitable for a wearable seizure detection system.

Wearable sensors in epilepsy and Parkinson's disease: A focus group study

Johansson D[1], Ozanne A[2], Alt Murphy M[1], Bergquist F[1] and Malmgren K[1]
1. Institute of Neuroscience and Physiology, Sahlgrenska Academy, University of Gothenburg, Gothenburg, Sweden.
2. Institute of Health and Care Sciences, Sahlgrenska Academy, University of Gothenburg, Gothenburg, Sweden.

Background:
Wearable sensors that measure movement and physiological variables are attractive for clinical evaluation of neurological diseases like epilepsy and Parkinson's disease (PD). In the last year alone, there were almost one hundred publications on this topic with respect to the use of wearables in neurological disease monitoring. There is, however, still a lack of knowledge about patients' and health professionals' perceptions regarding the use of wearables in epilepsy and PD. The aim of this study was to explore perceptions regarding the use of wearable technology in disease monitoring and management as reported by individuals with epilepsy, and PD as well as health professionals working with these patient groups.

Materials & Methods:
Six patient groups (n=25) and two groups with health professionals (n=15) participated in a qualitative, descriptive study with focus-groups interviews. The manifest qualitative content analysis was used.

Results and Conclusions:
Four categories and nine subcategories emerged from the analysis. Participants saw possible benefits for improved treatment effect and valued this benefit more than possible inconvenience of wearing the sensors. They emphasized the importance of interactive information between patients and health professionals before, during and after recordings. However, they were concerned about problems such as unclear information, lack of personal integrity and inconclusive recordings. Discrete design and simplicity were considered as facilitators for improved usability.

Health professionals and patients expressed some conflicting expectations and preconceptions that may hinder the use of wearables. Everyone involved needs to feel well-informed and find an added value in using the device. Wearables need to be user-friendly and have an attractive design to be applicable in clinical settings, and therefore patients have a role in contributing to the design of their monitoring.

Self-exciting point processes for modeling EEG data to forecast epileptic seizures

Perczel, György[1, 2]; Fabó, Dániel[1, 2]; Erőss, Loránd[1, 2]; Vágó, Zsuzsanna[1]; Gerencsér, László[1, 3]
1. Faculty of Information Technology and Bionics, Pázmány Péter Catholic University, Budapest, Hungary
2. National Institute of Clinical Neurosciences, Budapest, Hungary
3. Institute for Computer Science and Control, Hungarian Academy of Sciences, Budapest, Hungary

Background:
The idea to predict epileptic seizures dates back to the middle of the twentieth century. Despite intensive research in the field, a clinically applicable seizure prediction system has yet to be developed.

Here, we introduce a method that originates in the field of seismology. This choice is justified by the observation of D. Sornette and I. Osorio that epileptic seizures and earthquakes resemble with respect to their dynamics. Following this approach, we model the level crossings of an EEG signal by Hawkes' self-exciting point processes. Our aim is to develop a seizure warning system that fits this class of stochastic point processes to the EEG signal of epileptic patients and detects the changes in the parameters.

Materials & Methods:
We simulated the processes with a particular impulse response function using its dynamic representation, based on the work of A. G. Hawkes and T. Ozaki. This was followed by the maximum likelihood estimation (MLE) of the parameters of the simulated data.

Results and Conclusions:
A fairly good estimation of the parameters was received at various combinations of parameter values. However, at certain values, poor estimates of two of the three parameters occurred, thus visual inspection of the projections of the parameter-space was carried out. We found that these parameter-constellations belong to some degenerate regions of the parameter space, where the values of the cost function depend almost solely on the parameter that has been well estimated.

Our vision is to create a real-time change detection system for the parameters of the Hawkes processes fitted to the EEG of epileptic patients. The following step is to implement an on-line MLE method.

Non-patient specific forecasting of epileptic seizures using heart rate characteristics

Anton Popov[1,2], Oleg Panichev[1,2], Yevgeniy Karplyuk[1,2], Sebastian Zaunseder[3], Yaroslav Smirnov[1] and Volodymyr Kharytonov[3]
1. Department of Electronic Engineering, National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Kyiv, Ukraine
2. R&D Engineering, Ciklum LLC, Kyiv, Ukraine
3. Institute of Biomedical Engineering, Technische Universität Dresden, Germany
4. TMO "Psychiatry", Kyiv, Ukraine

Background:
Since several decades, heart rate variability (HRV) attracts lot of attention as a potential marker for epilepsy management due to availability of simple tools to reliably identify heartbeats in the everyday life environment. However, the techniques to extract the descriptive features of cardiac activity useful for robust classification between interictal and preictal states are still under development. The aim of this work is to develop the classification and validation approach for prediction of epileptic seizures using HRV characteristics.

Materials & Methods:
Recordings from subjects with generalized seizures (13 subjects, between 2 and 15 years old) were performed and validated by qualified neurophysiologist. Electroencephalogram recordings accompanied with video monitoring were used to label seizure start/stop times. Statistical, spectral, nonlinear HRV features of filtered and interpolated heartbeat intervals for raw rhythmogram and for its low- and high-frequency components were extracted in sliding windows of variable widths for interictal and preictal recordings. Support Vector Machine (SVM) was tested as classifier with Leave-One-Group-Out validation scheme.

Results and Conclusions:
Results for generalized seizure prediction with SVM, averaged over subjects: mean AUC 0.72±0.19, mean sensitivity 0.62±0.39, mean specificity 0.82±0.16. Inter-subject variance of parameters might indicate that patient-specific approach may work with HRV as a source of features. The study suggests that HRV is a promising for both patient specific and non-specific seizure prediction, but selection of both feature set and classifier is far from final solution.

Real-time seizure detection performance with Embrace alert system: One year real-life setting case study

Giulia Regalia[1], Chiara Caborni[1], Matteo Migliorini[1], Francesco Onorati[1], Rosalind W. Picard[1,2]
1. Empatica Inc, Milan, Italy
2. MIT Media Lab, Massachusetts Institute of Technology, Cambridge, Massachusetts, U.S.A

Background:
Automated mobile seizure detection devices can prompt caregivers to intervene and provide objective seizure counts in daily life. However, their performance outside epilepsy monitoring units (EMUs) is largely unknown. The Embrace system is the first commercially available multimodal system combining accelerometer and electrodermal activity to detect and alert to convulsive seizures (CSs). An automated machine-learning classifier was trained using video-EEG labeled EMU data (Regalia et al 2015, AES; Onorati et al 2016, Epilepsy Pipeline) and optimized using data from outpatient settings (Onorati et al 2016, Epilepsy Congress). In a longitudinal study with real-time detection (1 patient, 3 months), Embrace reached 92% sensitivity (Se) and less than 0.5 false alarms (FA) per day (Picard et al 2016, AES). Here, we monitor another patient for nearly 1 year, and report the results.

Materials & Methods:
A patient (age 15y) with Dravet Syndrome wore the Embrace smartwatch, which sent CS alerts to a smartphone for generating calls to caregivers, and logged the calls and alerts time in an online database. The patient was never left alone and the patient's caregivers were asked to meticulously report each CS. Two data experts independently inspected all the data to further verify the accuracy of caregivers' self-reports. Se was computed as the percentage of CSs that automatically triggered an alert. FAs were counted by subtracting the number of correctly recognized CSs from the total alerts.

Results and Conclusions:
Over a period of 11.3 months (341 days), the patient wore Embrace 5,968 hours (17.5±3.5 hours per day) and experienced 46 CSs. The watch generated 96 alerts, of which 45 were CSs (Se=98%), all successfully transmitted to the phone (mean delay=13 sec) and to the online database (mean delay=16 sec). The 51 FAs occurred between 6AM and 9PM, providing a FA rate of 0.14 per day worn. In 315 out of 341 days (92%) there were no FAs. The performances of Embrace for this patient are thus in the same range as previous results obtained in best-case clinical settings. Similar longitudinal analysis on a more heterogeneous patients' population is being performed to assess Embrace's validity in a greater variety of daily life settings.

A retrospective audit of the contribution made by a bed movement sensor (Emfit) in detecting tonic clonic seizures in an epilepsy assessment centre

Aline JC Russell, James Anderson, Victoria Grant, Mariam Elgammal , Alison Campbell , Julia Hampshire, Stig Hansen
The Scottish Epilepsy Centre, 20 St Kenneth Dr, Glasgow G51 4QD. UK.

Background:
The Scottish Epilepsy Centre (SEC) is a 12 bedded inpatient facility for the assessment and treatment of epilepsy (average length of stay 26 days). Patients are admitted for diagnostic clarification and/or medication rationalisation. 99% of patients admitted to the SEC are on treatment for epilepsy. Reducing medication underpins the process of diagnosis and rationalisation of treatment but carries a risk of harm. We wished to study the added contribution of using bed movement sensors (Emfit Ltd.) to nurse response times to tonic clonic seizures (GTCS).

Materials & Methods:
Patients are continuously observed via a network of 48 cameras (VOS). The audio-video feed can be time-locked to EEG – allowing for wireless video EEG telemetry without compromising patient mobility within the SEC. Emfit bed sensors are checked daily. Emfit alarms are visible on the VOS display screens in the nurses' office and on their handheld devices.

Daily Emfit test records, seizure record sheets, Emfit alerts, clinical incident reports and the VOS database of retained clinical events were reviewed on all patients admitted over for a 9 month period from April 2016. Response time to GTCS was calculated by reviewing the retained video clips of seizures; noting the time of clinical onset and the time nurses arrived in the patient room.

Results and Conclusions:
Of the 85 people admitted during the audit period, 15 experienced 61 GTCS. In 57 seizures the patient was in bed. The Emfit alert status was available in 51 (89%). In 8 the Emfit did not alert (16%). The GTCS was either not of sufficient duration or amplitude (5) or the patient fell out of bed early in the seizure (2). In one patient the alarm did not trigger. The average nurse response time to GTCS during the study period was 22 seconds. There was one significant injury that required medical treatment during the audit period.

The Emfit movement monitor has been shown to reliably detect GTCS. Our audit supports this, with one failure to alarm that we could not explain. We also observed a failure to trigger an alarm if clonic movements were relatively brief and/or low intensity, or, if the patient moved off the sensor at a very early stage. Our nurse response times have remained unchanged since the introduction of bed alarms.

Epileptic seizure detection based on wrist Photoplethymography (PPG): detection of noise segments

K. Vandecasteele[1,2], J. Lazaro[1,2], W. Van Paesschen[3], S. Van Huffel[1,2] and B. Hunyadi[1,2]
1. KU Leuven, Department of Electrical Engineering (ESAT), STADIUS Center for Dynamical Systems, Signal Processing and Data Analytics, Leuven, BE
2. Imec, Leuven, BE
3. KU Leuven, University Hospital, Department of Neurosciences, Leuven, BE

Background:
The aim of the global project is to develop a wearable seizure detection system based on the integration of Electroencephalogram and Cardiorespiratory information. In a first step, the Heart Rate (HR) is investigated measured by wrist-worn Photoplethysmography (PPG). A disadvantage of PPG is the presence of motion artifacts, which will lead to poor specificity in seizure detection. In order to reduce these false alarms, the noise segments should be detected and reconstructed.

Materials & Methods:
The data, used in this experiment, consists of 24-hour recordings of 9 patients, recorded in UZ Gasthuisberg with Empatica E4 (wrist PPG and trixial Accelerometry (ACC)) and Faros(ECG). The data is split in 7s segments. Each segment is labeled as clean or noisy by quantifying and comparing the HR extracted from ECG (reference) with the HR from PPG. For each segment, variance, first-/second-/third-largest peak of the spectrum, and spectral Shannon entropy are extracted in addition to other 8 features proposed in literature. Moreover, 20 ACC-derived features are calculated. A linear least-squares support-vector machine is proposed to classify the segments to a clean or noisy segment within a leave-one-patient-out approach. A backwards wrapper is applied for feature selection on PPG- and ACC-derived features.

Results and Conclusions:
The mean sensitivity and specificity (PPG/ ACC) are respectively 73.0.3 ± 18.71 /53.69 ± 19.36 and 84.65 ± 6.81/87.96 ± 6.35, showing ACC has lower sensitivity. To the best of our knowledge, this is the first study to combine these PPG-features, compare PPG- and ACC-performances and validate these features in an objective way on long-term epilepsy data.

Nocturnal supervision and SUDEP risk at an epilepsy residential setting

M van der Lende[1,2], DC Hesdorffer[3], JW Sander[1,4], RD Thijs[1,2,4]
1. Stichting Epilepsie Instellingen Nederland (SEIN), Heemstede, The Netherlands
2. Leiden University Medical Center (LUMC), Leiden, The Netherlands
GH Sergievsky
Center and Department of Epidemiology, Columbia University, New York, New York,U.S.A.
3. GH Sergievsky Center and Department of Epidemiology, Columbia University, New York, New York, U.S.A.
4. NIHR University College London Hospitals Biomedical Research Centre, Department of Clinical & Experimental Epilepsy, UCL Institute of Neurology, Queen Square, London WC1N 3BG, and Epilepsy Society, Chalfont St Peter, SL9 0RJ, UK

Purpose To ascertain whether nocturnal seizures and level of nocturnal supervision affects SUDEP risk.

Method We conducted a nested case control study. We reviewed records of all people who died over a 25-year period at two residential care settings. Four controls per case were selected from the same population, matched on age (+/- 5 years) and residential building. We recorded seizure frequencies and nature of nocturnal supervision. Nocturnal supervision was graded in three categories: 1: no supervision; 2: a listening device or a roommate or physical checks at least every 15 minutes; 3: a listening device and a roommate or a listening device and an additional device (e.g. bed motion sensor/ videomonitoring) or a listening device and physical checks at least every 15 mins. Outcome measures were compared using Mann Whitney U test and Chi square tests.

Results We identified 60 SUDEP cases and selected 198 matched controls. People who died of SUDEP were more likely to have more often had nocturnal seizures (85% of cases vs 60% of controls, p=0.001) and nocturnal convulsive seizures (77% of cases vs 33% of controls, p<0.001). Additionally, those who died of SUDEP had more nocturnal seizures (median 1,50 seizures per month vs <0,01 seizures per month; p < 0,001) and more nocturnal convulsive seizures (median 0,84 seizures per month vs < 0,01 seizures per month; p < 0,001). There was no significant difference in nocturnal supervision between cases and controls (p=0,205). The SUDEP incidence differed between both centers: 2,21 per 1000 patient years (95% CI 1,49 – 3,27) vs 6,12 per 1000 patient years. (95% CI 5,58-6,72). The highest SUDEP incidence was found in the center with a significantly lower grade of supervision (median 2 vs. 1; p<0,001) while number of nocturnal convulsive seizures was higher (median 0,84 vs. 0,33 per month; p<0,005)

Conclusions Having nocturnal seizures, in particular nocturnal convulsive seizures may increase SUDEP risk. Different levels of nocturnal supervision may account for some of the difference in SUDEP incidence.

Subcutaneous EEG recording – a tool for ultra long-term monitoring?

Sigge Weisdorf[1], Sirin W. Gangstad[2,3], Jonas Duun-Henriksen[3], Karina Mosholt[4], Troels W. Kjær[1]
1. Department of Neurology, Zealand University Hospital
2. Technical University of Denmark, cognitive systems section
3. UNEEG Medical A/S
4. Department of urology, Zealand University Hospital

Background:
Unawareness of seizures presents a barrier to adequate seizure control. It complicates precise reporting of seizures, making it difficult for physicians to evaluate the effect of the treatment. Long-term video-EEG during admission can remedy this problem, but it is costly, inconvenient and sometimes just not the right tool for the job.

A novel medical device has been developed allowing for ultra long-term EEG monitoring (weeks to months, and theoretically permanent) in an outpatient setting. The purpose of our study is to test the capabilities of this device in detecting epileptiform discharges compared to ordinary surface EEG.

Materials and Methods:
The device consists of two parts: a subcutaneous implant with three electrodes and an external device for power supply and data storage. The parts are small enough to be wearable during everyday activities, making the device truly mobile. The limited spatial coverage necessitates selection of subjects with a known seizure focus. We have chosen subjects with mesial temporal lobe epilepsy scheduled for admission in our Epilepsy Monitoring Unit. The diagnosis must be both clinically and paraclinically substantiated. We plan to recruit 5-10 subjects; two have completed admission so far. The subjects will have the subcutaneous electrode implanted prior to admission. Simultaneous EEG recordings will be performed, making it possible to compare ordinary surface EEG to the novel subcutaneous EEG. The recordings will be analyzed separately.

Results and Conclusions:
One subject had no seizures during admission, but many interictal epileptiform discharges (IEDs). Manuel quantification of three selected 15-minute epochs (sleep, awake and hypnagogic phase, respectively) identified 30 IEDs from the surface recording. 22 of these were identifiable from the subcutaneous recording, giving a sensitivity of 73,3%. The second

subject had two seizures during admission, both of which were identifiable from both recording modes.
While no firm conclusions can be drawn from these preliminary results, they do seem encouraging and we continue to recruit patients. If our current detection rate continues, this mobile device could prove to be an essential new tool for ultra long-term evaluation of treatment in the outpatient setting. We plan to test this in a follow-up study.

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