# A state-of-the-art wearable sensor for heart rate based seizure detection in epilepsy

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## PURPOSE

- To develop and validate a wearable low power prototype device for heart rate based epileptic seizure detection
- Objectives: sensitivity (SEN), positive predictive value (PPV) and technical feasibility

## METHODS

- Observational study (non-randomized, open, single-site)
- 10 subjects previously diagnosed with frequent (>1/week) major epileptic seizures with heart rate changes
- Major seizures: tonic-clonic, generalized tonic or clonic and hypermotoric
- At night during 1-4 weeks per subject
- Total of 30-50 major seizures
- Results verified by visual analysis of recorded video and comparison to previously analyzed EEG-video data

## ALGORITHM

Embedded real-time implementation of the algorithm proposed in [2] **(fig. 3)**

- Embedded RR interval computation based on wavelet transform [3]
- Detection of pattern that is characteristic for epileptic seizures **(fig. 4)**
- Original model extended with a plateau phase
- Events/alarms differ in relevance
- Adjustable parameters

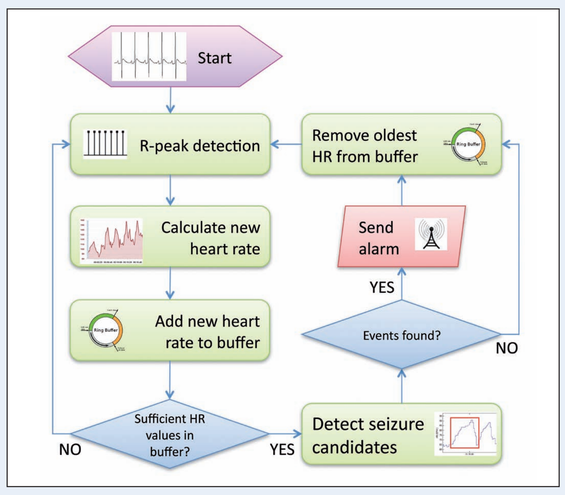


**Figure 3**
Program flow of the proposed algorithm.

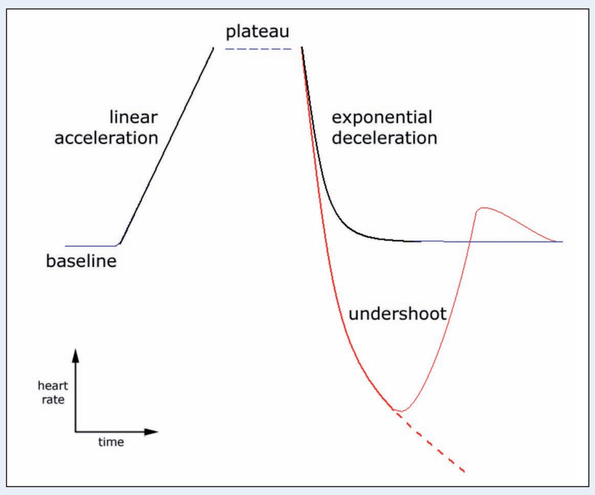


**Figure 4**
Characteristic pattern for epileptic seizures: a linear acceleration from baseline, a plateau phase and an exponential deceleration to baseline, possibly with an undershoot.

## CONCLUSIONS

- Preliminary results indicate heart rate based detection of major seizures by the proposed wearable sensor system is successful, clinically and technically
- Patients tolerate the device well and show no signs of discomfort
- For optimized sensitivity and positive predictive value the detection algorithm needs to be tuned to the patient based on seizure characteristics
- Tuned settings enable differentiation between clinically relevant and irrelevant (major) seizures (see patient 3)
- Current study will finish end of 2010
- Next phase: towards product development and market introduction
- Continuing R&D on seizure detection: multi-sensor approaches

## LITERATURE CITED

[1] Yazicioglu, R.F., T. Torfs, J. Penders, I. Romero, H. Kim, P. Merken, B. Gyselinckx, H.J. Yoo, and C. Van Hoof. 2009. Ultra-low-power wearable biopotential sensor nodes. *Conf Proc IEEE Eng Med Biol Soc* 2009:3205-8.

[2] Van Elmpt, W.J., T.M. Nijsen, P.A. Griep, and J.B. Arends. 2006. A model of heart rate changes to detect seizures in severe epilepsy. *Seizure* 15:366-75.

[3] Romero I., B. Grundlehner, and J. Penders. 2009. Robust beat detector for ambulatory cardiac monitoring. *Conf Proc IEEE Eng Med Biol Soc* 2009:950-3.

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## SYSTEM DESIGN

Wearable sensor system [1] for real-time heart rate based seizure detection

- Lightweight and miniaturized (~20g / 52x36x15mm$^3$) **(fig. 1)**
- Low power electronics (autonomy: 24 hours)
- Wireless communication for data and real-time event/alarm transmission
- Ultra-low-power bio-potential read-out ASIC
- Two wired electrode leads with patches on the chest
- Worn on the upper arm **(fig. 2)**

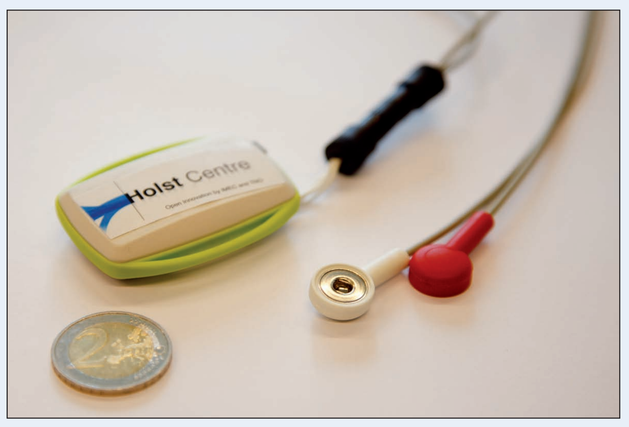


**Figure 1**
Prototype wearable system for real-time heart rate based seizure detection.

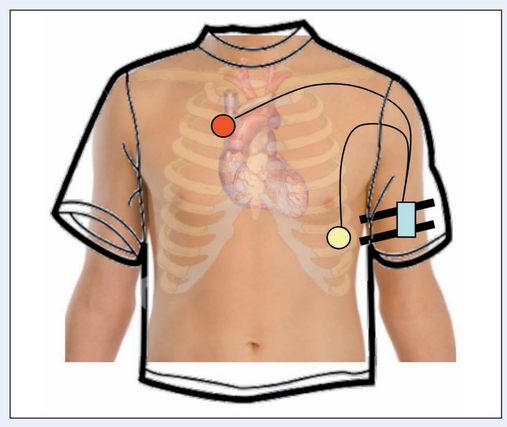

**Figure 2**
Location of the sensor system and electrodes on the body.

## RESULTS

Preliminary results available for 3 patients **(tab. 1)**

- Large heart rate changes with major seizures **(fig. 5)**
- In patient 1 and 2 PPV and SEN are 100%
  - Parameter settings tuned to patient
- Majority of seizures in patient 3 is major by definition, but clinically irrelevant **(fig. 6)**, i.e. no alarm and response is needed
  - Table shows uncompensated results
  - Improved PPV and SEN when compensated
- Technical performance is robust
  - Minor data loss due to (partial) electrode disconnections

| Patient | Results per seizure type *(true positive / false negative)* | | | | | | PPV | SEN |
|---|---|---|---|---|---|---|---|---|
| | Tonic-clonic | Gen. tonic | Gen. clonic | Hypermotoric | FP | Total | | |
| 1 | 3 / 0 | 1 / 0 | 0 / 0 | 0 / 0 | 0 | 4 / 0 | 100% | 100% |
| 2 | 0 / 0 | 0 / 0 | 0 / 0 | 3 / 0 | 0 | 3 / 0 | 100% | 100% |
| 3 | 0 / 1 | 1 / 13 | 0 / 0 | 0 / 1 | 40 | 1 / 15 | 2% | 7% |

**Table 1**
Preliminary results for patient 1 to 3.

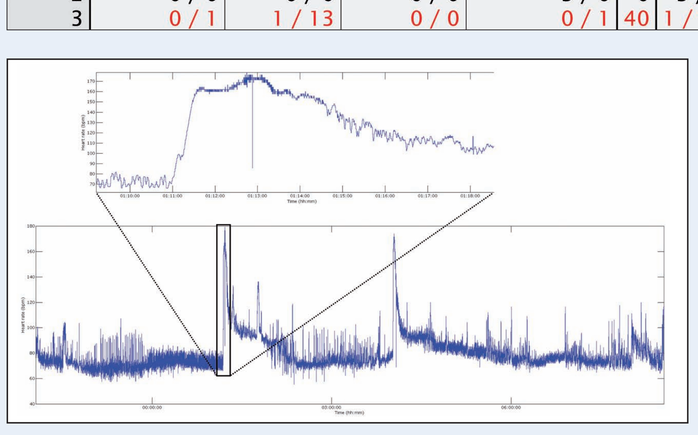

**Figure 5**
Example of heart rate changes with a hypermotoric seizure (patient 2).

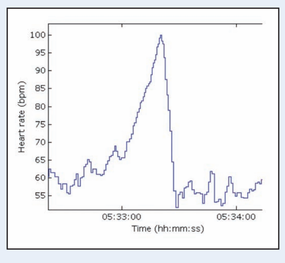


**Figure 6**
Example of a hypermotoric seizure that is clinically irrelevant (patient 3).

**FURTHER INFORMATION** Please contact *busselmv@kempenhaeghe.nl*

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