Predicting Clinical Deteriorations using Wearable Sensors

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Clinical Problem

Source: OpenClipArt

Hospital patients are at risk of clinical deteriorations such as heart attacks and strokes.

Source: OpenClipArt

Early signs of deteriorations can be identified from clinical measurements such as heart rate and blood pressure. These are measured by hand every 4-6 hours.

Source: Peter H Charlton. (2016). Wireless Wrist Pulse Oximeter Photo. Zenodo. http://doi.org/10.5281/zenodo.569814

It may be possible to monitor patients continuously using wearable sensors.

Source: Charlton, Peter H. (2016, July). The Processes and Benefits of Sharing Clinical Data. Zenodo. http://doi.org/10.5281/zenodo.166546

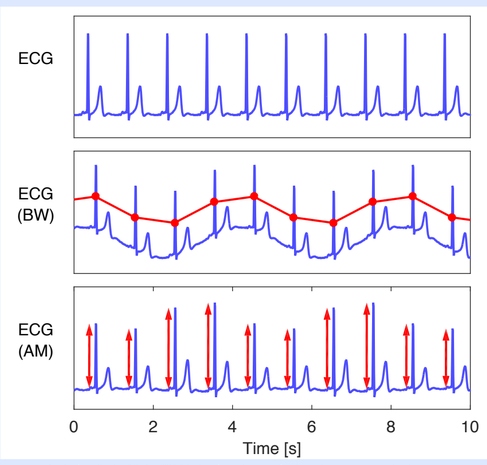
Breathing rate is a key marker of deteriorations, but it is difficult to measure electronically.

Aims

1. To develop a technique for monitoring breathing rate unobtrusively using wearable sensors.
2. To assess whether wearable sensors can be used to reliably predict deteriorations using this technique.

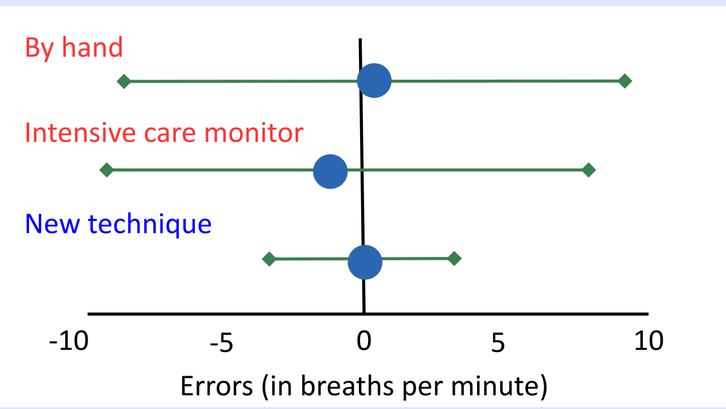
Monitoring breathing rate unobtrusively

Many wearable sensors monitor the heart using the **ECG signal**, which is influenced by **breathing**.



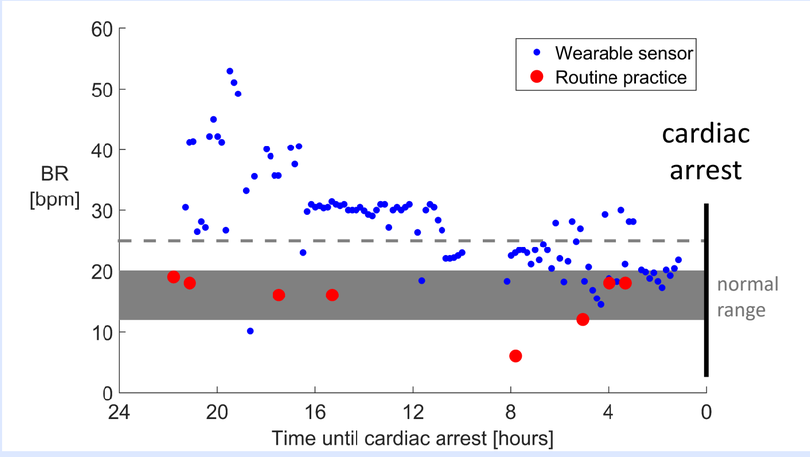
Adapted from:: Charlton, P.H. et al., 2017. Extraction of respiratory signals from the electrocardiogram and photoplethysmogram: technical and physiological determinants. *Physiological Measurement*, 38(5), pp.669–90. DOI: 10.1088/1361-6579/aa67de

A **novel technique** was developed to estimate breathing rate from the ECG. Laboratory tests showed that it was at least as precise as **existing methods**.



Adapted from: Peter H Charlton. (2018). Estimating respiratory rate from the electrocardiogram and photoplethysmogram. Zenodo. http://doi.org/10.5281/zenodo.1149001

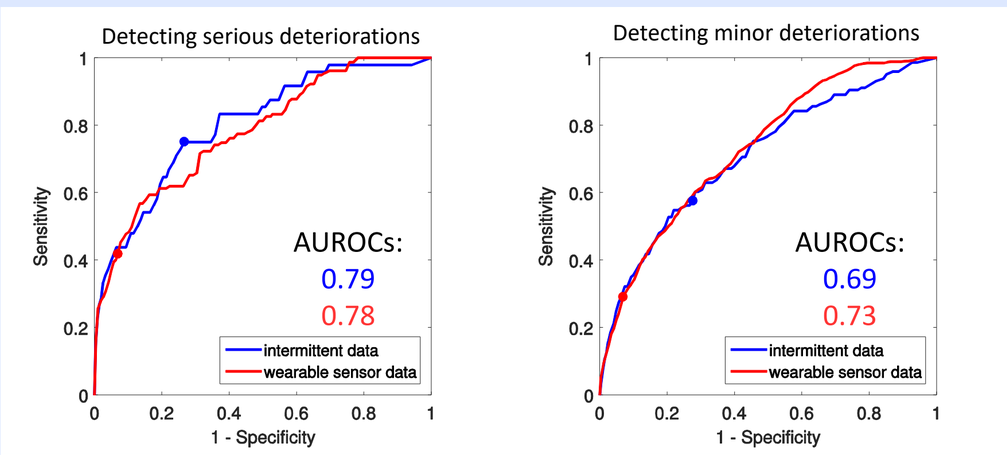
The **novel technique** was able to identify elevated breathing rates (BRs) in the hours preceding a cardiac arrest, when **routine practice** did not.



Predicting deteriorations using wearable sensors

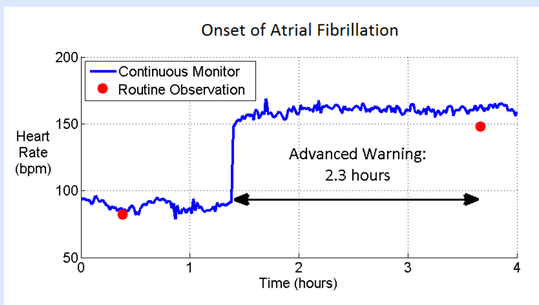
Wearable sensors predicted deteriorations with similar accuracy to routine practice

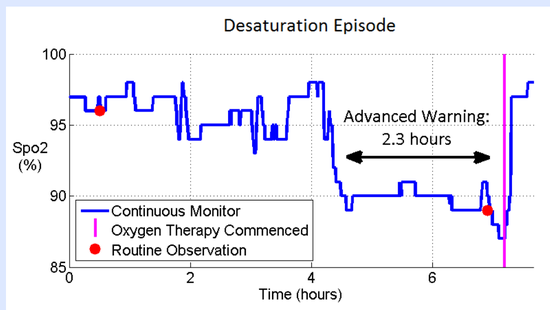
A system was designed to predict deteriorations from wearable sensor data. Its performance was assessed in a clinical trial of 184 patients. Its predictions were of similar accuracy to those made in routine practice.



Source: Charlton, P.H., 2017. *Continuous respiratory rate monitoring to detect clinical deteriorations using wearable sensors*. PhD Thesis, King's College London.

Wearable sensors gave advanced warning of physiological changes hours before routine practice





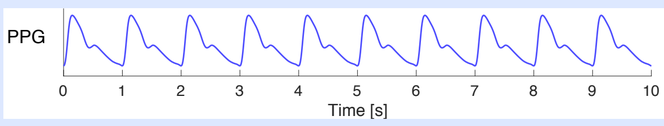
Adapted from: Bonnici, T *et al.* (2014). Continuous Physiological Monitoring of Ambulatory Patients. Zenodo. http://doi.org/10.5281/zenodo.572579

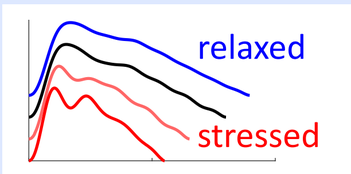
Atrial fibrillation is an arrhythmia affecting 25% of patients after heart surgery. Here, the wearable sensor identified an increase in heart rate, indicating atrial fibrillation, prompting treatment.

Here, the wearable sensor detected a drop in oxygen levels hours before routine practice, prompting earlier initiation of oxygen therapy to maintain healthy oxygen levels.

Next Steps

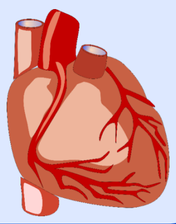
Smart watches routinely measure a signal which is influenced by both the heart and blood vessels.





Adapted from: Charlton, PH *et al.* (under review). Assessing Mental Stress from the Photoplethysmogram: A Numerical Study

The signal is indicative of **cardiovascular health**, providing opportunity to predict deteriorations in the wider population.



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