

## WELCOME—Wearable Sensors for Patients Suffering from Cardiopulmonary Diseases

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*WELCOME is a project on a vest equipped with more than 20 sensors for measuring body signals with a high spatial resolution. Being fully wearable and intuitive to use, the vest makes home monitoring of patients suffering from, for instance, chronic obstructive pulmonary disease (COPD) with comorbidities such as chronic heart failure feasible.*

An important area of progress in the modern treatment of chronic cardiopulmonary diseases is the personalization of therapy. Personalized therapy requires continuous monitoring of a patient's health status (e.g., to undertake preventive actions before an exacerbation). The most objective assessment of health status is done by measuring significant physiological signals and comparing them to a healthy population and/or by following them over time. Chronic diseases affecting multiple organs need parallel monitoring of several physiological parameters. Current devices for multi-signal recording are often bulky and do not allow the patients' state of health to be followed during their daily lives.

In the frame of the project WELCOME, CSEM has developed, together with a European consortium, a wearable system to continuously monitor a multitude of physiological parameters of patients suffering from chronic obstructive pulmonary disease (COPD) and comorbidities. The system consists of a vest with 21 so-called cooperative sensors based on a new technology patented by CSEM. The sensors are embedded in a vest (see Figure 1), where they measure and record multi-lead ECGs (electrocardiograms), heart rate and breath rate, arterial oxygen saturation (SpO<sub>2</sub>), physical activity, chest sounds, and trans-thoracic impedance for electrical impedance tomography (EIT) of the lungs. The use of many sensors allows the acquisition of body signals with a high spatial density, paving the way to wearable imaging devices and giving access to enough information to process new secondary signals such as cuffless continuous arterial blood pressure<sup>[1]</sup> or even pulmonary blood pressure<sup>[2]</sup>.

While existing multi-sensor systems usually require complex cabling between the sensors, the WELCOME vest contains only two simple wires, which facilitates production of the vest, allows a decrease in the size of the sensors, and increases the wearing comfort of the vest.<sup>[3]</sup> Besides, the WELCOME sensor vest is standalone; that is, no external cabling is needed, and it can therefore be put on like a conventional undergarment, which makes it extremely simple to use in everyday life.

Figure 2 shows signals measured with the WELCOME vest in the first experiments. A multi-lead ECG is shown in Figure 2a. Moreover, SpO<sub>2</sub> and activity-related measurements are shown in Figure 2b and c. Figure 2d shows a time series of EIT images during one respiratory cycle, depicting the intra-thoracic impedance change mainly influenced by the ventilated lungs.



Figure 1: The WELCOME sensor vest (here shown half open) is equipped with 21 sensors (diameter: 38 mm; height: 10 mm), which are in direct contact with the skin and measure a wide spectrum of body signals with a high spatial and temporal resolution.

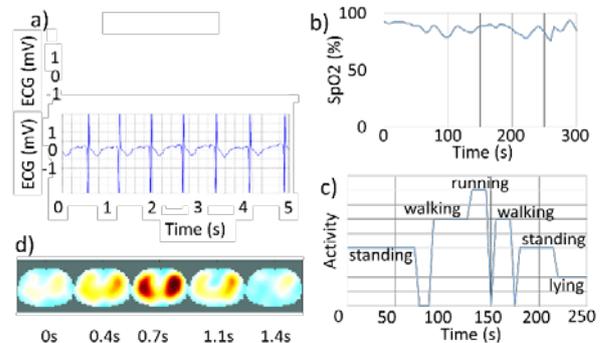


Figure 2: Some of the signals measured with the vest sensors: a) multi-lead ECG; b) SpO<sub>2</sub>; c) activity; d) time series of some of the 80-Hz EIT images of the lungs during one respiration cycle (blue = low conductivity; red = high conductivity)

In conclusion, we have developed and presented a sensor system for measuring, in a continuous manner, multiple health-relevant physiological signals of patients suffering from cardiopulmonary diseases in their home environment. Thanks to patented CSEM technology, the vest is comfortable to wear and intuitive to use. All these factors together make the WELCOME vest a new device, unique in its kind yet competitive with respect to traditional non-wearable and wearable medical measuring devices in many applications.

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<sup>[1]</sup> J. Solà, *et al.*, "Non-invasive and non-occlusive blood pressure estimation via a chest sensor", *IEEE Trans. Biomed. Eng.*, 60 (2013) 3505.

<sup>[2]</sup> M. Proença, *et al.*, "Non-invasive monitoring of pulmonary artery pressure from timing information by EIT: experimental evaluation

during induced hypoxia", *IOP Publishing, Physiol. Meas.* 37 (2016) 713–726.

<sup>[3]</sup> M. Rapin, *et al.*, "Cooperative dry-electrode sensors for multi-lead biopotential and bioimpedance monitoring", *IOP Publishing, Physiol. Meas.* 36 (2015) 767–783.