Electrode Localization through Impedance Measurements

J. Wacker, F. Braun, M. Rapin, J.-A. Porchet, C. Meier, O. Chételat, M. Egger •

Electrocardiographic imaging (ECGI) is a measuring modality which produces maps of the electrical activity of the heart by mathematically back-projecting on the epi- and endocardium the body surface potentials measured by more than 100 electrodes. The accurate localization of the electrodes on the body is important for the algorithms to correctly solve this inverse problem. The state-of-the-art methods for electrode localization, MRI and X-ray CT, are expensive, laborious, logistically complex, and potentially harmful. Here, we present a fast and safe localization method through impedance measurements performed via the same electrodes as for ECGI. For sensors measuring biopotentials, the additional hardware requirements for impedance measurement are low and therefore the method results in significant cost reductions.

One difficulty of ECGI is the necessity to precisely know the electrode positions used during the ECG acquisition. Currently, this issue is solved with an MRI or CT-scan that acquires simultaneously the body structures (thorax, heart and lungs) and the electrode positions needed for the ECGI algorithms. This approach has two drawbacks. First, it requires the patient to perform an MRI or CT-scan for every ECGI examination, which is costly, time-consuming and may overexpose the patient to ionizing radiation. Second, the ECGI examination has to be scheduled together with the MRI or CT-scan session, which is an important barrier for acceptance in clinical routine due to logistical difficulties. Methods based on optical imaging of the patient would be possible if the patient torso could be seen all around while lying. For this to be possible, cameras and especially a solution for a transparent bed are required.

The method presented here is based on impedance measurements and requires only some relatively minor modifications in the ECGI electronics. Therefore, no additional special equipment is needed. The method uses an initial recent MRI or CT scan of the patient required for the ECGI algorithm. However, the ECGI electrodes do not need to be affixed on the patient during this scan. Therefore, the ECGI examination is not logistically coupled to the MRI or CT scan. Moreover, it is frequent that the same patient requires several ECGI examinations (for example, before and after treatment) and therefore, no additional MRI or CT scans are needed.

In this so-called impedimetric self-localization (ISL) method, safe and imperceptible electrical currents are injected into the body between pairs of electrodes [1]. Simultaneously, the resulting potential is measured by other electrodes on the body. The strength of the potential is a function of space (distance from the current injecting electrodes) and local electrical properties of the body. In summary, the method consists in 1) calculating the potentials on the torso based on a model determined by the initial MRI or CT scan, and 2) identifying the positions matching the measured potentials. The model can be calibrated thanks to the knowledge of a few “landmark” electrode positions on the body. The landmarks are preferably spots which are easily detected by eye/palpation and on MRI/CT scans (e.g. the clavicles, vertebrae).

Using cooperative sensor technology [2], we developed a system with 12 landmark electrodes (injecting currents) and 100 measuring electrodes (recording the resulting potentials) and tested it on a water tank which was filled with saline water and serves as a model for a human torso (see Figure 1). A full recording to localize all sensors takes ~13 seconds.

Figure 1: Cooperative ECGI/ISL sensors mounted on a water tank.

The positions of the sensors were then calculated based on the measured potentials. Since the electrodes are arranged in a regular grid, their actual position is easily defined for comparison with the calculated position. Note that in a study on patients, the position of the electrodes is less regular, and the evaluation of the accuracy of ISL requires comparative imaging (e.g., photography, MRI/CT scans). Overall, we found a localization error of 5.45 ± 5.43 mm (mean $\pm$ standard deviation), and 86% of the electrodes had a localization error < 10 mm which was previously determined by simulations as acceptability threshold. These results therefore stimulated the drafting of a clinical study to verify the performance of the proposed method on a few healthy volunteers.

This study is currently on-going, in cooperation with the Geneva University Hospital (HUG). This project has received funding from Innosuisse (Innovation project 37705.1 IP-ENG). The authors thank Innosuisse for the support.

• EP-Solutions, Yverdon-les-Bains

[1] F. Braun, M. Rapin, J. Wacker, O. Chételat, System and method for automatic localization of the spatial position of electrodes on a conductive body, EP 4 129168A1

[2] O. Chételat, M. Rapin, B. Bonnal, A. Fivaz, J. Wacker, B. Sporrer, Remotely Powered Two-Wire Cooperative Sensors for Biopotential Imaging Wearables, Sensors, 22 (2022) 8219.