Functional image of separated ventilation and cardiac activity in EIT

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Abstract: Although primary used for monitoring ventilation, Electrical Impedance Tomography (EIT) can also give valuable information regarding cardiac activity. In this contribution we show a set of functional images which display the spatial intensity and relative phase of both the ventilation and the cardiac activity.

1 Introduction

Given the large impedance variation of the lungs during the respiration, Electrical Impedance Tomography (EIT) is routinely used to monitor the ventilation of a patient.

However, information associated with the cardiac cycle are also present [1]. These are likely connected with the volume changes, deformation in the heart, and with the shifting of structures produced by the cardiac dynamics [1]. Unfortunately, in a standard EIT setup, the intensity of the cardiac-related signals is much lower than that of the ventilation [1].

We propose to separate the ventilation and cardiac-related signals in EIT through an harmonic analysis [2, 3].

As schematized in the first row of Fig. 1, the impedance trend at every pixel of a series of EIT images can be expressed as an amplitude modulation of the harmonics of the ventilation $\mathbb{V}$ and cardiac-related signal $\mathbb{C}$ [2, 3].

$$p(t) = \sum_{f \in \mathbb{V} \cup \mathbb{C}} g_f(t)\cos(2\pi f t) - h_f(t)\sin(2\pi f t) \qquad (1)$$

where $g_f(t)$ and $h_f(t)$ are the in-phase and out-of-phase modulations at the frequency f, respectively, and they can be expressed through suitable polynomials [4].

Taking independently the frequencies belonging to $\mathbb{V}$ and to $\mathbb{C}$, the ventilation and cardiac-related signal can be reconstructed separately (see second row of Fig. 1).

From the polynomials $g_f(t)$ and $h_f(t)$ one can calculate the amplitude for the ventilation and cardiac-related signal for every pixel. These amplitudes can be used to construct two functional images, A_V and A_C, (third row of Fig. 1) which respectively map the local magnitude of the ventilation and cardiac activity at every pixel. Similar functional images are also possible for the phase ϕ_f.

2 Methods

The reliability of the functional image reconstruction based on the harmonic separation of the ventilation and cardiac-related signals was tested on a set of simulated data as well as on clinical data.

The pixel-wise algorithm was based on the extraction of the principal component (PCA) of the impedance trends.

3 Results

The functional images, A_V and A_C, clearly identified the location of maximal activity for ventilation and cardiac dynamics. For the simulated data, A_V and A_C well matched the ground truth. For the clinical data, the location of maximal activity for the ventilation and for the cardiac activity fell at the expected position of lungs and heart, respectively.

The phase-related functional images showed clear phase delay between the region of maximal activity and the surrounding areas. However the interpretation of these images is at the moment not clear.

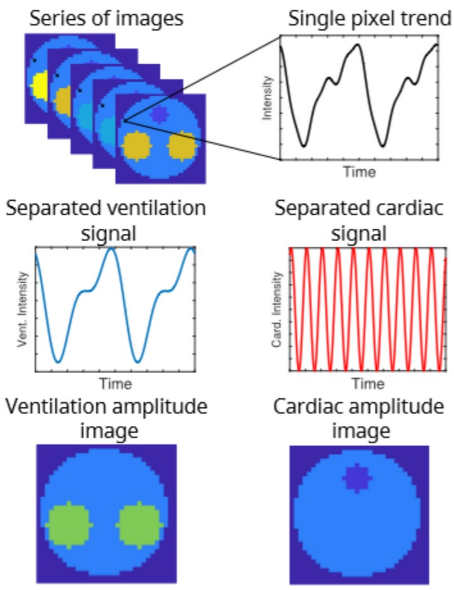

Figure 1: Schematic to represent the procedure to construct EIT functional images from a series of EIT frames.

4 Conclusions

Through harmonic analysis it is possible to create EIT functional images which display the region of maximal activity of the ventilation and cardiac dynamics.

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References

[1] JM Deibele, H Luepschen, S Leonhardt *Physiol. Meas.*, 29: S1–S14, 2008

[2] A Battistel, C Rongqing, N Hallemans, R Pintelon, J Lataire, K Möller, *IFAC-PapersOnLine*, 54: 281–286, 2021

[3] A Battistel, C Rongqing, N Hallemans, R Pintelon, J Lataire, J Lovas, K Möller, *AUTOMED 2021* , Basel, Switzerland, 2021

[4] N Hallemans, R Pintelon, X Zhu, T Collet, R Claessens, B Wouters, A Hubin, J Lataire *IEEE Trans. Instrum. Meas*, 70: 1–14, 2021