Influence of heart motion on EIT-based stroke volume estimation

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Abstract: Cardiac electrical impedance tomography (EIT) signals are affected by myocardial motion. The feasibility of stroke volume estimation using such signals is thus questionable. Results based on a dynamic model show that myocardial motion indeed affects but does not compromise stroke volume estimation.

1 Introduction

In EIT, cardio-synchronous impedance changes in the heart region are assumed to reflect variations of blood volume originating mainly from the ventricles [1]. EIT appears therefore as an interesting continuous and non-invasive modality for monitoring total ventricular volume (TVV), and thus estimating total stroke volume (TSV), defined as the maximal change in TVV over a full cardiac cycle. However, there is increasing evidence that other factors – unrelated to blood volume changes – are contributing to these variations of cardiac-related impedance [2]. In that context, simulations we performed on a finite element 2D extruded dynamic bio-impedance model showed that EIT signals in the heart region might be dominated by myocardial motion-induced changes [3].

These findings raised the question whether heart signals – affected by myocardial motion – remain valid for estimating changes in TVV and thus TSV. The hypothesis that the total impedance change in the heart area remains a true indicator for TVV and TSV is thus investigated here.

2 Methods

To test this hypothesis, we exploited the above 2D dynamic bio-impedance model – created from segmented magnetic resonance (MR) data imaged in the heart horizontal long axis plane – and considered three scenarios: In *Scenario A*, we reproduced cardiac blood volume-related impedance changes by simulating the filling and emptying of the cardiac cavities. In *Scenario B*, myocardial motion-induced changes were reproduced by simulating the dynamics of the heart muscle. Finally, *Scenario C* is the real-case scenario and simulates both blood volume-related and motion-induced changes [3].

These simulations were performed on our finite element model over a full cardiac cycle (corresponding to 20 simulated EIT frames) using the open source EIDORS toolbox, with image reconstruction carried out by the GREIT approach [4]. For each scenario, the impedance change ΔZ – with respect to end-diastole in the heart area – was computed for all frames, thus providing an EIT-based indicator for TVV, according to our hypothesis. Hereafter referred to as TVV_{EIT}, it was expected to perform best with *Scenario A* (no heart motion) and worse with *Scenario B* (heart motion only).

The reference TVV_{REF} was obtained by summing the volumes V_{LV} and V_{RV} of the left and right ventricles. V_{LV} and V_{RV} were computed via the area-length method [5] – with the areas (Σ_{LV} and Σ_{RV}) and lengths (L_{LV} and L_{RV}) coming from the MR data used to create our model:

$$TVV_{REF} = c_{LV} \cdot \Sigma_{LV}^2 / L_{LV} + c_{RV} \cdot \Sigma_{RV}^2 / L_{RV} \text{ (ml)}, \quad (1)$$

where $c_{LV} = 8/(3\pi)$ [5] and $c_{RV} = 2/3$ [6]. L_{RV} was measured in the vertical long axis plane [6]. The total end-diastolic volume $TEDV_{REF}$ and the total stroke volume TSV_{REF} inferred from TVV_{REF} (see Figure 1) were used to compute TVV_{EIT} by translating ΔZ – normalized by its maximal (systolic) value – into millilitres:

$$TVV_{EIT} = TEDV_{REF} - TSV_{REF} \cdot \Delta Z_{NORM} \text{ (ml)}. \quad (2)$$

3 Results

The estimation error (mean±SD) between TVV_{REF} and TVV_{EIT} was of 1.9±13.3, –14.1±19.5 and –10.1±15.7 ml for *Scenario A*, *B* and *C*, respectively.

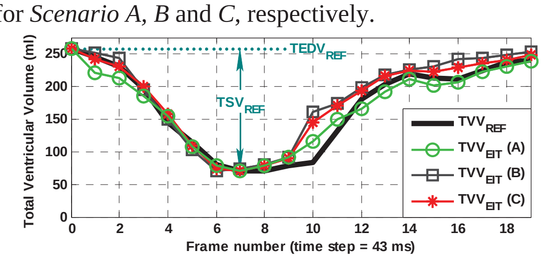

Figure 1: Total ventricular volume estimation using simulated EIT cardiac signals originating from blood volume-related impedance changes (*A*), motion-induced changes (*B*), or both (*C*).

4 Conclusions

In agreement with our expectations, simulations showed that myocardial motion increased the error on TVV_{EIT} and thus EIT-based TSV estimation, without however compromising the approach. When both blood volume changes and myocardial motion are in action (*Scenario C*, real-case scenario) an EIT-based TVV estimation error of –10.1±15.7 ml was obtained, which is sufficiently low to be clinically useful in normal subjects [5].

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Excerpted from:

Proceedings of the 15th International Conference on Biomedical Applications of

ELECTRICAL IMPEDANCE TOMOGRAPHY

Edited by Andy Adler and Bartłomiej Grychtol

April 24-26, 2014
Glen House Resort
Gananoque, Ontario
Canada

This document is the collection of papers accepted for presentation at the 15th International Conference on Biomedical Applications of Electrical Impedance Tomography.

Cover design: Bartłomiej Grychtol
Photo credit: ©1000 Islands Photo Art Inc. / Ian Coristine

Printed in Canada

ISBN 978-0-7709-0577-4

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