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Stroke Volume Monitoring via Electrical Impedance Tomography (EIT)

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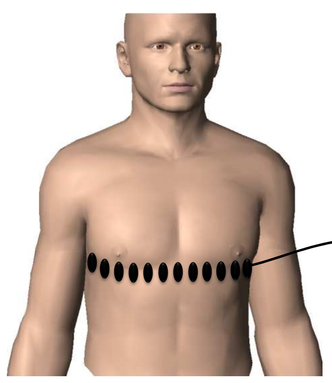
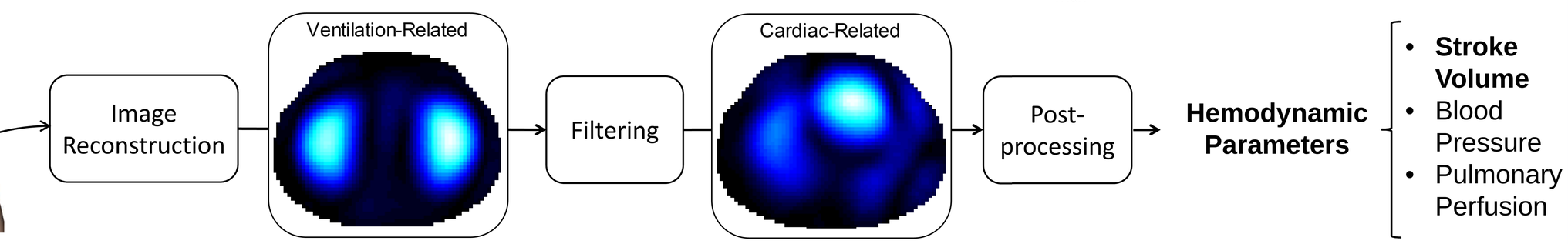
Introduction

Electrical Impedance Tomography (EIT) is a functional medical imaging technique successfully used to monitor ventilation [1]. Conductivity images enable a regional analysis of lung tissue. Besides that, EIT is also an appealing candidate to measure cardiovascular-related changes [2].

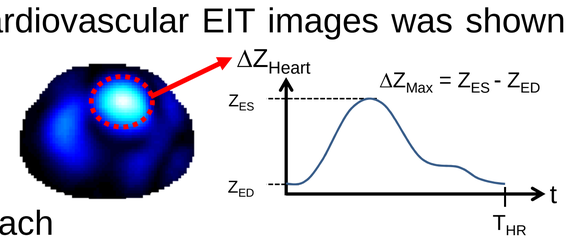
Compared to other medical imaging modalities, EIT has the advantages of being non-invasive, low-cost and enables continuous bedside monitoring.





Stoke Volume (SV) via EIT

The potential to estimate hemodynamic parameters – such as blood pressure or stroke volume – from cardiovascular EIT images was shown in different previous studies [3-6].



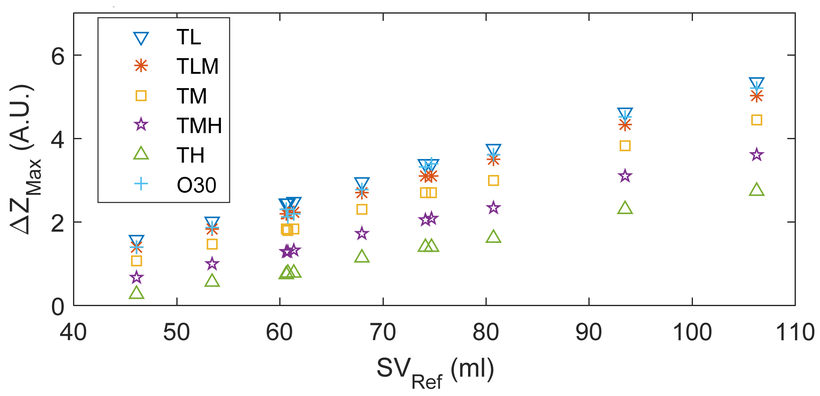
In the current work we concentrate on the non-invasive assessment of stroke volume in humans. This approach exploits the impedance changes in the heart region and relates the maximal impedance change ΔZ_{Max} to SV.

Bio-Impedance Simulations

To show the feasibility of EIT-based SV monitoring, impedance simulations were performed. To this end, a previously reported **4D bio-impedance model** [7] of a human thorax was adapted to simulate different SV.

1. Different SVs were simulated by altering the ventricular volumes:

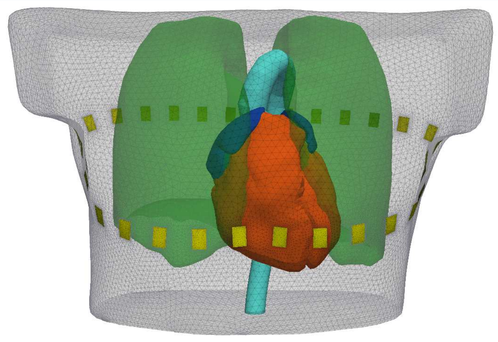
- 11 **different SVs** (46 to 106 ml) **simulated**
- Six EIT belts with were placed at the level of the heart
- **Strong correlation** (R>0.99) between **ΔZ_{Max} and SV_{Ref}** is observed



2. The influence of longitudinal (up/down) and rotational (left/right) electrode shifts on EIT-based SV estimation was investigated.

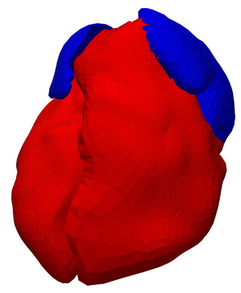
	Down		Up		Left			Right		
Shift (cm)	1.8	3.5	1.8	3.5	1.3	2.7	4.0	1.3	2.7	4.0
Abs. Error (ml)	7±2	12±4	-10±5	**-21±10**	4±4	11±10	**20±16**	-1±3	1±5	5±8
Rel. Error (%)	10±4	17±5	-14±7	**-30±13**	6±6	16±14	**28±23**	-1±5	2±7	7±11

- The **displacement** of **EIT electrodes** can induce **significant errors** severely impairing the estimation of absolute SV values.
- Results call into question the intra-subject repeatability and the inter-subject comparability of absolute SV values
- However, in all cases the **trending ability** was **not impaired**



4D Heart Model

- Artificial modulation of ventricular volumes
- Simulate different stroke volumes (SV)



4D bio-impedance model of the human thorax

Clinical Study

The concept of EIT-based SV monitoring is currently being tested in a **clinical trial** in **humans**:

- Patients undergoing surgery of cardiovascular system
- Reference SV measured with **right heart catheter**
- Compared to **EIT SV estimates** assessed **non-invasively**
- Measurements of SV before and after injection of anesthetics

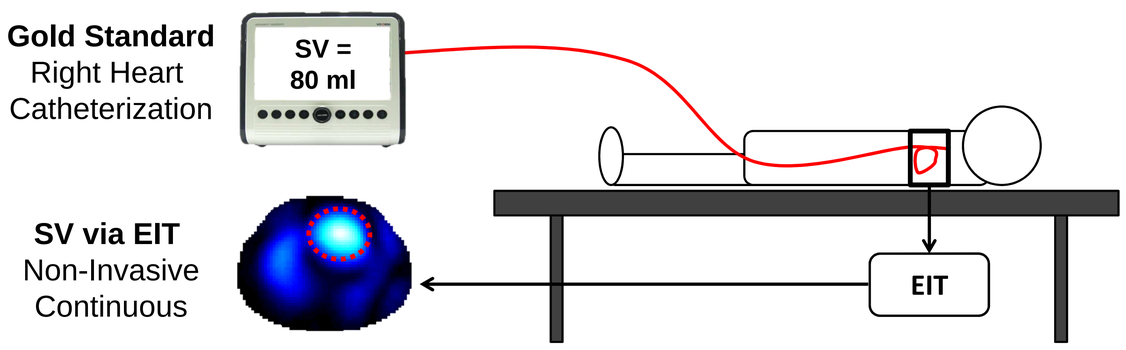


Illustration of the Clinical Study Setup

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