Abstract

There are a variety of inverse ECG algorithms and computational models currently available that attempt to reconstruct electrical images of the heart from densely sampled recordings at the body surface. However, to date their suitability for in-vivo and clinical situations is largely unknown. Before an inverse electrical imaging procedure can be used as a non-invasive diagnostic tool with confidence, it must first be validated so that recorded experimental observations can be faithfully reproduced.

We report here on an integrated experimental and modelling program that is working towards obtaining the necessary in-vivo data required to comprehensively validated and refine the various approaches to inverse electrocardiography. In particular, we aim to correlate, using a model-based approach, the electrical signals from a dense sampling of body surface ECGs with concurrent electrical activity recorded directly from the ventricles in closed-chest anaesthetised pigs, under conditions of sinus rhythm, epicardial pacing and regional ischaemia.

An *In-vivo* Experimental-Computational Framework for Validating Inverse ECG Methods

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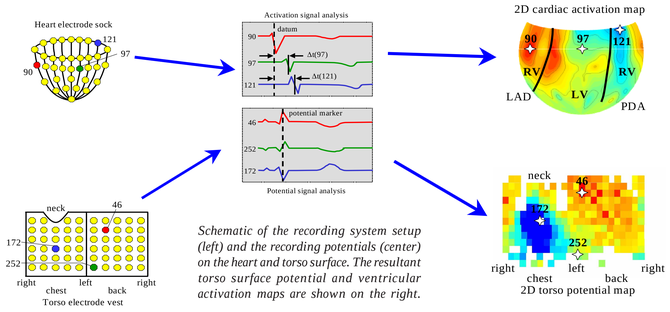
Aim

We aim to develop an experimental framework to gather the necessary data to validate numerical algorithms for solving the inverse problem of electrocardiography. The data involves an appropriate geometrical model and concurrent potential measurements on the torso and heart surfaces. These data will then be used as input for a variety of myocardial activation time and epicardial potential based inverse procedures.

Heart & Body Surface Potential Mapping

Dense potential recordings can be obtained, *in-vivo*, concurrently on the epicardial and torso surface signals using an epicardial sock and a torso vest. There is a inter-electrode spacing of ~10 mm on the epicardial sock and ~15 mm spacing on the torso vest.

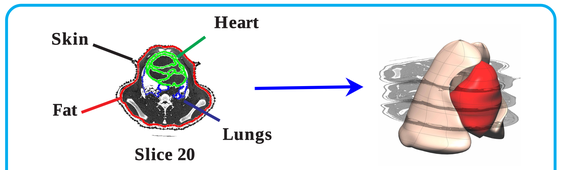


Schematic of the recording system setup (left) and the recording potentials (center) on the heart and torso surface. The resultant torso surface potential and ventricular activation maps are shown on the right.

- Anaesthetised domestic pigs are thoracotomized and pericardectomized and an epicardial sock placed around the heart.
- The chest is closed and intra-thoracic pressure re-established.
- The electrode vest is then placed over the torso surface.
- Concurrent potential recordings can then be obtained on the epicardial and torso surfaces.
- Sock electrodes are located *in-vivo* using sonomicrometry and torso surface electrodes located using a mechanical digitizer.

Generic Model Construction

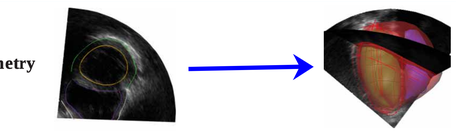
- A generic geometric model was constructed from 99 transverse CT images of a pig. These images were then digitized to provide three-dimensional data sets for each anatomical surface (endocardium, epicardium, lungs, fat and skin). A non-linear optimization procedure was used to obtain a bicubic Hermite description of each surface.
- The appropriate mesh resolution required for the forward and inverse problems was then determined by performing a series of convergence simulations.
- The converged model is then used as the initial mesh for subject-specific customization.



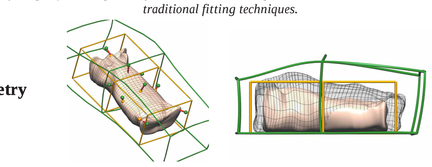
Construction of the porcine model from transverse CT images. The assembled model is shown above with CT images overlayed at 25 mm intervals.

Subject Specific Models

A geometric model specific for each subject is required for the data to be accurately interpreted. Heart geometry is obtained from three-dimensional ultrasound and the torso surface customized by matching exterior landmarks.



Subject specific heart geometry can be obtained using three-dimensional ultrasound and traditional fitting techniques.



Creation of a subject specific torso model from ten control point pairs. The gold spheres represent the landmark positions and the green spheres the target points. The distances between the control points are then minimized by adjusting the gold host mesh.

Experimental Protocols

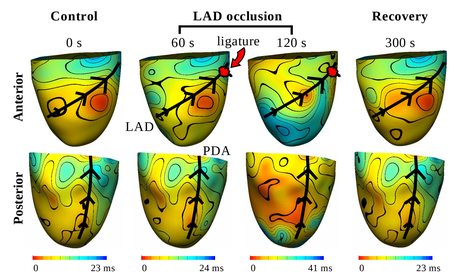
With our experimental setup it is possible to examine the potentials under both control and pathological conditions such as:

- ventricular epicardial pacing
- regional ventricular ischaemia
- hyperkalaemia

The effect of regional ischaemia is illustrated below.

Effect of Regional Ischaemia

The left anterior descending (LAD) coronary artery was ligated proximally and occluded for 2 minutes. Ventricular epicardial potentials were sampled at 60 s intervals. The epicardial activation sequence was largely unchanged for the first minutes of ischaemia, however, gross changes in activation and signal amplitudes were observed following the subsequent 60 s of occlusion. Epicardial activation fully recovered after 3 minutes of re-perfusion.



The effect of LAD occulsion over a 2 minute period on the activation sequence on the epicardial surface. During this period the activation pattern is largely unchanged but duration of the activation sequence is significantly lengthened. Full recovery is achieved after 3 minutes of re-perfusion.

Current State

We have now established the experimental protocol to simultaneously record *in-vivo* epicardial and torso potentials and aim to validate the inverse algorithms using these data. The information gained from this study will help to determine the feasibility of using body surface mapping as a clinical diagnosis tool.