Simulations towards optimal esophageal lead system

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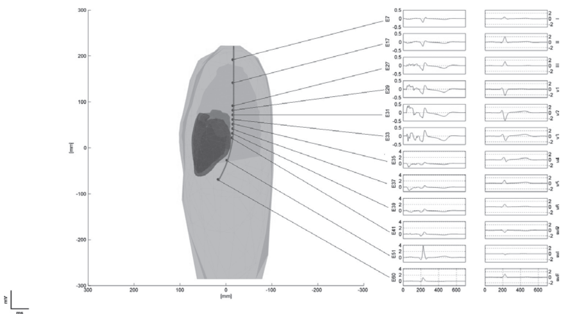
Rhythm disorders in the heart like atrial fibrillation may have serious consequences. The standard and most effective approach to detect arrhythmias is the electrocardiogram (ECG). In particular for paroxysmal arrhythmias long-term recording is crucial. Lead positioning and signal morphologies are still under investigation. A mathematical model may help us from, to make predictions helping us to understand the signals better. The aim of this work is to derive such a model. 1

Heart rhythm disorders like atrial fibrillation have serious consequences and increase the risk for stroke, heart failure, and ultimately death. The standard test to detect any arrhythmia is the electrocardiogram; anyway, for paroxysmal arrhythmias and infrequent episodes of syncope a long recording time is required. Esophageal leads are a good candidate to measure long-term signals, and could be the base of an implantable monitor. The anatomical relation of the esophagus with the left atria allows us to have a more detailed electrical activity of the heart's atria. Lead positioning and signal morphologies are still undergoing study, making a mathematical model of first necessity. Its predictions can save a lot of resources. The aim of this work is to derive such a model and make some predictions like the optimal lead configuration.

In bioelectricity problems, the currents, capacitances, and other electromagnetic elements are distributed in the media, and a volume conductor model has to be derived for Poisson's equation in order to know how the potentials are distributed. In these scenarios the Green's second identity is one of the most powerful and elegant mathematical techniques available, it basically allows us to know the potential solution in the whole space just by knowing the solution in one of the boundaries.



Normal esophageal signals calculated at different depths

The source model of electrocardiography was implemented by rewriting Ohm's law with the help of the previously sketched method. Boundary element method techniques are used to discretize the equations and set up a transfer matrix relating the activity in the heart with the potential on the different surfaces. The codes to carry the calculations were generated in MATLAB and the anatomical model and reference data was exported from the ECGsim software.

Two cases where evaluated, a healthy young male and a handpicked pathological case.

The healthy young male was used as a validation of our technique in a real life scenario. The pathological case was studied with the aim of proving if an ectopic beat which can be difficult to detect on the surface ECG can be unmasked and easily detected with an esophageal measurement.

Our calculations show that the highest peak-to-peak atrial signal amplitude obtained with a bipolar lead configuration in the esophagus is located in the 15 to 30 [mm] inter electrode distance range around a zero line that can be defined by different criteria; like signal steepness, amplitude, etc. Specific ectopic activity was successfully identified on the esophageal channel.

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