Esophageal ECG Signal Acquisition System and Left Atrium Size Estimation for EsoLive

Degree programme: Master of Science in Engineering | Specialisation: Electrical Engineering
Thesis advisors: Prof. Dr. Marcel Jacomet, Christof Baeriswyl
Expert: Emily Kathryn Thompson

A prototype version of a biopotential signal acquisition system for standard 12-lead electrocardiography (ECG) and multichannel esophageal ECG (EECG) is evaluated for its signal quality characteristics and appropriate design changes are proposed. Research and proof-of-concept investigating how the heart size can be estimated based primarily on EECG and ECG is realized. In a first step, the focus is on the left atrium (LA).

Introduction & Problem Statement

EsoLive is a novel tool for noninvasive, real-time 3D-mapping of cardiac activation. This medical device consists of an embedded biopotential acquisition system, a 3D electrode esophageal catheter and the EsoLive software. The acquisition hardware was developed in previous works and is now evaluated for its signal quality and safety requirements for use in a medical environment. Esophageal ECG (EECG) signals are acquired close to the left atrial (LA) posterior wall, implying that the height of the LA can be inferred. Together with literature research, methods to estimate the LA geometry are developed that ideally rely only on immediately available patient data.

Esophageal ECG Acquisition System

Embedded and host-PC software was refined, and the performance successfully verified. Patient leakage currents were tested according to IEC 60601-1 limits. 12-lead ECGs exhibited high levels of powerline interference, especially on precordial leads. The cause was identified as an isolation mode leakage current, together with insufficient common mode rejection in the signal path. Several improvements were proposed and tested successfully, leading to noise readings below 2.1 uVrms and making our system comparable to the baseline reference (g.HIAMP from g.tec medical engineering GmbH), at a much lower cost.

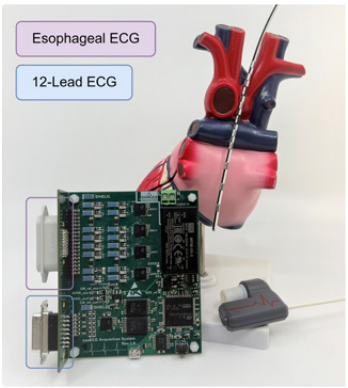
Left Atrium Size Estimation

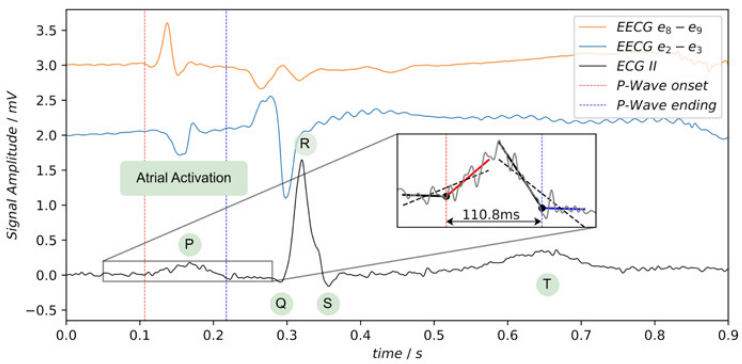
EECG signals measure the time-varying cardiac electric field as projected in the esophagus. Hence the extent of where the esophagus 'touches' the LA posterior wall, a measure for LA height, can be assessed. Alternatively, linear mapping of the P-Wave duration, measured by utilizing a two-sided line model generated with autonomous linear state space models, gives an estimation of the LA diameter.
With known anatomical reference values, the two remaining orthogonal linear dimensions can be inferred, although significant inter-patient variability exists. With these size estimations, a simplified parametric 3D model of the LA chamber is conceived, which is in good agreement with a small number of patient recordings made in a previous clinical study.

Conclusions & Outlook

Signal quality and safety design issues were evaluated, and proposed changes are documented to enable a swift redesign and short time-to-market for a specialized, IEC 60601-1 compliant hardware at lower cost than comparable systems. Derived methods and documented limitations for LA size estimation constitute the basis for further clinical studies that shall result in a patient specific heart model, thus improving EsoLive's 3D mapping accuracy without requiring invasive and expensive imaging modalities.

Bruno Stucki
bruno.stucki@hotmail.com





Signal Acquisition Hardware and Heart with Catheter in Posterior View | Selected EECG and ECG Signals with P-Wave Detection