Catheter-based Acquisition of Multi-Modal Esophageal Signals

Gabriele Zambelli

Supervisors: Prof. Dr. Thomas Niederhauser, PD Dr. med. Dr. phil. Andreas Häberlin, MSc Nishant Gupta
Institutions: Institute for Human Centered Engineering, Bern University of Applied Sciences
Department of Cardiology, Bern University Hospital, University of Bern
Examiners: Prof. Dr. Thomas Niederhauser, PD Dr. med. Dr. phil. Andreas Häberlin

Introduction

Many biosignals can be monitored using esophageal catheters: blood oxygen saturation through PPG, peristaltic motion through pressure sensors and temperature are some examples. By using a catheter equipped with electrodes, ECG and impedance can possibly be measured from different locations via multiplexing. For this reason, acquisition time has to be minimized, either maximizing the excitation frequency for impedance measurement, or acquiring ECG and impedance simultaneously, to separate them subsequently in digital domain through filtering. In this master thesis it has been investigated the frequency range for impedance measurements in the esophagus, and also the feasibility to digitally filter simultaneously acquired ECG and Impedance data.

Materials and Methods

To demonstrate that respiration can be monitored with impedance, it has been set a measuring setup with a Lock-in Amplifier used as dedicated measuring device. *In-vivo* esophageal measurement tests have been performed using 10kHz and 1MHz excitation frequencies, alternating apnea and normal breathing.

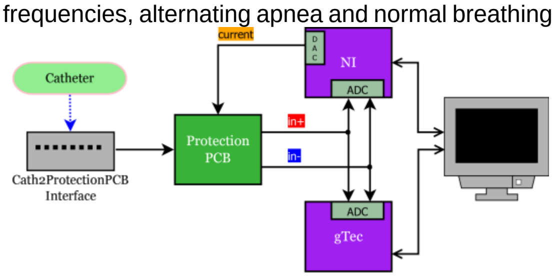

Fig. 1 Simultaneous sampling of ECG and impedance through a multipurpose and a reference device

A multipurpose setup is proposed to measure both ECG and impedance simultaneously, and a biopotential dedicated setup is used as reference to quantify the ECG quality delivered by the proposed setup. The measurements have been taken simultaneously with both devices, which combination is shown in figure 1. The impedance data is handled by the proposed setup. Also in this case, *in-vivo* esophageal measurement have been performed.

Results

The measured impedance signals show a qualitative contrast between normal breathing and apnea, suggesting that respiration can be monitored using this modality (figure 2). The electrode location and the excitation frequency changes the sensitivity to other physiological signals (heart motion, peristalsis).

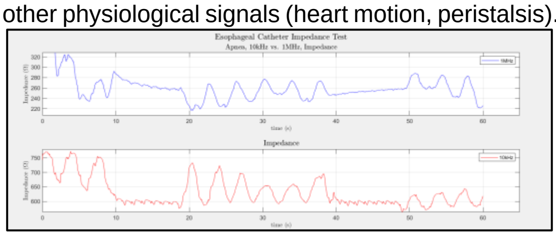

Fig. 2 in-vivo esophageal impedance measurement data showing respiration and apnea time intervals

When ECG gets sampled simultaneously with an excitation frequency, the distortion of ECG signals taken with the proposed setup is negligible. The presence of the frequency seems to reduce the baseline wander intensity caused by respiration, making it easier to filter out from the raw signal: this even leads to an improvement of the ECG signal quality. This can be observed in the ratio V_{ECG} / V_{BLW} (peak-to-peak voltage of ECG and baseline wander), which gets higher with higher frequency: 0.07 without excitation, 1.25 with 10kHz excitation and 5 using 100kHz. Besides, results of respiration detected with a digital Lock-in algorythm are very similar to those acquired with dedicated lock-in hardware device.

Discussion

This work demonstrates that impedance as an additional modality is feasible without requiring any modifications to the catheter, and shows relevant physiological signals, such as respiration, with excitation frequency at least in 10kHz-1MHz range. The proposed setup can monitor ECG and impedance without causing ECG signal quality loss or significant distortion. Additionally, the setup can be extented to multiple electrode configurations in a multiplexed environment, allowing ECG/impedance measurments from multiple positions. Multichannel measurments will probably give the possibility to monitor other physiological phenomena. Moreover, the measurments suggest that the presence of an excitation frequency for impedance measurments in fact improves ECG signal quality, but that requires more investigation to be claimed.

References

Gupta N., *"Feasibility study of multi-modal esophageal measurements for the monitoring of preterm infants"*, Master Thesis in Biomedical Engineering, University of Bern, Dec. 2020.