TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

Removing respiratory artefacts from transthoracic bioimpedance spectroscopy measurements

Citation for published version (APA):
Cuba-Gyllensten, I., Abtahi, F., Bonomi, A. G., Lindecrantz, K., Seoane, F., & Amft, O. (2013). Removing respiratory artefacts from transthoracic bioimpedance spectroscopy measurements. *Journal of Physics: Conference Series*, *434*(1), Article 012018. https://doi.org/10.1088/1742-6596/434/1/012018

DOI:
10.1088/1742-6596/434/1/012018

Document status and date:
Published: 01/01/2013

Document Version:
Publisher's PDF, also known as Version of Record (includes final page, issue and volume numbers)

Please check the document version of this publication:

• A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
• The final author version and the galley proof are versions of the publication after peer review.
• The final published version features the final layout of the paper including the volume, issue and page numbers.

Link to publication

General rights
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

• Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
• You may not further distribute the material or use it for any profit-making activity or commercial gain
• You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license above, please follow below link for the End User Agreement:

www.tue.nl/taverne

Take down policy
If you believe that this document breaches copyright please contact us at:

openaccess@tue.nl

providing details and we will investigate your claim.

Download date: 04. Oct. 2023

Journal of Physics: Conference Series

Removing respiratory artefacts from transthoracic bioimpedance spectroscopy measurements

To cite this article: I Cuba-Gyllensten *et al* 2013 *J. Phys.: Conf. Ser.* **434** 012018

View the article online for updates and enhancements.

Related content

- Pulse Wave Velocity and Cardiac Output vs. Heart Rate in Patients with an Implanted Pacemaker Based on Electric Impedance Method Measurement
Ladislav Soukup, Vlastimil Vondra, Ivo Višor et al.
- A model-based approach for analysis of intracellular resistance variations due to body posture on bioimpedance measurements
Sören Weyer, Mark Ulbrich and Steffen Leonhardt
- Bioimpedance-based respiratory gating method for oncologic positron emission tomography (PET) imaging with first clinical results
T Koivumäki, M Vauhkonen, J Teuho et al.

IOP ebooks™

Bringing you innovative digital publishing with leading voices to create your essential collection of books in STEM research.

Start exploring the collection - download the first chapter of every title for free.

This content was downloaded from IP address 131.155.151.138 on 20/11/2018 at 08:18

Journal of Physics: Conference Series **434** (2013) 012018 doi:10.1088/1742-6596/434/1/012018

Removing respiratory artefacts from transthoracic bioimpedance spectroscopy measurements

I Cuba-Gyllensten[1,2,5], F Abtahi[2], AG Bonomi[1], K Lindecrantz[1,3], F Seoane[1,4] and O Amft[5]

[1] School of Technology and Health, Royal Institute of Technology, 141 52 Huddinge, Sweden.
[2] Philips Research Europe, High Tech Campus 34, 5656AE, Eindhoven, the Netherlands.
[3] School of Engineering, University of Borås, 501 90, Borås, Sweden.
[4] Department of Clinical Science, Intervention and Technology, Karolinska Institute, 141 86 Stockholm, Sweden.
[5] ACTLab, Signal Processing Systems, TU Eindhoven, 5600MB Eindhoven, the Netherlands.

E-mail: illapha.cuba.gyllensten@philips.com

Abstract. Transthoracic impedance spectroscopy (TIS) measurements from wearable textile electrodes provide a tool to remotely and non-invasively monitor patient health. However, breathing and cardiac processes inevitably affect TIS measurements, since they are sensitive to changes in geometry and air or fluid volumes in the thorax. This study aimed at investigating the effect of respiration on Cole parameters extracted from TIS measurements and developing a method to suppress artifacts. TIS data were collected from 10 participants at 16 frequencies (range: 10 kHz - 1 MHz) using a textile electrode system (Philips Technologie Gmbh). Simultaneously, breathing volumes and frequency were logged using an electronic spirometer augmented with data from a breathing belt. The effect of respiration on TIS measurements was studied at paced (10 and 16 bpm) deep and shallow breathing. These measurements were repeated for each subject in three different postures (lying down, reclining and sitting). Cole parameter estimation was improved by assessing the tidal expiration point thus removing breathing artifacts. This leads to lower intra-subject variability between sessions and a need for less measurements points to accurately assess the spectra. Future work should explore algorithmic artifacts compensation models using breathing and posture or patient contextual information to improve ambulatory transthoracic impedance measurements.

1. Introduction

On-body measurements of impedance spectroscopy provide a tool for non-invasive monitoring of important health markers such as hydration and oedema, which are key elements to enable novel and effective management strategies for chronic conditions [1]. To achieve this in a telehealth home-monitoring setting the impedance spectroscopy measurements must be robust in presence of noise and/or slight deviations from the assumed measurement protocol.

To this end we have carried out a data collection study to quantify and characterize some disturbances that are thought to adversely affect measurements of transthoracic impedance spectroscopy (TIS). One such contributor for TIS measurements is the subject's respiration [2] during the measurement period. Respiration changes the structure of the alveoli and the thorax, which poses a challenge for TIS estimations based on a frequency sweep techniques were the

Published under licence by IOP Publishing Ltd

measurement time is slower than the physiological change [3]. This could lead to errors in the estimated TIS parameters and interpreted patient fluid status.

2. Methods

Ten healthy participants, 5 male and 5 female, were included in the analysis. The volunteers were all screened so that no one had any breathing abnormality, cardiac dysfunction or any other objection to take part in the study. Prior to the trial, each subject was properly informed and provided written informed consent. The whole procedure was reviewed and approved by the internal ethical review board and covered by the regional MEC.

2.1. Study population

An effort was done to recruit participants in a large age-range. Half of the recruited subjects were female and half of the subjects were older than 30 (four older than 50). The characteristic of the subjects were (Age: 38 $\pm$ 15 years, BMI: 24.3 $\pm$ 4.7 kg/m^2).

2.2. Devices, calibration and synchronization

Tetrapolar measurements were made using the BIM (Philips Technologie Gmbh, Aachen, Germany) which applies a sinusoidal current at 16 different frequencies sequentially (10 kHz-1MHz) at a rate of 5Hz. Wetted textile electrodes were then placed on either side of the ribcage at the approximate level of the tenth rib and held in place with an adjustable vest. The measurements obtained should relate to the impedance of the thorax.

To measure the respiration participants were fitted with a sized mask, which connected to a heated pneumotach (Hans Rudolph Inc., Shawnee, KS USA) with data-logging provided by a DAQ (NI USB 6353, Texas Instruments, Dallas, TX USA) at a sample rate of 1kHz. The system used factory set calibration for the Voltage to Flow conversion. Tidal volume was then estimated by integrating the flow measurements over time. To account for the slight drift in the pneumotach the output was calibrated using a 3 liter calibration syringe at the start and end of recording and at fiduciary end-expiratory points.

To account for any clock drift between the devices the time stamps were linearly adjusted to synchronize detected ECG peaks. Signals were then downsampled to the sampling frequency of the BIM.

2.3. Study protocol

Participants enrolled in this study took part in a larger study protocol which also included sessions to estimate artifact arising from movements and increased cardiac activity. The presented protocol is the selected part that was used for this analysis according to table 1.

Table 1. Part of the study protocol used for the presented analysis

Posture	Breathing instructions
Lying down, session 1	Paced shallow breathing at 10 and 16 bpm (60s each).
Lying down, session 2	Paced deep breathing at 10 and 16 bpm (60s each).
Reclining, session 1	Paced shallow breathing at 10 and 16 bpm (60s each).
Reclining, session 2	Paced deep breathing at 10 and 16 bpm (60s each).
Sitting, session 1	Paced shallow breathing at 10 and 16 bpm (60s each).
Sitting, session 2	Paced deep breathing at 10 and 16 bpm (60s each).

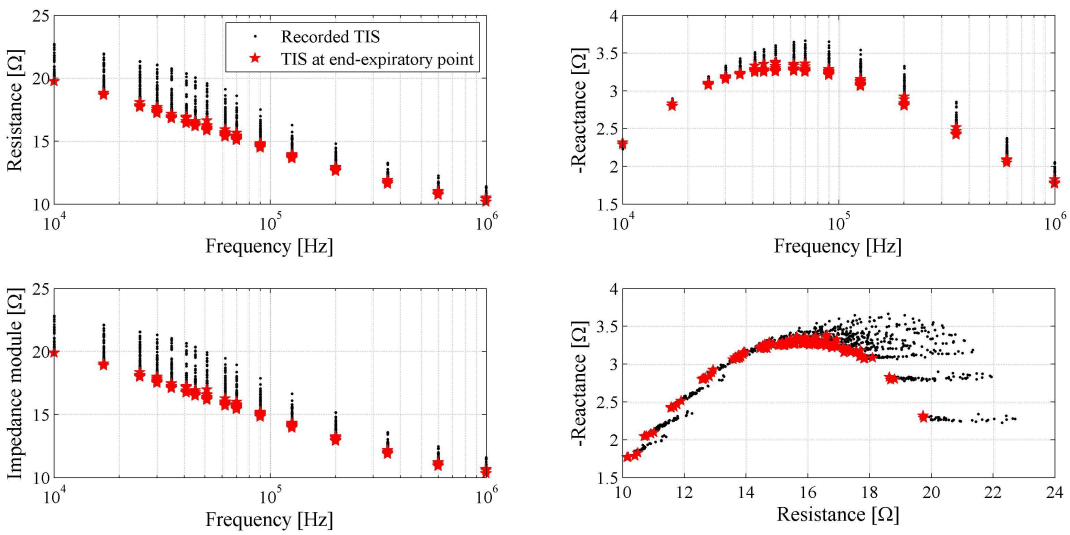

Figure 1. TIS data from participant 4 while lying down. The black dots show the data for the full recording (shallow and deep breathing at both 10 and 16 bpm). The red stars indicate the recorded data at the end-expiratory points extracted from the spirometer.

2.4. Impedance Spectroscopy Modelling

The Cole function (equation 1) was fitted to each of the TIS measurements by non-linear least squares. Minimization was done on the squared sum of the absolute difference between the recorded complex impedance and the model value for the frequency [4][5]. Two models were estimated using this minimization scheme: one by using all the input data for one session and a second using only the data at exhalation (these points were estimated from the recorded volume measurements).

$$Z = R_{\text{inf}} - \frac{R_{\text{inf}} - R_0}{1 + (j\frac{f}{f_c})^{\alpha}} \tag{1}$$

3. Results

Figure 1 shows the transthoracic bioimpedance during the measurement of an example subject separated to show all data and data at the end-expiratory points. It is clear that transthoracic impedance can be highly affected by respiration. Indeed R_0 seem to change with almost 4 Ohms (from 20 to 24) between maximum inhalation and exhalation for this specific subject.

The population-mean of the fitted Cole parameters for the two methods and intra-subject variability between the different breathing sessions is presented in table 2. These findings show that the high variability in the recorded impedance at different stages of the respiratory cycle creates difficulty in finding a representative Cole fitting even though these fittings had a substantially larger amount of data points (544 points per session) when compared to the fittings which only used the data at the end-expiratory points (median 72 points per session). On average the difference between the Cole parameters for the two sessions were four times larger when respiration was not taken into account.

Table 2. Intra-subject variability measured by absolute difference between two breathing sessions of the estimated Cole parameters using either: all data or only data at exhalation for the session. Population mean and standard deviation are shown within parenthesis.

Cole parameter	Estimation at exhalation	Estimation using all data
R_0	0.33 ± 0.26 Ω	1.24 ± 1.65 Ω
	(mean 26.44 ± 4.64 Ω)	(mean 27.11 ± 4.36 Ω)
R_{inf}	0.30 ± 0.25 Ω	1.05 ± 1.50 Ω
	(mean 12.10 ± 2.66 Ω)	(mean 12.02 ± 3.21 Ω)
f_c	1.90 ± 1.36 kHz	8.26 ± 17.25 kHz
	(mean 53.81 ± 12.30 kHz)	(mean 58.83 ± 20.82 kHz)
α	0.0250 ± 0.0226	0.0779 ± 0.0762
	(mean 0.607 ± 0.049)	(mean 0.587 ± 0.085)

4. Discussion and Conclusion

Reducing artifacts from on-body measurements provides more accurate non-invasive assessments of important health markers. This analysis shows that one such artifact that can be reduced is respiration. TIS using frequency sweep techniques usually average over the recorded data span [3] to ensure frequency coverage when the physiological changes are faster than the frequency changes. However, this analysis suggests that averaging is not a suitable technique, especially if respiration patterns are prone to changes.

Furthermore, it is known that the impact of respiration on impedance varies at different frequencies [2], which can be seen in the example data. An averaging technique might therefore produce a spectrum which does not correspond to any respiratory position and might provide sub-optimal values for a Cole fitting procedure.

Cole model fitting could be improved by taking into account the respiratory cycle leading to lower intra-subject variance of TIS parameters. Future work should look into effective algorithms to accomplish this, also in presence of other sources of errors such as movements. The population studied in this analysis, although varied, was healthy and unlikely to be targeted for monitoring. There is therefore also need to control such algorithms against the specific population, which is intended for monitoring.

Acknowledgments

This work was supported by the EU Marie Curie Network iCareNet under grant number 264738.

References

[1] Reiter H, Muehlsteff J and Sipila A 2011 Medical application and clinical validation for reliable and trustworthy physiological monitoring using functional textiles: Experience from the HeartCycle and MyHeart project *Conf. Proc. IEEE Eng. Med. Biol.* 3270-3

[2] Brown BH, Barber DC, Morice AH and Leathard AD 1994 Cardiac and respiratory related electrical impedance changes in the human thorax *IEEE Trans. Biomed. Eng.* **41** 729-34

[3] Sanchez B, Schoukens J, Bragos R and Vandersteen G 2011 Novel Estimation of the Electrical Bioimpedance Using the Local Polynomial Method. Application to In Vivo Real-Time Myocardium Tissue Impedance Characterization During the Cardiac Cycle *IEEE Trans. Biomed. Eng.* **58** 3376-85

[4] Kun DS and Peura RA 1999 Selection of measurement frequencies for optimal extraction of tissue impedance model parameters *Med. Biol. Eng. Comput.* **37** 699-703

[5] Buendia R, Gil-Pita R and Seoane F 2011 Cole Parameter Estimation from the Modulus of the Electrical Bioimpeadance for Assessment of Body Composition. A Full Spectroscopy Approach *J. Electr. Bioimp.* **2** 72-8