

Impedance-Cystovolumetry from Multifrequency Electrical Impedance Tomography

Jakob Orschulik, Thomas Schlebusch, Steffen Leonhardt

Chair for Medical Information Technology, RWTH Aachen University,

Pauwelsstr. 20, D-52074 Aachen, Germany, orschulik@hia.rwth-aachen.de

Abstract: The objective of impedance-cystovolumetry is the continuous, non-invasive monitoring of bladder volume. By using electrical impedance tomography, a correlation between the change of impedance in the image and bladder volume can be found. However, the typically used time-differential approach has the problem of both requiring a calibration measurement with an empty bladder and being dependent on the urine conductivity. This paper presents an improvement to the time-differential approach using multifrequency electrical impedance tomography.

1 Introduction

The continuous monitoring of the bladder volume is of great interest to patients with paraplegia as they have to empty the bladder manually using catheterization. Currently, this is done using a fixed-time scheme. To allow a demand driven catheterization, a continuous monitoring is necessary.

2 Methods

One possibility for the estimation of the bladder volume from electrical impedance tomography is the global impedance method. After reconstructing an image using the GREIT-algorithm [1], all pixel values are summed up. To retain phase information, both data acquisition and image reconstruction are performed in the complex domain. Previously it was shown, that this sum over all pixel values and the bladder volume correlate with each other [2]. However, the time-differential approach that has been used has the two problems of requiring a reference measurement with an empty bladder as well as being dependent on the urine conductivity. Thus, a frequency-differential approach is examined, where the measurements are performed nearly simultaneously using frequencies of 51.8 kHz and 100 kHz. Since the urine conductivity is not frequency dependent in our frequency range, the reconstructed impedance change in this area is zero. In contrast, the impedance of muscle or fat is frequency dependent. As a full bladder displaces more tissue than an empty one, the global change of impedance in the tomogram correlates with the bladder volume while being independent of urine conductivity.

2.1 Simulation

The simulation was performed in Matlab using the EIDORS-framework [3]. The finite element model con-

sists of a cylinder inside of a tank with 8 electrodes. The conductivity of the environment was simulated as complex, frequency dependent muscle tissue according to the tissue database from Gabriel & Gabriel [4]. In contrast, the urine conductivity was simulated using frequency independent values in the physiological range of 12–28 mS/cm.

2.2 Measurement

The real measurement was performed using an agar-agar model inside a tank similar to the simulation. To simulate the bladder, holes were cut into the model and filled with distilled water (0 mS/cm), 0.9 % saline (approx. 16 mS/cm), and 1.8 % saline (approx. 30 mS/cm).

3 Results

To analyze the influence of urine conductivity, a calibration curve was calculated based on the data at a reference conductivity of 20 mS/cm in the simulation and 0.9 % saline in the measurement. Then, the mean of the relative error $\bar{\epsilon}_r$ and the standard deviation σ_{ϵ_r} between the data at other conductivities and the calibration curve were calculated. A comparison between the time-differential and the multifrequency approach is shown in Table 1. The simulation results show an improvement regarding the impact of urine conductivity on volume estimation as the average error decreases significantly compared to the time-differential approach. Furthermore, the standard deviation improves as well. This simulation results were verified in the agar-agar measurement.

4 Conclusion

Multifrequency impedance tomography for impedance-cystovolumetry is a very promising approach as it provides urine conductivity independent results. In addition, no empty bladder reference measurement is required taking the concept one step further towards clinical use.

References

- [1] Adler A, Arnold JH, Bayford R, et al. *Physiological Measurement* **30**(6):S35, 2009
- [2] Leonhardt S, Cordes A, Plewa H, et al. *Biomedizinische Technik/Biomedical Engineering* **56**(6):301–307, 2011
- [3] Adler A, Lionheart WRB. *Physiological Measurement* **27**(5):S25, 2006
- [4] Gabriel S, Lau R, Gabriel C. *Physics in medicine and biology* **41**(11):2251, 1996

Table 1: Mean relative error $\bar{\epsilon}_r$ and its standard deviation σ_{ϵ_r} in simulation and measurement with different urine conductivities. Both in simulation and measurement the time-differential (TD) and multifrequency (MF) results are compared.

σ (mS/cm)	simulation				measurement				
	TD		MF		saline conc.	TD		MF	
	$\bar{\epsilon}_r$ (%)	σ_{ϵ_r} (%)	$\bar{\epsilon}_r$ (%)	σ_{ϵ_r} (%)		$\bar{\epsilon}_r$ (%)	σ_{ϵ_r} (%)	$\bar{\epsilon}_r$ (%)	σ_{ϵ_r} (%)
12	-27.46	1.50	-6.26	0.73	0.0 %	-18.24	15.76	2.87	8.54
28	13.92	1.07	2.15	0.40	1.8 %	13.45	10.39	9.45	10.07

Excerpted from:

Proceedings
of the
15th International Conference on
Biomedical Applications of
**ELECTRICAL IMPEDANCE
TOMOGRAPHY**

Edited by Andy Adler and Bartłomiej Grychtol

April 24-26, 2014
Glen House Resort
Gananoque, Ontario
Canada



This document is the collection of papers accepted for presentation at the 15th International Conference on
Biomedical Applications of Electrical Impedance Tomography.
Each individual paper in this collection: © 2014 by the indicated authors.
Collected work: © 2014 Andy Adler and Bartłomiej Grychtol.
All rights reserved.

Cover design: Bartłomiej Grychtol
Photo credit: ©1000 Islands Photo Art Inc. / Ian Coristine

Printed in Canada

ISBN 978-0-7709-0577-4

Systems and Computer Engineering
Carleton University, 1125 Colonel By Drive
Ottawa, Ontario, K1S 5B6, Canada
adler@sce.carleton.ca
+1 (613) 520-2600

www.eit2014.org