# EIT of the Human Body with Optimal Current Patterns and Skin-Electrode Impedance Compensation

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**Abstract:** Following the lead of the EIT research group at Rensselaer Polytechnic Institute, we have designed and implemented a system comprising 32 independent current sources, in which it is possible to apply current patterns optimizing distinguishability. One potential technical problem is that we are measuring voltages on current-carrying electrodes, giving some sensitivity to time varying skin-electrode impedances. We demonstrate here an algorithm to estimate simultaneously changes in the medium and time-varying skin-electrode impedances.

## 1 Introduction

Most of the electrical impedance tomography systems developed to date, with the notable exception of the group at Rensselaer Polytechnic Institute (RPI) [1, 2], have been based upon pairwise current patterns utilizing a single current source. These systems have the advantage of relative simplicity, but a significant disadvantage is that the current patterns utilized are not optimal with respect to maximizing distinguishability [3].

One technical issue involved in utilizing the optimal patterns and multiple-electrode excitation is that voltage changes are induced by time-varying skin-electrode impedances. We have developed algorithms, similiar to those described previously [4], but with significantly reduced computational complexity, to simultaneously estimate time-varying skin-electrode impedances and changes within the body.

## 2 Methods

### 2.1 Estimation and compensation of skin-electrode impedances

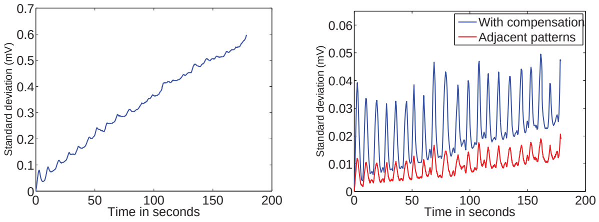
We assumed that electrode skin-electrode impedances could be modeled as being due to a discrete complex circuit element coupling the electrode to the body. Given this model, the Jacobian of voltage changes with respect to time-varying changes in the value of this discrete element could be computed explicitly for a given pattern set. We could then compute the skin-electrode impedance changes responsible for a set of voltage changes directly using least-squares methods.

### 2.2 Experimental protocol

Under institutional review board (IRB) supervision, we collected free respiration data from several human subjects measuring with 32 adhesive AgCl electrodes equally spaced in a single ring around the circumference of the chest. We utilized the GE-built GENESIS EIT system, currently an investigational prototype, and for each of the cases applied the optimal current patterns, as generated by a geometry-specific finite-element model and EIDORS [5].

## 3 Results

We computed the standard deviations of the changes in voltages vs. a reference data frame, in mV, for the optimal pattern set, with and without compensation for changes in skin-electrode impedances. We also synthesized the voltages that would have resulted from application of adjacent current patterns, measuring voltage differences between pairs of electrodes not carrying currents. We found that the preponderance of the voltage differences for the optimal patterns was due to changes in skin-electrode impedance, but that these changes could be estimated and compensated. The adjacent patterns were largely immune to skin-electrode impedance changes, but, for the same maximal current, smaller changes in voltage were induced, thus a larger SNR would be required for imaging. The results are summarized in Fig. 1.



(a) (b)

**Figure 1:** Standard deviations of difference in voltages of a given frame from a reference frame, in mV, for optimal patterns without compensation (a), with compensation, and adjacent current patterns (b).

## 4 Conclusions

In conclusion, it is possible to probe the body with "optimal" current patterns and to measure on current-carrying electrodes, but careful consideration needs to be taken of changes in skin-electrode impedances.

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Excerpted from:

# Proceedings
# of the
# 15th International Conference on
# Biomedical Applications of

# ELECTRICAL IMPEDANCE TOMOGRAPHY

Edited by Andy Adler and Bartłomiej Grychtol

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This document is the collection of papers accepted for presentation at the 15th International Conference on Biomedical Applications of Electrical Impedance Tomography.

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

Printed in Canada

ISBN 978-0-7709-0577-4

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