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Breath-by-breath regional expiratory time constants by electrical impedance tomography – a feasibility study

Péter L. Róka^{1,2}, Andreas D. Waldmann¹, Beat Müller¹, Ferenc Ender², Stephan H. Böhm¹,
Wolfram Windisch³, Stephan Strassmann³ and Christian Karagiannidis³

¹Swisstom AG, Landquart, Switzerland, ²Budapest University of Technology and Economics, Budapest, Hungary,
pro@swisstom.com, ³Department of Pneumology and Critical Care Medicine, Kliniken der Stadt Köln, Cologne, Germany

Abstract: In this feasibility study we used EIT to analyse three different lung conditions to determine regional expiratory time constants (τ). The initial results show that EIT can be used to determine regional τ on a breath-by-breath basis and distinguish different lung pathologies.

1 Introduction

During relaxed breathing expiration can be compared to a RC-circuit with R being the airway resistance, C the respiratory system compliance and $\tau=RC$ the time constant. τ reveals information about respiratory mechanics and the time required for the lungs to empty. Traditional pulmonary function tests provide global information only. EIT is a non-invasive real-time (~50 images/sec) imaging technology which determines changes of lung volumes on a regional basis assuming that local impedance changes $I(t)$ are proportional to local changes in lung volume $V(t)$. Pikkemaat et al. [1] calculated regional τ during a forced expiration manoeuvre needing patient cooperation. We improved this method such that it is now applicable also during passive expiration and, more importantly, breath-by-breath.

2 Methods

Passive expiration is an exponential decay: $I(t) = A * e^{-\frac{t-t_0}{\tau}} + K$, where A is the peak-to-peak impedance value between start and end of expiration; t the time, t_0 the start of the expiration and K the impedance at the end of the expiration. Since the onset of expiration is mostly dominated by inertial effects it does not show an exponential behaviour [2], Lourens et al. [3] advised to start analysis only at 75% of the signal amplitude. Skipping the first 25% of the global signal's amplitude we analysed the regional temporal behaviour of each pixel

until the end of global expiration of an EIT sequence by fitting an exponential curve in a nonlinear least square manner using MATLAB (The MathWorks, USA). EIT data were measured with *Swisstom BB²* (Swisstom AG, Switzerland) and the τ (s) of 10 consecutive breaths of one healthy person, a patient with chronic obstructive pulmonary disease (COPD) and one with acute respiratory distress syndrome (ARDS) were determined. Only τ values within the range of 0.05 and 5 s stemming from curve fits with an R^2 higher than 0.6 were considered thereby excluding poorly ventilated areas and those in which curve fitting was poor. Overall results for each individual are expressed as (mean \pm SD) whereas each breath is represented by a box-plot.

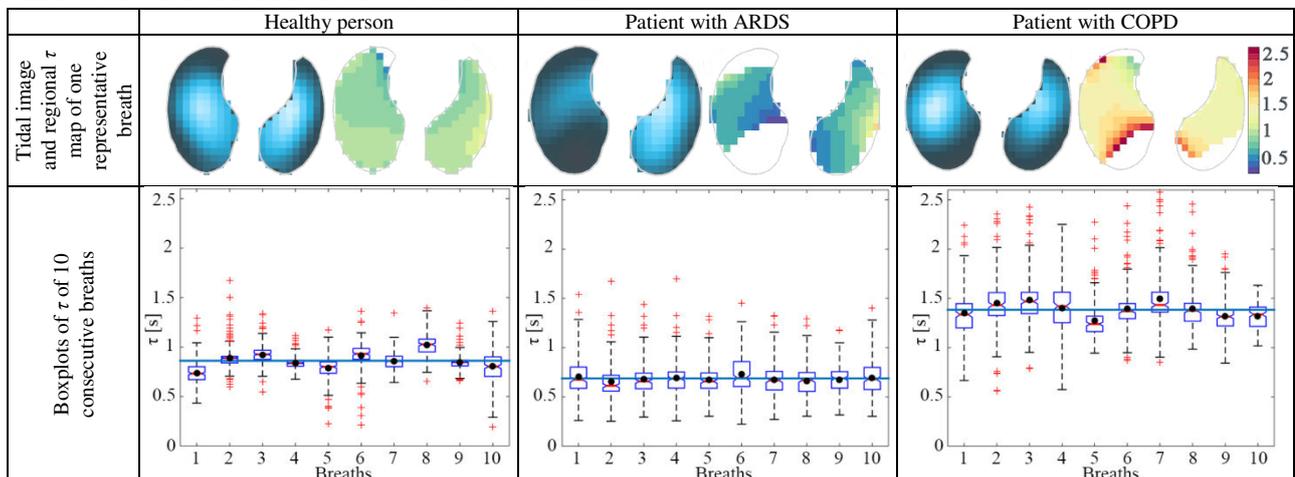
3 Results and Conclusions

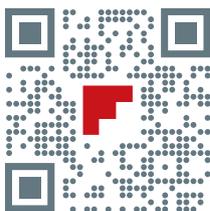
In these three cases τ was 0.86 ± 0.13 s in healthy, 0.68 ± 0.18 s in ARDS and 1.39 ± 0.24 s in COPD. Moreover, breath-by-breath correlations were highly consistent. These preliminary results show that regional time constants can be assessed by EIT. In ventilated areas their values and distribution were within the expected range and rather homogenous. ARDS lungs were “faster” whereas COPD-lungs were “slower” than normal ones reflecting the lower respiratory system compliance of injured lungs and the higher resistance of COPD. We showed that EIT can be used to determine regional time constants on a breath-by-breath basis from passive exhalation and distinguish different lung pathologies.

References

- [1] R. Pikkemaat, *Appl. Cardiopul. P.* 16: 212-225, 2012.
- [2] J. Guttman, *Eur. Respir. J.* vol. 8, no. 1, 114-120, 1995.
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Table 1: Ventilation and τ distribution in three different cases.





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call: + 41 (0) 81 330 09 72
mail: info@swisstom.com
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Schulstrasse 1, CH-7302
Landquart, Switzerland

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Swisstom creates its competitive edge by passionate leadership in non-invasive tomography with the goal to improve individual lives and therapies.

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