The EIT-based global inhomogeneity index is highly correlated with regional lung opening in patients with acute lung injury

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Introduction

Electrical impedance tomography (EIT) is a noninvasive, radiation-free imaging technique that can monitor regional lung ventilation and aeration distribution by measuring the electrical potentials at the chest wall surface [1]. Unfortunately, due to the difficult interpretation of the results, EIT is still not widely accepted in the clinical environment.

Recently, a so-called global inhomogeneity (GI) index was proposed to quantify the tidal volume distribution within the lung [2]. The GI index was used in different studies [3-5] showing that it represented an uncomplicated and efficient approach to summarize the complex pulmonary impedance distribution pattern by one number.

Up to now, the GI index was evaluated for plausibility, but a detailed investigation of how it is influenced by physiological factors is still missing. In this investigation we hypothesized that the GI index is mainly determined by the fraction of open lung regions.

Methods

EIT data of seven patients with ALI were analyzed retrospectively. The protocol applied in the patients was described in detail in [6]. In short, a low-flow inflation was performed (Evita XL; Dräger, Lübeck, Germany) with a constant gas flow of 4 L/min up to a tidal volume of 2 L or until a maximum airway pressure of 35 cmH_2O was reached. EIT examinations were performed with the Goe-MF II EIT device (CareFusion, Höchberg, Germany). EIT raw data was acquired at 25 Hz and reconstructed offline with filtered back-projection [7]. The reconstructed data was smoothed by a low-pass filter with 1 Hz cut-off frequency.

The lung regions in EIT images were defined based on functional EIT scans [8]. The maximum impedance amplitudes were determined in all pixels of the lung regions. Recruited lung regions were identified when the local pixel amplitudes exceed 10% of the maximum [6]. The percentage of recruitable lung regions was defined as 100% minus the number of recruited pixels divided by the total number of pixels of lung regions.

The calculation of GI index was described in previous studies [2, 4] and is presented in Eq. 1.

$$GI = \frac{\sum_{x,y \in lung} \left| DI_{xy} - Median\left(DI_{lung}\right) \right|}{\sum_{x,y \in lung} DI_{xy}} \qquad (1)$$

where DI is the value of the differential impedance in the difference images; DI_{xy} denotes the pixel in the identified lung area; DI_{lung} are all pixels in the lung area under observation. In the present study, we modified the GI index slightly. A series of GI indices was calculated during the inflation based on the differential images between the time point t_{20} to t_1, t_{21} to t_1, t_{22} to t_1, …, t_n to t_1 (t_1, the first EIT scan during inflation; t_n, the *n*th EIT scan, n=20, 21, …, until the end of inflation). The corresponding percentages of recruitable lung regions were calculated and compared using linear regression.

Data analysis was performed using MATLAB 7.2 (The MathWorks Inc., Natick, MA, USA). The Lilliefors test was used for normality testing. For normally distributed data, results were expressed as mean values ± standard deviations. A P value < 0.05 was considered to be significant.

Results

The GI index decreased during the low-flow inflation, while the number of lung opening regions increased. The trend of GI index and percentages of recruitable lung regions in one patient are plotted in Fig. 1. The values were highly correlated in all 7 patients (r^2=0.88±0.09, p<0.0001).

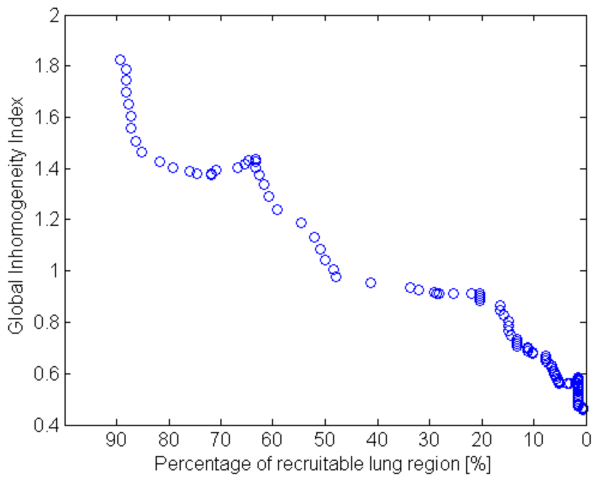

Figure 1. The trend of GI index and percentages of recruitable lung regions in one patient during low-flow inflation.

Discussion and conclusion

In the present study, we confirmed that the GI index partly represented the fraction of regional lung opening. This may be one of the possible explanations for the previously observed differences in the GI index between healthy volunteers and patients with various lung diseases [2, 4-5]. In further studies, the correlation between the GI index and regional overdistention should be investigated.

We conclude that the GI index is reliable measure of ventilation heterogeneity which may prove to be a useful EIT-based index to guide ventilation therapy.

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