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Clinical Investigation

CLINICAL INVESTIGATION

Characteristic pattern of pleural effusion in electrical impedance tomography images of critically ill patients

T. Becher*, M. Bußmeyer, I. Lautenschläger, D. Schädler, N. Weiler and I. Frerichs

Department of Anaesthesiology and Intensive Care Medicine, University Medical Centre Schleswig-Holstein, Campus Kiel, Kiel, Germany

*Corresponding author. E-mail: tobias.becher@uksh.de

Abstract

Background: Electrical impedance tomography (EIT) is increasingly used for continuous monitoring of ventilation in intensive care patients. Clinical observations in patients with pleural effusion show an increase in out-of-phase impedance changes. We hypothesised that out-of-phase impedance changes are a typical EIT finding in patients with pleural effusion and could be useful in its detection.

Methods: We conducted a prospective observational study in intensive care unit patients with and without pleural effusion. In patients with pleural effusion, EIT data were recorded before, during, and after unilateral drainage of pleural effusion. In patients with no pleural effusion, EIT data were recorded without any intervention. EIT images were separated into four quadrants of equal size. We analysed the sum of out-of-phase impedance changes in the affected quadrant in patients with pleural effusion before, during, and after drainage and compared it with the sum of out-of-phase impedance changes in the dorsal quadrants of patients without pleural effusion.

Results: We included 20 patients with pleural effusion and 10 patients without pleural effusion. The median sum of out-of-phase impedance changes was 70 (interquartile range 49–119) arbitrary units (a.u.) in patients with pleural effusion before drainage, 25 (12–46) a.u. after drainage ($P<0.0001$) and 11 (6–17) a.u. in patients without pleural effusion ($P<0.0001$ *vs* pleural effusion before drainage). The area under the receiver operating characteristics curve was 0.96 (95% limits of agreement 0.91–1.01) between patients with pleural effusion before drainage and those without pleural effusion.

Conclusions: In patients monitored with EIT, the presence of out-of-phase impedance changes is highly suspicious of pleural effusion and should trigger further examination.

Keywords: critical care; pleural effusion; thoracocentesis; tomography

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Editor's key points

- Electrical impedance tomography has several potential applications in patients with respiratory failure.
- In this small study, differences in out-of-phase impedance on electrical impedance tomography were found between patients with and without a pleural effusion.
- There were also differences before and after drainage of an effusion.
- Electrical impedance tomography could be useful in detecting pleural effusion in intensive care patients.

Electrical impedance tomography (EIT) is a relatively new, non-invasive, and radiation-free imaging modality which can serve for a variety of purposes in critically ill patients.[1] Possible clinical applications include assessment of ventilation distribution,[2,3] detection of alveolar recruitment, derecruitment, overdistension,[4,5] tidal recruitment,[6] assessment of regional respiratory mechanics in controlled mechanical ventilation,[7] assisted spontaneous breathing,[8] quantification of ventilation heterogeneity,[9,10] and individual adjustment of ventilator settings to improve lung-protective ventilation.[11]

EIT is increasingly used in patients with or at risk for respiratory failure.[12] Typically, lung aeration during inspiration leads to an increase in impedance in the ventilated lung areas, followed by a similar decrease in impedance during expiration. However, in some patients, regional out-of-phase impedance changes can be observed. These are characterised by a seemingly paradoxical decrease in impedance in some areas of the EIT image during inspiration, followed by an increase in impedance during expiration (Fig. 1).

Clinical observations in patients with pleural effusion and previous studies[13,14] suggest that out-of-phase impedance changes may occur when areas of high ventilation-related impedance change, such as the lungs,[15] are in close proximity to areas of low ventilation-related impedance change, such as the heart or fluid accumulations. This is most likely caused by an overshoot phenomenon introduced by the algorithms used for EIT image reconstruction[1,16,17] that may occur under these circumstances.[14]

This is typically the case in patients with pleural effusion (Fig. 2). While previous studies have assessed the effects of pleural aspiration on lung reaeration and reventilation,[18] to our knowledge the diagnostic value of out-of-phase impedance changes in the detection of pleural effusion has not been investigated.

We hypothesised that out-of-phase impedance changes in the dependent image quadrants are a typical finding in patients with pleural effusion and could be useful for the detection of pleural effusion in critically ill patients undergoing monitoring with EIT.

Methods

We conducted an observational study in three mixed surgical and medical intensive care units (ICUs). Patients were enrolled between January 2015 and June 2016.

EIT monitoring was initiated as per clinical decision by the attending intensivist in patients with acute respiratory failure or who were considered as being at risk for developing acute respiratory failure, taking into account clinical parameters such as gas exchange and impairment of respiratory mechanics.

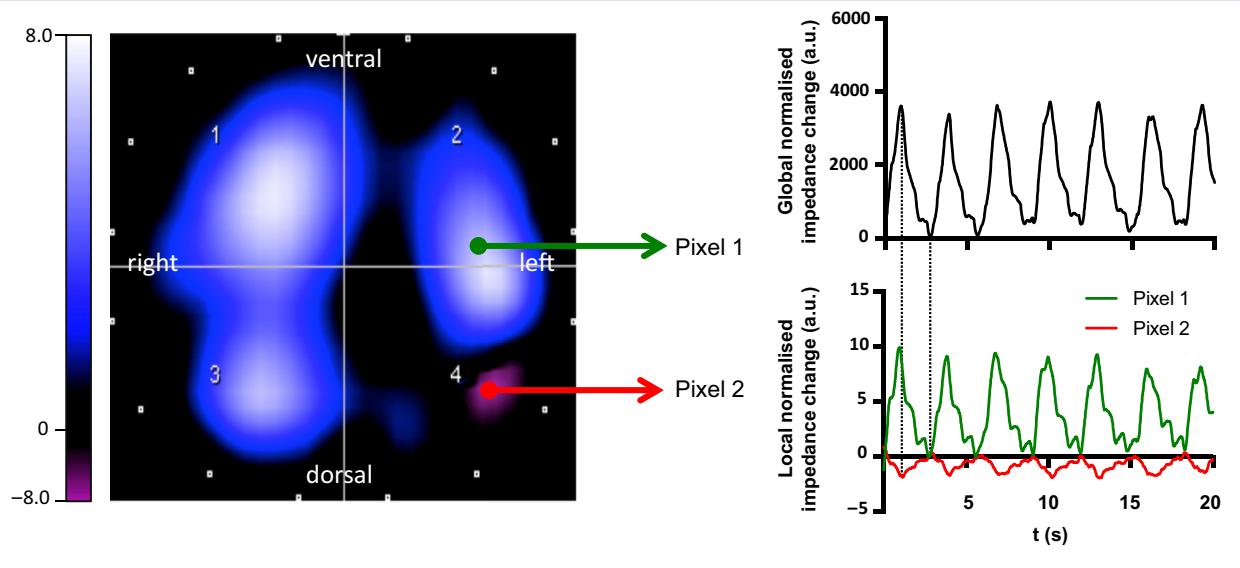

Fig 1. In-phase (pixel 1) and out-of-phase (pixel 2) impedance changes in a representative patient suffering from left-sided pleural effusion. Left: tidal image, illustrating the pixel differences between the time points of end-expiration (global impedance minimum) and end-inspiration (global impedance maximum). Out-of-phase impedance changes are shown in purple colour. Right: time course of global (top) and local (bottom) relative impedance changes for the same patient over a period of 20 s. Pixel 1 shows a typical 'in-phase' behaviour with the global electrical impedance tomography (EIT) signal, whereas pixel 2 shows 'out-of-phase' behaviour that may be a typical finding in patients with pleural effusion. a.u., arbitrary units.