

Rongqing Chen*, András Lovas, Balázs Benyó and Knut Moeller

Electrical Impedance Tomography might be a Practical Tool to Provide Information about COVID-19 Pneumonia Progression

Abstract: COVID-19 induced acute respiratory distress syndrome (ARDS) could have two different phenotypes, which might have different response and outcome to the traditional ARDS positive end-expiratory pressure (PEEP) treatment. The identification of the different phenotypes in terms of the PEEP recruitment can help improve the patients' outcome. In this contribution we reported a COVID-19 patient with seven-day electrical impedance tomography monitoring. From the conductivity distribution difference image analysis of the data, a clear course developing trend can be observed in addition to the phenotype identification. This case might suggest that EIT can be a practical tool to identify phenotypes and to provide progressive information of COVID-19 pneumonia.

Keywords: electrical impedance tomography, COVID-19 pneumonia, progressive information, monitoring, ARDS.

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1 Introduction

It is frequently reported (e.g. [1]), that severe cases of COVID-19 pneumonia fall under the Berlin definition of acute respiratory distress syndrome (ARDS)[2]. Instead of following the treatment recommendations for ARDS patients[3], Gattinoni et al. suggested that COVID-19 pneumonia should be treated as a different disease[4]–[6]. Despite sharing the same etiology, the COVID-19 patients were observed with different characteristics requiring different therapeutic

approaches[4]. In [5], they reported more than 50% of the patients they have observed had severe hypoxemia, but with a near normal respiratory system compliance. These patients were called L-type patients characterized by low elastance, low ventilation-to-perfusion (VA/Q) ratio, low lung weight and low recruitability. In contrast, there exist H-type patients who have high elastance, high ventilation-to-perfusion (VA/Q) ratio, high lung weight and high recruitability[5]. A common method to identify the different COVID-19 pneumonia phenotypes is through CT scans[7]. However, the course of the COVID-19 pneumonia has shown to develop very fast. Zhao et al. recently reported that some COVID-19 pneumonia patients had low recruitability even though large amount of non-aerated tissue was observed and the compliance was fairly low[8]. The possible transition from L-Type to H-Type was reported by different authors[4], [9], [10]. The reason for this transition might be found in the progression of the COVID-19 pneumonia or in acute lung injury caused by high peak pressure of the mechanical ventilation or both [5]. It was also suggested by Zhao et al. that the bedside tools, e.g. electrical impedance tomography (EIT), can play an important role detecting the different phenotypes of the COVID-19 pneumonia in addition to CT examination[8].

2 Material and Method

The analysis was conducted using Matlab 2019a (Mathworks, Natick, MA) and Dräger EIT Data Analysis Tool 6.1 Dräger, Lübeck, Germany).

2.1 Patient Data

This contribution was conducted on a retrospective COVID-19 patient dataset. Informed consent was collected according to the ethics approval by the Human Investigation Review Board in University of Szeged (approval number 67/2020-SZTE). The corresponding patient was deeply sedated and ventilated in volume controlled mode. The positive end-expiratory pressure (PEEP) trial was conducted on the patient During the inflation part of the PEEP trial, a 3 cmH₂O stepwise

*Corresponding author: Rongqing Chen: Institute of Technical Medicine, Furtwangen University, Jakob-Kienzle-Str. 17, VS-Schwenningen, Germany. e-mail: chr@hs-furtwangen.de

András Lovas: Kiskunhalas Semmelweis Hospital, Department of Anaesthesiology and Intensive Therapy, H-6400, Dr. Monszpart L. u. 1, Hungary

Balázs Benyó: Budapest University of Technology and Economics, Department of Control Engineering and Information Technology, 1117 Budapest, Magyar tudósok krt. 2, Hungary

Knut Möller: Institute of Technical Medicine, Furtwangen University, Jakob-Kienzle-Str. 17, VS-Schwenningen, Germany

increase in airway pressure from 10 cmH₂O to the maximum pressure of 25 cmH₂O were applied leading to an overall peak pressure of 40 cmH₂O. In the deflation limb, in steps of 3 cm H₂O the PEEP was reduced from the maximum of 25 cmH₂O to the minimum pressure of 10 cmH₂O. On each PEEP level PEEP was kept constant for two minutes with ongoing ventilation. The PEEP trial was monitored by the PulmoVista500 EIT device (Dräger Medical, Lübeck, Germany). EIT belt was placed on chest circumference in a transverse plane around the 5th intercostal space. EIT data were measured with adjacent injection current and adjacent voltage measurement with 50 frames per second. Time difference EIT images were reconstructed by Newton-Raphson algorithm with Tikhonov prior.

2.2 Tidal variation image

The tidal variation image is one kind of functional EIT (fEIT) images that depicts the image value difference between each pixel at the end of inspiration and at the end of expiration[11]. The identification of the end-inspiration and end-respiration events are conducted on global impedance curve, which is illustrated in Fig. 1. In this contribution, the tidal variation image was obtained from the averaged end-inspiration and end-respiration values, which were averaged using the last ten breath cycles within every PEEP level.

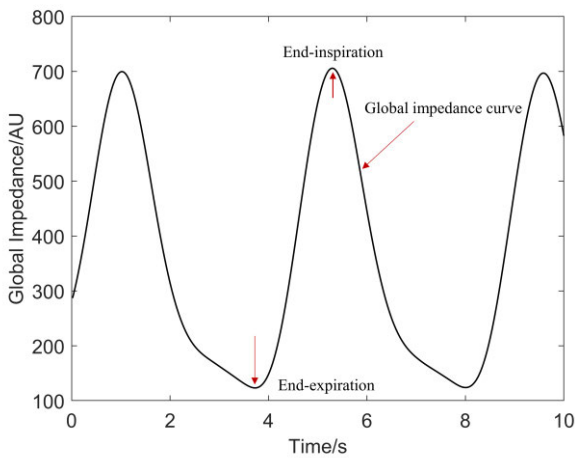


Figure 1: An example to identify the end of inspiration and end of respiration in a global impedance curve.

The difference image obtained from the different tidal variation images within the same PEEP trial can reveal the PEEP related conductivity distribution change (Δ ventilation). Thus, the described difference image is capable of showing recruitment and overdistention lung area during the PEEP trial.

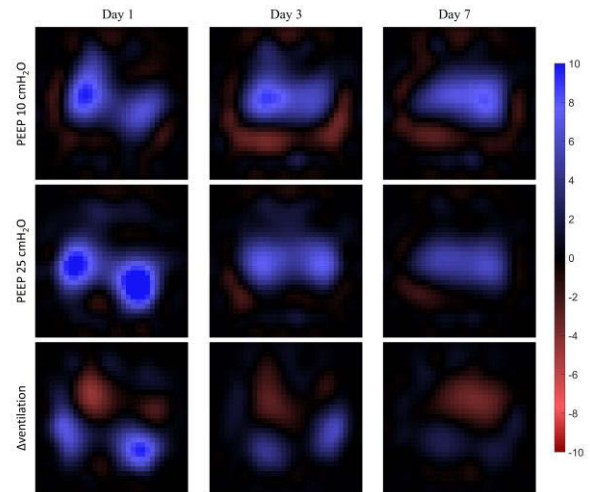


Figure 2: Electrical impedance tomography results of a COVID-19 patient during PEEP increases from 10 to 25 cmH₂O on day 1, day 3 and day 7 after the admission to the ICU. Upper row: tidal images of ventilation distribution at PEEP 10 cmH₂O on day 1, day 3 and day 7. Middle row: tidal images of ventilation distribution at PEEP 25 cmH₂O on day 1, day 3 and day 7. Lower row: The differences in ventilation distribution between PEEP of 25 and PEEP of 10 cmH₂O. Ventilation loss is marked in red and ventilation gain is marked in blue.

In this contribution, tidal variation images were obtained at PEEP 10 cmH₂O and 25 cmH₂O of the PEEP trial inflation part on day 1, day 3 and day 7 after the patient's admission. For each day, a PEEP related conductivity distribution difference image was obtained.

3 Results and Discussion

EIT tidal images of monitored patient during a stepwise increase of positive end-expiratory pressure (PEEP) from 10 to 25 cmH₂O on day 1, day 3 and day 7 respectively in the upper two rows of Fig. 2. On day 1, the respiratory system compliance decreased from 52 to 34 ml/cmH₂O, potential recruitment was found in the dependent part (dark blue area shown in third row /day 1 in Fig. 2). However, on day 3, the respiratory system compliance changed from 63 to 33 ml/cmH₂O during the PEEP trial, conductivity decreased, which might be due to overdistention, that is found in the nondependent lung area (red area shown on day 3 in the third row in Fig. 2). In addition, the recruitment on day 3 is negligible compared to day 1. On day 7, the respiratory system compliance dropped from 47 to 29 ml/cmH₂O in the PEEP trial, there was hardly recruitment observed in the dependent area (the third row on day 7 in

Fig. 2). This patient was classified as the L-type patient according to the corresponding CT scan. From day 1 to day 7, the respiratory system compliance at the 25 cmH₂O witnessed a decreasing, which might suggest a course developing of the patient and should lead to decreasing recruitability. Similarly, the decreasing trend of recruited areas found in Fig. 2 suggested the patient was poorly recruitable, which could be attributed to the deteriorating patient status. Gattinoni et al. pointed out that the deteriorating of the patient might be ascribed to the evolution of the COVID-19 pneumonia on one hand and to the lung injury attributable to high-stress ventilation on the other[5]. If this is the case, the traditional high PEEP maneuver practiced on the L-type patients might not provide the expected results, on the contrary might introduce an increased risk of structural damage, e.g. barotrauma, of the lung.

4 Conclusion

The course of the COVID-19 pneumonia is still poorly understood and has shown to develop very fast. In this contribution, a rather clear status development of a L-type patient can be observed from the long-term EIT monitoring. EIT might develop into a useful and practical tool to assist with the classification of the different phenotypes of the COVID-19 patients in addition to the CT, and might provide additional information about progression of the disease and the evaluation of its treatment strategies.

Author Statement

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