Assessment of tidal recruitment and overdistension by regional analysis of respiratory system compliance at different tidal volumes

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Abstract: In this pilot clinical study, we assessed the effects of positive end-expiratory pressure (PEEP) on tidal recruitment and overdistension in mechanically ventilated patients. Changes in EIT-derived regional respiratory system compliance (C_{rs}) induced by variation of tidal volume (V_T) were analysed in the chest cross-section and identified the simultaneous occurrence of tidal recruitment and overdistension in the examined patients.

1 Introduction

Tidal recruitment associated with cyclic opening and closing of alveoli and alveolar overdistension are important mechanisms in the genesis of ventilator-induced lung injury [1]. One promising method for detection of these phenomena is the calculation of regional C_{rs} in individual image pixels [2] or as profiles in 32 horizontal chest layers [3].

When a patient is ventilated with two different values of V_T and regional C_{rs} is calculated in each setting, the differences in regional C_{rs} induced by the V_T variation can be determined. In the present paper, we used this approach to quantify the amount of tidal recruitment and overdistension by calculating the V_T-dependent changes in C_{rs} at two PEEP values on a pixel-by-pixel basis.

2 Methods

We performed a retrospective analysis of data from five critically ill patients (4 male, 1 female, 74±6 years (mean age±SD)) with acute respiratory distress syndrome (ARDS). The patients were ventilated in a volume-controlled mode at two different PEEP values ($PEEP_{high}$, $PEEP_{low}$). As described in [2], $PEEP_{high}$ and $PEEP_{low}$ were set individually in each patient based on the analysis of a quasi-static pressure-volume manoeuvre. For the diagnosis of tidal recruitment and overdistension, a variation of V_T between a high value of 10 ml/kg ideal body weight (IBW) and low value of 6 ml/kg IBW was performed at both PEEP values.

EIT measurements were carried out with the Goe-MF II device (CareFusion, Höchberg, Germany) using a set of 16 electrodes (L-00-S, Ambu, Ballerup, Denmark). EIT images were generated using the back-projection algorithm.

Regional C_{rs} was calculated by dividing the individual pixel values of tidal amplitude of relative impedance change (rel.ΔZ) by the sum of all these values and by multiplying them with the global C_{rs}. The regional C_{rs} values at low V_T were subtracted from the respective values with high V_T to generate difference images, visualising ΔC_{rs} between high and low V_T in every pixel (Fig.1). For quantitative estimation of tidal recruitment and overdistension, we calculated the sum of pixels with positive values of ΔC_{rs} and divided the resulting value by the global C_{rs} at high V_T. This analysis rendered a dimensionless index value of the amount of tidal recruitment that was finally multiplied by 100 to yield a value in %. This was performed similarly for all pixels with negative values of ΔC_{rs} to create an index value of alveolar overdistension.

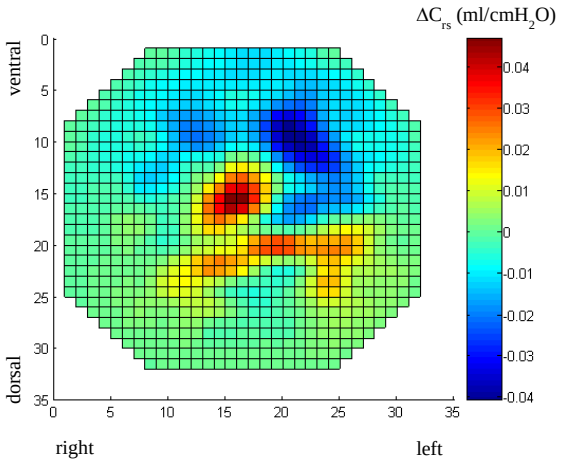

Figure 1: Map of regional differences in respiratory system compliance (ΔC_{rs}) between high and low V_T at the high positive end-expiratory pressure ($PEEP_{high}$) in one of the examined patients. Positive values imply tidal recruitment, whereas negative values show overdistension. At this PEEP level, 10% overdistension and 6% tidal recruitment were identified in this patient.

3 Results

Tidal recruitment and alveolar overdistension occurred simultaneously at both PEEP levels in all studied patients. At $PEEP_{high}$, we found a non-significant reduction in tidal recruitment (11% vs 14%; p=n.s.) and a non-significant increase in overdistension (18% vs 11%; p=n.s.) in comparison with $PEEP_{low}$.

4 Conclusions

Analysis of changes in EIT-derived regional C_{rs} between high and low V_T is feasible in mechanically ventilated patients and may be used to quantify the overall amount of tidal recruitment and overdistension at a given PEEP. This might be used for an individualized optimization of PEEP and V_T setting adapted to the regional respiratory system mechanics.

References

[1]Caironi P et al. Am J Respir Crit Care Med **181**: 578-86, 2010
[2]Costa EL et al. Intensive Care Med **35**: 1132-7, 2009
[3]Zick G et al. PLoS One **8**: e72675, 2013