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Perioperative assessment of regional ventilation during changing body positions and ventilation conditions by electrical impedance tomography with increased spatial and signal resolution

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Introduction: Concepts for lung protective ventilation are well established in ARDS patients. There is evidence that also in patients with healthy lungs intraoperative ventilation can lead to lung injury1. Electrical impedance tomography (EIT) is a functional imaging technology allowing to regionally monitor aeration of the lungs. The working principle of EIT is the application of alternating current to the thorax and the measurement of voltages via electrodes placed at the body surface2. These voltages are then used to create tomographic images of the changes in regional impedance caused by ventilation.

Methods: In 40 patients scheduled for robot-assisted radical prostatectomy we performed EIT measurements (Swisstom BB² prototype (Swisstom, Landquart, Switzerland)) at five different time points (Fig. 1), using 32 active electrodes. Based on the resulted voltages tomographic images of the changes in regional impedance caused by ventilation were created and regions of interest (ROI) were defined analyzing the lung contours (Fig. 1A).

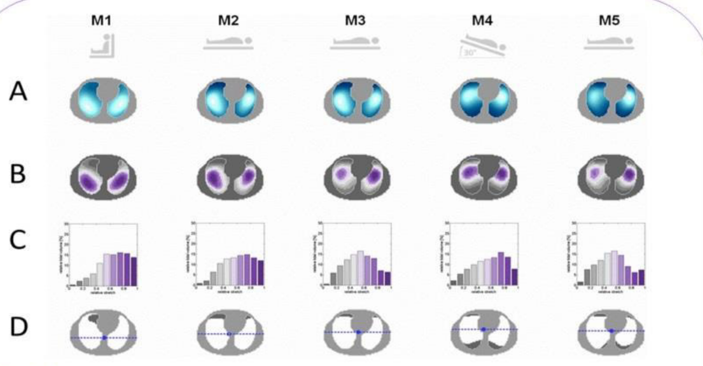

Fig. 1: Representative EIT images and EIT-derived parameters along the protocol (M1: spontaneous breathing, sitting position; M2: spontaneous breathing supine position, M3: mechanical ventilation; M4: mechanical ventilation, head down, capnoperitoneum; M5: mechanical ventilation, supine position). A tidal image, B stretch, C frequency distribution of stretch, D silent spaces, centre of ventilation (blue dot) and ventilation horizon (dotted horizontal blue line) .

For the present analysis, tidal variations of impedance within the ROIs were measured as the difference between the end of inspiration and the beginning of the previous inspiration (Fig 1B). The maximal pixel amplitude within the tidal image was divided by 10, which resulted in 10 different amplitude or relative "stretch" categories (Fig 1B). A ten-bar histogram was created where the height of each bar represents the relative contribution of this particular stretch category to the overall tidal volume (Fig 1C) .

Then, for each breath a virtual line perpendicular to the gravity vector through the geometric focal point of overall ventilation (Centre of Ventilation) of that same breath was defined as the "ventilation horizon" (Fig 1D). All pixels lying below this horizon and belonging to the lowermost stretch category were defined as dependent silent space (DSS). The number of these pixels was counted and expressed as % of all pixels within the ROI. Accordingly, the non-dependent silent space (NSS) value describes the percentage of poorly ventilated pixels physically located above the ventilation horizon (Fig. 2D).

Results: Compared to baseline (M1) the number of pixels assigned to DSS increased significantly at all points in time. The DSS value at M4 was also significantly elevated compared to M3. The percentage of pixels belonging to the NSS category decreased along the protocol and was significantly reduced at M2 – M5 compared to M1 (see figure 4).

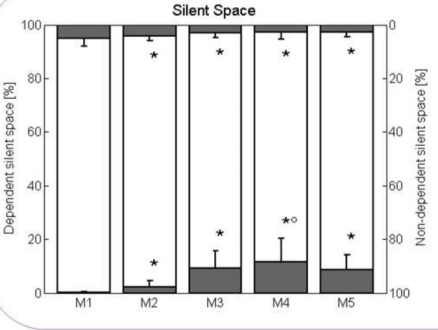

Figure 2: Perioperative silent spaces with standard deviation for all time points compared to baseline. Statistically significant differences are tagged with * (P<0.05) when compared to M1 or with ° when compared to M3.

Conclusion: We describe for the first time the mapping of non-dependent silent spaces and dependent silent spaces during spontaneous breathing, changing ventilation conditions and body positions in 40 pulmonary healthy patients using EIT with increased spatial and signal resolution compared to earlier EIT devices. The location of silent spaces illustrates the gain of none or poorly ventilated areas of the dependent lung. Taking the simultaneous decrease of non-dependent silent spaces into account a ventral shift of ventilation could be identified. Dependent silent spaces are either collapsed or at risk of becoming atelectatic whereas non-dependent silent spaces tend to be overdistended. Identifying these lung areas of particular clinical relevance by EIT may help develop perioperative protective ventilation strategies.

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2.Henderson RP, Webster JG: An impedance camera for spatially specific measurements of the thorax. IEEE Trans Biomed Eng 1978; 25: 250-4

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Content: Dr. Stephan Böhm; Concept & Design: Zweizeit Brand Development

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