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ULTRASOUND ASSESSMENT OF DIAPHRAGMATIC KINETICS IN HEALTHY VOLUNTEERS BREATHING WITH INCREASED RESISTIVE AND ELASTIC RESPIRATORY LOADS

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INTRODUCTION. The ultrasound assessment of diaphragmatic motion patterns during different respiratory conditions remain poorly documented.

OBJECTIVES. The aim of our study was to evaluate with echo the diaphragmatic motion under conditions of increased respiratory resistive and elastic loads in healthy volunteers.

METHODS. The kinetics of the diaphragm [diaphragmatic displacement (D_d, cm) and the speed (cm/s) of the diaphragmatic contraction] were studied using M-mode sonography of the right diaphragm. The breathing pattern of the respiratory system [T_i, T_e, T_{tot}, V_t, V_E, RR, V_d/V_t, RQ and Resting Energy Expenditure (REE)] were measured using an indirect calorimetry device in 40 (20 male and 20 female) healthy volunteers in semi recumbent position. The experiment was conducted first while the individuals were breathing quietly (phase I), then while breathing under a resistive load of 40 cmH_2O/lit/s (phase II) and finally while breathing under a 4 kg weight on their chest and a 3 kg weight on their abdomen, in order to reduce the chest wall compliance (phase III).

RESULTS. Using a multivariable-adjusted fixed effect linear regression model (adjusted for age, gender, BMI and respiratory rate) we found a statistically significant tidal volume increase by 422, 552 and 535 ml per each centimeter of diaphragmatic displacement in phases I, II, and III, respectively ($p < 0.01$). Male gender was associated with a 270 ml higher tidal volume compared to females. Resistive and elastic loads significantly decreased the D_d from 2.3 to 2.15 and 2.19 cm, respectively ($p < 0.05$). The speed of D_d remained constant with elastic loads, but decreased with resistive loads from 1.2 to 0.7 cm/s ($p < 0.05$). Minute ventilation (V_E) remained constant (10 l/min) during the three phases. However, with resistive loads RR decreased due to an increase in T_{tot} from 5 to 6.2 s, while V_t significantly increased. On the contrary, with the elastic loads used, no significant change in the respiratory pattern was observed. REE increased, compared to baseline, only with resistive loads, from 1524 kcal/day to 1772 kcal/day ($p < 0.001$).

CONCLUSIONS. Resistive loads represent a significant burden to the respiratory system compared to the elastic loads. To minimise this burden, the respiratory system decreases the speed of the diaphragmatic contraction and the RR, maintaining constant the V_E through an increase in V_t.

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CALCULATION OF FUNCTIONAL RESIDUAL CAPACITY BY ELECTRICAL IMPEDANCE TOMOGRAPHY

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INTRODUCTION. If changes of functional residual capacity (FRC) could be estimated by end-expiratory lung impedance (EELI) provided by electrical impedance tomography (EIT) is under debate [1, 2].

OBJECTIVES. We studied the accuracy of FRC as measured with EIT (FRC_{EIT}) compared with direct measurements of FRC with the oxygen washout technique ($FRCO_2$) in ventilated postoperative cardiac surgery patients.

METHODS. Following approval of the local ethics committee, we studied 54 postoperative ventilated cardiac surgery patients after alveolar derecruitment, i.e. open endotracheal suctioning, and alveolar recruitment (RM). Patients were ventilated with biphasic positive airway pressure, positive end-expiratory pressure of 10 cmH_2O, and a tidal volume of 6–8 ml/kg. All patients received a standard suctioning procedure with disconnection of the ventilator (20 s, 14 F catheter, 200 mmHg negative pressure). The patients were randomized into two groups, receiving either a RM (PEEP 15 mbar, PIP 35-40 mbar for 30 s, group RM) or no RM, in which ventilation was resumed without a RM (group NRM). Measurements were conducted at the following time points: Baseline (T1), after suctioning (T2), after RM or NRM (T3), and 15 and 30 min after T3 (T4 and T5). We measured $FRCO_2$ using the oxygen washout technique (LUFU System, Dräger Medical AG, Lübeck, Germany) [3]. By means of EIT (EIT Evaluation kit, Dräger Medical AG, Lübeck, Germany) we measured global impedance tidal variation (TV) and end-expiratory lung impedance (EELI). FRC_{EIT} was calculated in two ways: 1. at each time point using TV and simultaneous measured tidal volume (V_T): $FRC_{EIT\_Vt} = EELI \times V_T/TV$; and 2. using absolute FRC values at T1: $FRC_{EIT\_T1} = EELI_{Tx} \times FRCO_2(T1)/EELI(T1)$. FRC_{EIT_Vt} and FRC_{EIT_T1} were compared with $FRCO_2$ using Bland–Altman analysis.

RESULTS. FRC values calculated by V_T and TV (FRC_{EIT_Vt}) underestimate $FRCO_2$ by 1.8 L with limits of agreement of 1.6 to 2.4 L. When comparing FRC values calculated with $FRCO_2$ at T1 (FRC_{EIT_T1}) with $FRCO_2$ bias was −0.1 to 0.7 L with limits of agreement ranging from 1.4 to 2.8 L. There were no differences between the two groups.

CONCLUSIONS. During routine bedside manoeuvre as endotracheal suctioning or alveolar recruitment FRC cannot be estimated by EIT measurement with reasonable accuracy.

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LUNG REGIONAL STRESS/STRAIN RELATION IN MECHANICALLY VENTILATED PATIENTS

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INTRODUCTION. Transpulmonary pressure (Ptp) or stress, deforms lung parenchyma from its resting position, which is the Functional Residual Capacity (FRC). Ratio of lung volume change to FRC is named strain.

OBJECTIVES. Aim of the study was to evaluate the Stress versus Strain (S/S) relation of five lung Regions of Interests (ROI) in supine, mechanically ventilated patients by using computed tomography (CT).

METHODS. During sedation, ten intubated and ventilated patients without pulmonary pathologies, were transported to CT unit. We collected the tracings of flow, volume and pressure at airways opening together with esophageal pressure. During volume controlled mechanical ventilation we executed 8 end-inspiratory hold maneuvers (IHM) at different inflation volumes (from 4 to 11 ml/kg in steps of 1 ml/kg). Simultaneously with each IHM and at FRC, we performed CT scans at a level between heart and diaphragm. Each scan was divided 4 regions of interest (ROI) into nondependent, intermediate, dependent and sub-cardiac. By the gas content of the ROIs and of the entire slice, we calculated regional and global strains. Stress was estimated by Ptp. Exponential regression of the single S/S curves was performed, tested for statistical significance and compared by Fisher test.

RESULTS. Global and regional S/S curves are exponential and described by statistically different equations. At the same stress, dependent ROIs show a fourfold higher strain than nondependent regions.

CONCLUSIONS. Lung is inherently inhomogeneous. While titrating mechanical ventilation, it is necessary to be cautious in using parameters derived from global lung strain because it can be very different from the strain of single ROIs.

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EFFECTS OF FLUIDS QUANTITY ON RESPIRATORY MECHANICS

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INTRODUCTION. Anaesthesia induction determines a reduction of functional residual capacity (FRC) [1]. Furthermore, the surgical insult is associated with an increased extra-vascular lung water mainly because of the pro-inflammatory response induced by surgery itself and the administration of intra-operative fluids. The decrease of FRC associated with increased extra vascular water could be responsible of oedema of the small to medium airways, and hence of an increases of inspiratory and expiratory resistances up to the development of expiratory flow limitation (EFL) [2].

OBJECTIVES. The aim of this prospective randomized trial was to determine whether different quantitative strategies of fluids administration could have different effects on perioperative respiratory function, particularly on the development of EFL.

METHODS. Including criteria: adult patients undergoing elective major abdominal surgery. Exclusion criterion: the presence of EFL before surgery, evaluated through the NEP test both in seated and supine position [2]. On the day of surgery, patients were randomized in two groups on the basis of the volume replacement strategy: Group A: 12 ml/kg/h and Group B: 18 ml/kg/h. They were ventilated in volume controlled mode. An inspiratory pause of 20% allowed the calculation of the quasi-static compliance of respiratory system (Cqst, rs) whilst the determination of the peak inspiratory pressure and the pressure at the point of 0 flow (V') allowed the calculation of the resistance of the respiratory system (Rmin, rs).The presence of EFL during general anaesthesia was assessed with PEEP test which consisted of the rapid subtraction of 3 cmH_2O of PEEPe immediately before expiration (i.e. passing at the beginning of exhalation from a value of PEEP of 3 cmH_2O to ZEEP). In patients with EFL, no difference of expiratory flow was detected between the breath at ZEEP and PEEPe, while in patients without EFL, a difference in expiratory flow ($\Delta V'$) was found. This difference of V' was quantified and calculated at mid-expiration.

RESULTS. We enrolled 22 patients, 11 in Group A and 11 in Group B. Cqst, rs (47 $\pm$ 3.3 vs. 36 $\pm$ 1.6 l/$cmH_2$0), Rmin, rs, (8 $\pm$ 2.6 vs. 10 $\pm$ 4.8 $cmH_2$0/l/s) the PaO_2/FiO_2 ratio (372 vs. 338) and $\Delta V'$ (0.09 vs. 0.07 l/s) were statistically worse in the group B. Moreover the presence of EFL was detected only in four patients of the group B.

CONCLUSIONS. The main result of our study is that differences in terms of quantity volume replacement strategy seem to influence both changes in of the respiratory system compliance and reduction in expiratory flows up to the development of expiratory flow limitation.

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