EVALUATION OF EFFECTS OF REPETITIVE RECRUITMENT MANEUVERS

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Original paper
SUMMARY
Introduction: Acute respiratory failure is manifested clinically as patient with variable degrees of respiratory distress, but characterized as an abnormal arterial blood partial pressure of oxygen or carbon dioxide. The application of mechanical ventilation in this setting can be life saving. Goals: The aim of this study is to evaluate the effects of two recruitment maneuvers not only on oxygenation, but on aeration of the lung as well. For that purpose chest x ray and thoracic computed tomography scan (CT) of the lung were used as safe and objective methods for evaluation the impact of recruitment maneuvers on aeration of the lung. CT scan and chest x ray were performed before recruitment maneuvers as confirmation of diagnose and one day after the last recruitment maneuvers. Material and methods: Sixty patients who met arDS criteria of the American European consensus conference were included in this study. This study was conducted in ICU in our hospital between November 2009 and December 2011. Patients were orally intubated, sedated with 2-0, 4 μg/kg/min and midazolam 4 mg/h, and ventilated with evita 2 Dura ventilator (Dräger Germany). According to the recommendation of the Consensus Conference of the American College of Chest physician all patients had an arterial catheter and central venous catheter. Hemodynamic data were collected from Datex Ohmeda monitors. Gas analyses were measured from blood samples taken from arteria radialis. Partial pressure of oxygen of mixed blood was measured from blood sample taken from v jugularis interior. We used arterial blood collection syringe 8d preset, and blood samples were analyzed with AVL 995 HB blood gas analyzer. Results: Hemodynamic changes: there wasn’t any differences in heart rate, and mean arterial blood pressure before the recruitment five minutes and sixty minutes after the recruitment in both groups. Respiratory mechanics: Highest values of the compliance are achieved during the recruitment maneuver in both groups. There was better improvement in compliance during the e sigh recruitment maneuver, then in Cpap recruitment maneuver. There was improvement in chest x ray in both groups. 93,4% of patients in the Cpap group and 96,7% in e sigh group. CT scan: in Cpap group there were 8 patients with focal changes and 22 patients with diffuse changes. In e sigh group 29 patients had diffuse changes of the lung and one patient had focal changes. We noticed that there was better improvement in aeration in patients with diffuse changes of the lung 96.7% in e sigh group and 73,3% in Cpap group. In patient with focal changes there was improvement in 26,7% in e sigh group and 3,3% in Cpap group. We noticed that there was better improvement in aeration in patients with diffuse changes than in patients with focal changes. E sigh maneuver had better impact on aeration of the lung then Cpap recruitment maneuver. Conclusion: In our study we proved that e sigh recruitment maneuvers better improved oxygenation in arterial blood than Cpap recruitment maneuver. Repetative e sigh maneuvers proved to be essential for arDS patients. They reopned collapsed alveoli and improved aeration of the lung which was confirmed by X ray and CT scan as an objective methods for verification of lung condition. Key words: acute respiratory failure, respiratory distress, repetitive recruitment maneuvers.

1. INTRODUCTION
Acute respiratory failure is manifested clinically as patient with variable degrees of respiratory distress, but characterized as an abnormal arterial blood partial pressure of oxygen or carbon dioxide. The application of mechanical ventilation in this setting can be life saving (1). Acute respiratory distress syndrome is characterized with acute lung inflammation, with increased vascular permeability. There are bilateral widespread infiltrates on X-ray, PaO2/FiO2 ratio is < 40 k Pa, and pulmonary arterial wedge pressure is less than 2.5 kPa (PAWP < 2.5 kPa) (2). By definition ARDS is lung permeability edema, which means that alveolar are not collapsed but liquid filled (3). Reduction of tidal volume and plateaux pressure (Pplat) < 35 cm H2O and adequate positive end expiratory pressure to improve oxygenation, FiO2 < 0,5 is recommended for the ventilatory management of ARDS (4, 5). It is well known that reduction in tidal volume promotes a decrease in lung aeration (6, 7). Several studies recommend the adjunction of recruitment maneuvers to mechanical ventilation to limit alveolar derecruitment induced by low tidal volume (8, 9, 10, 11). During ongoing management of ALI/ARDS, a lung recruitment maneuvers requires briefly increasing of the alveolar pressure to a level above that recommended, in order to aerate lung units filled with edema or inflammatory cells. Recruitment is a physiological process that reopens previously gas less lung units exposed to positive pressure ventilation (12). Until now there
are lot of studies that evaluated effects of extended sigh (e sigh) and continuous positive airway pressure (CPAP) recruitment maneuvers not only on gas exchanges but on respiratory mechanics as well (13, 14, 15, 16, 17, 18).

2. GOAL OF STUDY
The aim of this study is to evaluate the effects of two recruitment maneuvers not only on oxygenation, but on aeration of the lung as well. For that purpose chest x ray and thoracic computed tomography scan (CT) of the lung were used as safe and objective methods for evaluation the impact of recruitment maneuvers on aeration of the lung. CT scan and chest x ray were performed before recruitment maneuvers as confirmation of diagnosis and one day after the last recruitment maneuvers. We established that the last recruitment maneuver would be considered the maneuver after which two consecutive gas analysis (the first one will be taken at 7 h, and the last one at 19h) would fulfill these criteria: PaO2 > 12.9 kPa and PaO2/FiO2 > 40 kPa.

3. MATERIALS AND METHODS
Sixty patients who met ARDS criteria of the American European consensus conference (2) were included in this study. This study was conducted in ICU in our hospital between November 2009 and December 2011. Exclusion criteria were age under eighteen years, chronic obstructive pulmonary disease, asthma, restrictive respiratory insufficiency, bronchoplaeural fistula, intracranial hypertension, and hemodynamic instability despite support therapy. Patients were orally intubated, sedated with 0, 2-0, 4 µg/kg /min and midazolam 4 mg/h, and ventilated with Evita 2 Dura ventilator (Drager Germany) according to the recommendation of the Consensus Conference of the American College of Chest Physician (19). All patients had an arterial catheter and central venous catheter. Hemodynamic data were collected from Data Ohmeda monitors.

Gas analyses were measured from blood samples taken from artemia radialis. Partial pressure of oxygen of mixed blood was measured from blood sample taken from jugularis interior. We used arterial blood colection syringe Bd preset, and blood samples were analyzed with AVL 995HB blood gas analyzer. Patients were ventilated in volume control ventilation with tidal volume (Vt) 6ml/kg and respiratory rate was 12 respiration per minute. Positive end expiratory pressure (PEEP) and fraction of inspired oxygen (FiO2) were set to obtain partial pressure of carbon dioxid (PaCO2) equal or less then 6.13kPa. We continuously monitored compliance, tidal volume, respiratory rate, plateau pressure, paek airway pressure on the display of Evita 2 Dura ventilators (Drager Germany). The image of pressure volume curves were obtained under quasi static conditions during mechanical ventilation (20).

An investigator who was responsible for the collection of the data and statistical analyses was blinded in respect of the protocol.

Before the RM, hemodynamic status of the patient was checked. Noninvasive blood pressure, pulse and electrocardiogram (EKG) were monitored on Data Ohmeda monitors. If fluid administration or vaso-presors were not enough for hemodynamic stability, we didn’t start recruitment maneuver. Patients were ventilated in zero end expiratory pressure (ZEEP) for five minutes. Compliance of the lung was recorded and lower inflation point (LIP) and upper inflation point (UIP) were established on the pressure–volume curve of the ventilator. Then we proceeded with recruitment maneuvers

3.1. Recruitment manuevers
Group 1. The continuous positive airway pressure (CPAP) recruitment maneuver: The ventilator was set to CPAP mode with pressure of 35 cm H2O applied for 35 seconds. After that patients were ventilated in baseline values.

Group 2. Extended sigh maneuver: Positive end expiratory pressure (PEEP) was 10 cm H2O above LIP was applied for 15 minutes. Patients were on volume control ventilation. If plateau pressure was higher then upper inflation point or higher then 35 cm H2O, we decreased tidal volume. During the recruitment maneuver maximum peak pressure was limited to 50 cm H2O. In case of severe hemodynamic instabilti ( systolic pressure <70mmHg, heart rate < 50 breaths per minute, hypoxemia SpO2<80%) recruitment maneuver was immediately stopped.

Before recruitment maneuvers (time 1) five minutes (time 2); and one hour (time3) after the recruitment maneuvers we collected data from: a) hemodynamic parameters: heart rate, mean arterial pressure (MAP), EKG; b) gas analyzes taken from blood samples from a. radialis partial pressure of oxygen (PaO2),

<table>
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<th>St dev</th>
<th>Mean</th>
<th>St dev</th>
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<tr>
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<tr>
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Table 1. Mean minimum, and maximum values and standard deviation for gas analyses in three time points. t1 before recruitment maneuver t2 five minutes after the recruitment maneuver, t3 one hour after the recruitment maneuver.
Table 2. Mean, minimum-maximum values of Tidal volume, Peak Pressure, Positive end expiratory pressure (PEEP), plateau pressure, compliance, before and during recruitment maneuver (mean, minimum, maximum values and standard deviation). t1 before recruitment, t2 during the recruitment.

<table>
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<th></th>
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<th>t2</th>
<th>p-value</th>
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<tr>
<td>TV (ml)</td>
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<td>363.8</td>
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<tr>
<td>PEEP cmH2O</td>
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<td>20.9</td>
<td></td>
</tr>
<tr>
<td>Compliance ml/cmH2O</td>
<td>29.9</td>
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<tr>
<td>p peak cmH2O</td>
<td>37.1</td>
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</tr>
<tr>
<td>p plat cmH2O</td>
<td>29.9</td>
<td>37.0</td>
<td></td>
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</table>

Table 3. Analysis of variance ANOVA test

Two chest x ray films were taken during this study. The first one was before we started with recruitment maneuvers. We were looking for presence of intense parenchymal opacification (focal or homogeneous increase in density). The extent of these changes were scored 0 none, 1-focal, 2-diffuse. We were looking for signs of pneumothorax, pneumo-mediastinum, as a assessment of safest performed recruitment maneuver. These second chest x rays were taken one day after the last recruitment maneuver. Thoracic computed tomography scan was taken before recruitment maneuvers and one day after the last recruitment maneuver.

Thoracic computed tomography scan procedure (CT): Lung scanning was performed in supine position from apex to the diaphragm by Ge Bright Speed Elite General Elektrik (Ge) USA. All images were observed at a window width of 1600 Hounsfeld units (HU) and a window level of 600 HU. The exposures were taken without contrast materials. By protocol CT was performed before RM at zero PEEP and one day after the last RM when gas analysis of the patients filled this criteria: PaO2 > 12.9 k Pa and PaO2/FiO2 > 40 k Pa. During the CT scan we monitored: puls oximetry, electrocardiogram and blood pressure. If there was hemodynamic instability or peripheral saturation (SpO2), was ≤85% we stopped the procedure. Qualitative assessment of lung were performed by a applying CT scan ARDS criteria: focal loss of aeration, diffuse loss of aeration and patchy loss of aeration (25).

3.2. Statistical analysis

All data are expressed as mean and standard deviation. Baseline clinical and ventilator data are compared by student t-test for parametric data and Mann-Whitney U test for nonparametric data. Kolmogorov Smirnov test was used for verification of normal distribution of quantitative data. The statistical significance level eas fixed at 0.05.

4. RESULTS

The mean values of PaO2, SpO2, PaO2/FiO2 ratio, SjVO2, O2 sat heart rate and mean arterial pressure are shown at Table 1. The highest value PaO2, SpO2, PaO2/FiO2 ratio, SjVO2, O2 sat was achieved five minutes after the recruitment maneuvers in both groups. There is significant difference in PaO2, PaO2/FiO2 ratio, O2 saturation before the recruitment maneuvers and after recruitment maneuvers (p=0.0000) (Table 3). The lowest mean value of PaCO2 in e sigh group was achieved one hour after the RM. In CPAP group, the lowest value was achieved 5 minutes after the RM. According to the post hoc Turkey HSD, both recruitment maneuvers had positive impact on PaO2, PaO2/FiO2 ratio, SjVO2, O2 saturation and PaO2/FiO2 ratio not only five minutes after the recruitment maneuvers, but also sixty minutes after the recruitment maneuvers (p=0.000). We used Mann-Whitney U test (Table 4) to compare the impact of two recruitment maneuvers on gas exchange in three measuring points. For partial pressure of oxygen (PaO2) five minutes after the recruitment maneuvers there wasn’t any differences between two groups. One hour after the renovations, extended sigh had better impact on PaO2 comparing to values in CPAP group p=0.007. Extended sigh also had better impact on PaO2/FiO2 ratio (p=0.0000) peripheral saturation of ox-
ygen (SpO₂) and saturation of oxygen in mixed blood (SjVO₂) five minutes and one hour after the recruitment maneuver. There wasn’t significant differences in oxygen saturation in arterial blood sample (O₂ sat) and partial pressure of oxygen taken from blood sample of jugular vein (SjVO₂) between two groups.

**Hemodynamic changes:** There wasn’t any differences in heart rate, and mean arterial blood pressure before the recruitment five minutes and sixty minutes after the recruitment in both groups.

**Respiratory mechanics:** Highest values of the compliance are achieved during the recruitment maneuver in both groups. There was better improvement in compliance during the sigh recruitment maneuver, then in CPAP recruitment maneuver (Table 2).

There was improvement in chest x ray in both groups. 93.4% of patients in the CPAP group and 96.7% in sigh group. CT scan: In CPAP group there were 8 patients with focal changes and 22 patients with diffuse changes. In sigh group 29 patients had diffuse changes of the lung and one patient had focal changes. We noticed that there was better improvement in aeration in patients with diffuse changes of the lung 96.7% in sigh group and 73.3% in CPAP group. In patient with focal changes there was improvement in 26.7% in sigh group and 3.3% in CPAP group. We noticed that there was better improvement in aeration in patients with diffuse changes than in patients with focal changes. Sigh maneuver had better impact on aeration of the lung then CPAP recruitment maneuver.

5. **DISCUSSION**

In our study we proved that sigh recruitment maneuver improved arterial oxygenation. Partial pressure of oxygen/PaO₂ and oxygen saturation (O₂ sat) in arterial blood showed better results in sigh maneuver. Partial pressure of oxygen in venous jugularis interna (SjVO₂) was also improved but there was not statistical differences in SjVO₂ before and after the recruitment maneuvers. Compliance of lung was also better improved during the sigh recruitment maneuvers RM.

Lim and al. (27) used e sigh as recruitment maneuvers. He gradually reduced tidal volumes from 8 to 2 ml/kg and increased PEEP from 10 to 25 cmH₂O. When PEEP of 25 cmH₂O was reached, CPAP of 30 cmH₂O was applied for 30 seconds. This was a successful maneuver, oxygenation was increased and patients were hemodynamically stable. Lots of authors (11, 17, 19) showed that e sigh was safe and efficient method for improvement in oxygenation. Constantin et al. (28) compared two recruitment maneuvers, e sigh with PEEP 10 cmH₂O above LIP for 15 minutes and CPAP 40 cmH₂O for 40 seconds.

Both maneuvers approved oxygenation but CPAP was associated with hemodynamic instability. Khaled M Mahmoud and Amany S Ammar (28) also proved that extended sigh was more effective in oxygenation of the patients then CPAP. In study of Pellosi (29) was shown that conventional e sigh improved oxygenation but the effect of improvement was limited until the discontinuation. Lapinsky et al. (30) applied inflation maneuver using 45 cmH₂O or the peak pressure at he tidal volume at the tidal volume of 12ml/kg which was lower.

The maneuver was applied for 20 seconds. Improvement in oxygenation occurred in 10 minutes. No barotrauma nor nor complications were recorded. Five patient developed hypotension and mild oxygen desaturation.

6. **CONCLUSION**

In our study we proved that e sigh recruitment maneuvers better improved oxygenation in arterial blood than CPAP recruitment maneuver. Repetative e sigh maneuver proved to be essential for ARDS patients. They reopened collapsed alveoli and improved aeration of the lung which was confirmed by x ray and CT scan as an objective methods for verification of lung condition.

**REFERENCES**


