EVALUATION OF EFFECTS OF REPETITIVE RECRUITMENT MANEUVERS

Tatjana Trojik1,2,3, Mirjana Shosholcheva1, Jasmina Radulovska-Chabukovska1, Margita Lovach-Chepujnoska4
University Clinic for surgical diseases of "St. Naum Ohridski", Skopje Macedonia1,2,3
General Private Hospital "Remedika", Skopje, R.Macedonia4

Corresponding author: Tatjana Trojik, MD. University Clinic for surgical diseases of "St. Naum Ohridski", Skopje, R Macedonia.

Original paper

SUMMARY

Introduction: acute respiratory failure is manifested clinically as patient with variable degrees of respiratory distress, but characteristically 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 artDS criteria of the american european consensus conference were included in this study. This study was conducted in ICU in our hospital be-tween november 2009 and December 2011. 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 [Dragger gemany]. According to the recom-men-dation of the Consensus Conference of the american College of Chest physician all patients had an arterial catheter and cen-trl venous catheter. Hemodynamic data were collected from Data Ohmeda monitors. Gas analysals 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 colection syringe 8d preset, and blood samples were analyzed with AVL 995HB blood gas analiser. 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 achived during the recruitment maneuver in both groups. There was better improvement in compliance during the e sigh recruitment maneuver, then in Cpp manoeuver. There was improvement in chest x ray in both groups. 93,4% of patients in the Cpp group and 96,7% in e sigh group. CT scan: in Cpp 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 Cppgroup. In patient with focal changes there was improvement in 26,7% in e sigh group and 3,3% in Cpp 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 Cpp recruitment maneuver. Conclusion: in our study we proved that e sigh recruitment maneuvers better improved oxygenation in arterial blood than Cpp recruitment maneu-ner. Repetative e sigh manoeuvers proved to be essential for artDS 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.

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 characteristically 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/FiO2ratio is < 40 k Pa, and pulmonary arterial wedge pressure is less than 2,5kPa (PAWP < 2,5kPa) (2). By definition ARDS is lung permeability edema, which means that alveolar are not collapsed but liq-uid filled (3). Reduction of tidal vol-ume and plateau pressure (Pplat) < 35 cm H2O and adequate positive end expiratory pressure to improve oxygenation , FiO2< 0,5 is recom-mended for the ventilatory man-agement of ARDS (4, 5). It is well known that reduction in tidal vol-ume promotes a decrease in lung aeration (6, 7). Several studies rec-commend the adjunction of recruit-ment maneuvers to mechanical ven-tilation to limit alveolar derecruit-ment induced by low tidal volume (8, 9, 10, 11). During ongoing man-agement of ALI/ARDS, a lung re-cruitment maneuvers requires brief-ly 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 pro-cess that reopens previously gas less lung units exposed to positive pres-sure 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 also 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 analyses (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 respiratory insufficiency, 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 arteria radialis. Partial pressure of oxygen in mixed blood was measured from blood sample taken from jugularis interior. We used arterial blood coelction 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 than 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 inflection point (LIP) and upper inflection point (UIP) were established on the pressure–volume curve of the ventilator. Then we proceeded with recruitment maneuvers

3.1. Recruitment maneuvers
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 inflection 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 instability (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 (time 3) after the recruitment maneuvers we colected 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),

| values       | mean       | St dev    | Mean       | St dev |
|--------------|------------|-----------|------------|--------|
| PaO2/FiO2    |            |           |            |        |
| t1           | 20.3       | 5.02947   | 20.8       | 4.134599 |
| t2           | 55.9       | 15.25669  | 31.8       | 7.654351 |
| t3           | 41.7       | 6.89757   | 26.8       | 5.510946 |
| PaO2         |            |           |            |        |
| t1           | 9.1        | 2.087160  | 8.3        | 1.580301 |
| t2           | 19.5       | 4.639190  | 16.7       | 5.035783 |
| t3           | 14.8       | 1.775452  | 12.7       | 3.142383 |
| PaO2/FiO2    |            |           |            |        |
| t1           | 22.50568   | 4.92459   | 22.5       | 6.92459  |
| t2           | 31.2       | 1.28678   | 31.2       | 3.51782  |
| t3           | 55.9       | 15.76542  | 55.9       | 16.76542 |
| sJVO2        |            |           |            |        |
| t1           | 4.9        | 0.830788  | 4.9        | 0.830788 |
| t2           | 26.9       | 1.675189  | 26.9       | 1.675189 |
| t3           | 55.9       | 15.76542  | 55.9       | 16.76542 |
| MAP          | mmHg       |           | mmHg       |        |
| t1           | 110.7      | 17.5207   | 110.7      | 17.5207 |
| t2           | 110.7      | 17.5207   | 110.7      | 17.5207 |
| t3           | 110.7      | 17.5207   | 110.7      | 17.5207 |

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 |
Evaluation of Effects of Repetitive Recruitment Maneuvers

Table 2. Mean, minimum maximum values of Tidel volume, Peak Pressure, Positive endexpiratory pressure (PEEP), plato pressure, compliance, before and during recruitment manoeuver (mean, minimum, maximum values and standard deviation). t1 before recruitment, t2 during the recruitment

Table 4. 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 parenchimal 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 safely performed recruitment manoeuver. These second chest x ray was taken one day after the last recruitment manoeuver. Thoracic computed tomography scan was taken before recruitment manoeuver and one day after the last recruitment manoeuver.

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 Hounsfield 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 fulfilled this criteria: \( PaO_2 > 12.9 \text{ k Pa and } PaO_2/FiO_2 > 40 \text{ k Pa} \). During the CT scan we monitored: pulse oxymetry, electrocardiogram and blood pressure. If there was hemodynamic instability or periferal saturation (\( SpO_2 \)), 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 quantative data. The statistical significance level eas fixed at 0.05.

4. RESULTS

The mean values of \( PaO_2, SpO_2, PaO_2/FiO_2 \) ratio, \( SjVO_2, O_2 \) satu rate before the recruitment maneuvers and after recruitment maneuvers (p=0.0000) (Table 3). The lowest mean value of \( PaCO_2 \) 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 \( PaO_2, PaO_2/FiO_2 \) saturation \( SpO_2 \), 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 manoeuvers on gas exchage in three measuring points. For partial pressure of oxygen \( (PaO_2) \) five minutes after the recruitment manoeuvers there wasn’t any differences between two groups. One hour after the recruiements, extended sigh had better impact on \( PaO_2 \) comparing to values in CPAP group p=0.007. Extended sigh also had better impact on \( PaO_2/FiO_2 \) 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 for 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 achived during the recruitment maneuver in both groups. There was better improvement in compliance during the e 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 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.

**5. DISCUSSION**

In our study we proved that e sigh recruitment maneuver improved arterial oxygenation. Partial pressure of oxygen (PaO₂) and oxygen saturation (O₂ sat) in arterial blood showed better results in e sigh recruitment maneuvers. Partial pressure of oxygen in vena jugularis interna (SjVO₂) was also improved but there wasn’t statistical differences in SjVO₂ before and after the recruitment maneuvers. Compliance of lung was also better improved during the e 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 improved 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 of 12 ml/kg which was lower.

The maneuver was applied for 20 seconds. Improvement in oxygenation occurred in 10 minutes. No barotrauma 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 maneuvers 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**

1. Donahoe M. Basic ventilator management: Lung protective Strategies. Surg Clin N Am 2006; 86: 1389-1408.
2. Bernard GR, Artigas A, Brigham KL, Carlet J, Falke K, Hudson L, Lamy M, Legall Jr, Morris A, Spragg R. The American-European Consensus Conference on ARDS. Definitions, mechanisms, relevant outcomes, and clinical trial coordination. Am J Respir Crit Care Med. 1994 Mar; 149(3 Pt 1): 818-824.
3. Guerin C, Debord S, Leray V, Delannoy B, Bayle F, Bourdin G, Jean-Cristophe Richard. Efficacy and safety of recruitment maneuvers in acute respiratory distress syndrome. Annals of Intensive care, 2011; I: 9.
4. Wolthuis EK, Veelo DP, Choi G, Determann RM, Korevaar JC, Sronk PE, Kuiper MA, Schulz MJ. Mechanical ventilation with lower tidal volumes does not influence the prescription of opioids or sedatives. Crit Care. 2007; II: R77.
5. Villar J, Kacmarek RM, Perez-Mendez L, Aguierre-Jaime A. A high positive end-expiratory pressure, low tidal volume ventilatory strategy improves outcome in persistent acute respiratory distress syndrome: a randomized, controlled trial. Crit Care Med. 2006, 34: 1311-1331.
6. Richard JC, Maggiore SM, Jonson B, Mancebo J, Lemaire F, Brochard L. Influence of tidal volume on alveolar recruitment. Respective role of PEEP and a recruitment maneuver. Am J Respir Crit Care Med. 2001, 163: 1609-1613.
7. Lapinsky SE, Mehta S. Bench to bedside review: Recruitment and recruiting maneuvers. Crit Care. 2005, 9: 60-65.
8. Rouby JJ, Lu Q. Bench to bedside review: Adjuncts to mechanical ventilation in patients with acute lung injury. Crit Care. 2005, 9: 465-471.
9. Barbas CS, de Mattos GF, Borges Eda R. Recruitment maneuver: positive end-expiratory pressure/tidal ventilation titration in acute lung injury/acute respiratory
distress syndrome: translating experimental results to clinical practice. Crit Care. 2003; 9: 424-426.
10. Gaver DP, Samsel RW, Solway J. Effects of mechical ventilation in patients with acute lung injury. Crit Care. 2005; 9: 465-471.
11. Barbas CS, de Mattos GF, Borges Eda R. Recruitment maneuver sand positive end-expiratory pressure/tidal ventilation titration in acute lung injury/acute respiratory distress syndrome: translating experimental results to clinical practice. Crit Care. 2005; 9: 424-426.
12. Medoff BD, Harris RS, Kesselman H, Venegas J, Amato MB, Hess D. Use of recruitment maneuvers and high-positive end-expiratory pressure in a patient with acute respiratory distress syndrome. Crit Care Med. 2000; 28: 1210-1216.
13. Riva DR, Contador RS, Baez-Garcia CS, Xisto DG, Cagido VR, Martini SV, et al. Recruitment maneuver: RAMP versus CPAP pressure profile in a model of acute lung injury. Respir Physiol Neurobiol. 2009; 169: 62-68.
14. Rothen HU, Neumann P, Berglund JE, Valtbysson J, Magnusson A, Hedenstierna G. Dynamics of re-expansion of atelectasis during general anaesthesia. Br J Anaesth. 1999; 82: 551-556.
15. Pelosi P, Bottino N, Chiumello D, Caironi P, Panigada M, Gamboni C, et al. Sigh in supine and prone position during acute respiratory distress syndrome. Am J Respir Crit Care Med. 2003; 167: 521-527.
16. Lapinsky SE, Aubin M, Mehta S, Boiteau P, Slutsky AS. Safety and efficacy of a sustained inflation for alveolar recruitment in adults with respiratory failure. Intensive Care Med. 1999; 25: 1297-1301.
17. Lim CM, Koh Y, Park W, Chin JY, Shim TS, Lee SD, et al. Mechanistic scheme and effect of “extended sigh” as a recruitment maneuver in patients with acute respiratory distress syndrome: A preliminary study. Crit Care Med. 2001; 29: 1255-1260.
18. Rodriguez L, Marquer B, Mardrus P, Molenat F, Le Grand JL, Rebull M, et al. A new simple method to perform pressure-volume curves obtained under quasi-static conditions during mechanical ventilation. Intensive Care Med. 1999; 25: 173-179.
19. Ware LB, Matthay MA. The acute respiratory distress syndrome. N Engl J Med. 2000 May 4; 342(18): 1334-1349.
20. Rodriguez L, Marquer B, Mardrus P, Molenat F, Le Grand JL, Rebull M, et al. A new simple method to perform pressure-volume curves obtained under quasi-static conditions during mechanical ventilation. Intensive Care Med. 1999; 25: 173-179.
21. Constantin JM, Cayot-Constantin S, Roszyk L, Dutier E, Sapin V, Dastugue B, Bazin JE, Rouby JJ. Response to recruitment maneuver influences net alveolar fluid clearance in acute respiratory distress syndrome. Anesthesiology. 2007; 106: 944-951.
22. Bernard GR, Artigas A, Brigham KL, Carlet J, Falke K, Hudson L, Lamy M, Legall JR, Morris A, Spragg R. The American-European Consensus Conference on ARDS. Definitions, mechanisms, relevant outcomes, and clinical trial coordination. Am J Respir Crit Care Med. 1994; 149: 818-824.
23. Lu Q, Vieira S, Richecoeur J, Puybasset L, Kalfon P, Coriat P, Rouby JJ. A simple automated method for measuring pressure-volume curve during mechanical ventilation. Am J Resp Crit Care Med. 1999; 159: 257-282.
24. Lu Q, Constantin JM, Nieszkowska A, Elman M, Vieira S, Rouby JJ. Measurement of alveolar derecruitment in patients with acute lung injury: computerized tomography versus pressure-volume curve. Crit Care. 2006; 10: R95.
25. Koutsoukou A, Bekos B, Sotiriopoulou C, Koulouris NG, Rousos C, Milic-Emili J. Effects of positive end-expiratory pressure on gas exchange and respiratory flow limitation in adult respiratory distress syndrome. Crit Care Med. 2002; 30: 1941-1949.
26. Thille AW, Richard JC, Maggiore SM, Ranieri VM, Brochard L. Alveolar recruitment in pulmonary and extrapulmonary acute respiratory distress syndrome: comparison using pressure-volume curve or static compliance. Anesthesiology. 2007; 106: 212-217.
27. Malbouisson LM, Muller JC, Constantin JM, Lu Q, Puybasset L, Rouby JJ. Computed tomography assessment of positive end-expiratory pressure-induced alveolar recruitment in patients with acute respiratory distress syndrome. Am J Respir Crit Care Med. 2001; 163: 1444-1450.
28. Lim CM, Koh Y, Park W, Chin JY, Shim TS, Lee SD, et al. Mechanistic scheme and effect of “extended sigh” as a recruitment maneuver in patients with acute respiratory distress syndrome: A preliminary study. Crit Care Med. 2001; 29: 1255-1260.
29. Constantin JM, Jaber S, Dutier E, Cayot-Constantin S, Verny-Pic M, Jung B, et al. Respiratory effects of different recruitment maneuvers in acute respiratory distress syndrome. Crit Care. 2008; 12: R50.
30. Mahmoud KM, Ammar AS. A comparison between two different alveolar recruitment maneuvers in patients with acute respiratory distress syndrome. Int J Crit Illn J. 2011; 1: 114-120.
31. Pelosi P, et al. Sigh in acute respiratory distress syndrome. Am J Respir Crit Care Med. 1999; 159: 1081-1085.
32. Lapinsky SE, Aubin M, Mehta S, Boiteau P, Slutsky AS. Safety and efficacy of a sustained inflation for alveolar recruitment in adults with respiratory failure. Intensive care medicine. 1999; 25: 1297-1301.