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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 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 ar DS 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 germany). According to the recom-mendation of the Consensus Conference of the american College of Chest physician all patients had an arterial catheter and cen-tral venous catheter. Hemodynamic data were collected from Data Ohmeda monitors. Gas analyses were mesured from blood samples taken from arteria radialis. Partial pressure of oxygen of mixed blood was messured from blood sample taken from v jugularis interior. We used arterial blood colection syringe Bd preset, and blood samples were analyzed with aVI 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 manouver in both groups. There was better improvment in compliance during the e sigh recruitment maneouver, then in Cpap recruitment maneouver. 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 diffusse 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 improvment in aeration in patients with diffuse changes of the lung 96.7% in e sigh group and 73,3% in Cpapgroup. In patient with focal changes there was improvment in 26,7% in e sigh group and 3,3% in Cpap group. We noticed that there was better improvmnet 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 manouvers proved to be essential for arDS patients. They reopened collapsed alveolli 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, PaO_2/FiO_2ratio 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 liquid filled (3). Reduction of tidal volume and plateau pressure (Pplat) < 35 cm H_2O and adequate positive end expiratory pressure to improve oxygenation , FiO_2< 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 diagnose 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 k Pa and PaO2/FiO2 > 40 k Pa .

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 (Dragger 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 mesured from blood samples taken from arteria radialis. Partial pressure of oxygen of mixed blood was messured from blood sample taken from v jugularis interior. We used arterial blood colection syringe Bd preset, and blood samples were analyzed with AVL 995HB blood gas analiser. Patients were ventilated in volume control ventilation with tidel 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 continously monitored compliance , tidel 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 responsable 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,puls and electrocardiogram (EKG) were monitored on Data Ohmeda monitors. If fluid adminstartion or vasopresors were not enough for hemodynamic stabilty ,we didn't start recruitment manouver. Patients were ventilated in zero end expiratory pressure (ZEEP) for five minutes. Compliance of the lung was recorded and lower inflaction point (LIP and uper inflaction point (UIP) were established on the pressure–volume curve of the ventilator. Then we proceeded with recruitment maneuvers

3.1. Recruitment manouvers

Group 1. The continous positive airway pressure (CPAP) recruitment maneuver: The ventilator was set to CPAP mode with pressure of 35 cm H_2O applied for 35 seconds. After that patients were ventilated in baseline values.

Group 2. Extended sigh manouver: Positive end expiratory pressure (PEEP) was 10 cm H_2O above LIP was applied for 15 minutes. Patients were on volume control ventilation. If plato pressure was higher then upper inflaction point or higher then 35 cm H_2O, we decreased tidel volume. During the recruitment manouver maximum peak pressure was limited to 50 cm H_2O. 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 colected data from: a) hemodynamic parametars: heart rate, mean arterial pressure (MAP), EKG; b) gas analyzes taken from blood samples from a. radialis partial pressureof oxygen (PaO_2),

values	mean	St dev	Mean	St dev
Pao2/FiO2	kPa		kPa	
t1	20.3	5.02947	20.8	4.134599
t2	55.9	15.25669	31.8	7.651431
t3	41.7	6.89757	26.8	5.510946
PaO2	kPa		kPa	
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
O2 sat	%		%	
t1	84.9	7.234989	88.2	5.335218
t2	95.6	3.557870	95.8	2.872581
t3	93.7	2.582648	92.8	2.175189
SjVO2	kPa		kPa	
t1	4.9	4.9	5.9	0.830788
t2	5.5	5.5	6.4	0.947151
t3	5.2	5.2	6.2	0.955089
MAP	mmHg		mmHg	
t1	106.7	13.44028	106.9	15.82708
t2	100.5	15.19335	99.6	16.66963
t3	105.8	13.10077	103.9	15.55571
HR	beats/min		beats/min	
t1	110.7	16.57571	102.4	19.10515
t2	106.5	18.41801	94.3	22.50568
t3	108.8	23.36428	97.2	19.65460

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

	mean	minimum	maximum	St.deviation
TV t1	(ml) 457.4	(ml) 350.0	(ml) 520.0	48.00609
t2	363.8	250.0	489.0	54.41374
Peep t1	(cmH_2O) 13.9	(cmH_2O) 11.0	(cmH_2O) 16.0	1.40770
t2	20.9	17.0	24.0	1.50707
p peak t1	(cmH_2O) 37.1	(cmH_2O) 31.0	(cmH_2O) 45.0	3.63634
p peak t2	45.8	41.0	49.0	2.30567
p plat t1	(cmH_2O) 29.9	(cmH_2O) 27.0	(cmH_2O) 35.0	2.27328
p plat t2	37.0	32.0	39.0	1.79046
Compliance t1	(ml/cmH_2O) 29.3	(ml/cmH_2O) 24.0	(ml/cmH_2O) 37.0	2.98444
t2	41.9	32.0	49.0	3.44347

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

partial pressure of carbon dioksid ($PaCO_2$,), saturation of oxygen (sat O2) and partial pressure of oxygen in intern jugular vein ($SjVO_2$). PaO_2/FiO_2ratio was mathematically established; c) respiratory mechanics were read from the display of the ventilator: compliance, platau pressure (p plat), peak airway pressure (p peak), positive end expiratory pressure (PEEP). Lower inflaction point (LIP) and upper inflaction point (UIP) were read on pressure – volume curve (21, 22, 23, 24).

	p-level
HR time 1	0.096264
time2	0.020681
time 3	0.073629
SjVO2 time 1	0.000730
time 2	0.001680
time 3	0.000572
PaO_2 time 1	0.141278
time 2	0.071279
time 3	0.002266
PaO_2/FiO_2 time 1	0.539511
time 2	0.000000
time 3	0.000000

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 parenchimal opafication (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 saftly perfomed reccruitment manover. Thesecond chest x ray was 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 scaning 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 k Pa and PaO_2/FiO_2 > 40 k Pa . During the CT scan we monitored: puls oxymetry, electrokardiogram and blood pressure.If there was hemodinamic 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 sat heart rate and mean arterial pressure are shown at Table 1. The highest value PaO_2, SpO_2, PaO_2/FiO_2 ratio, $SjVO_2$, O_2 sat was achieved five minutes after the recruitment maneuvers in both groups. There is significant difference in PaO_2 PaO_2/FiO_2 ratio, O_2 saturation 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. Acording to the post hoc Turkey HSD, both recruitment maneuvers had positive impact on PaO_2, PaO_2/FiO_2,O_2 saturation SpO_2, not only five minutes afer the recruitment maneuvers , but also sixty minutes after the recruitment maneuvers (p=0.000). We used Mann-Whitney U test (Table 3) to compare the imapact of two recruitment manouvers on gas exchage in three measuring points. For partial presure of oxygen (PaO_2) five minutes after the recruitment manouvers there wasn't any differences bteween two groups. One hour after the recruitments , 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=o. ooooo) peripheral saturation of oxygen (SpO_2) and saturation of oxygen in mixed blood ($sjVO_2$) five minutes and one hour after the recruitment maneuver. There wasn't significant differences for oxygen saturation in arterial blood sample (O_2 sat) and partial pressure of oxygen taken from blood sample of jugulair vein ($SjVO_2$) 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 manouver in both groups. There was better improvment in compliance during the e sigh recruitment maneouver,then in CPAP recruitment maneouver (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 diffusse 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 improvment 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 improvment in 26,7% in e sigh group and 3,3% in CPAP group. We noticed that there was better improvmnet 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 oxygenatin. Partial pressure of oxygen(PaO_2) and oxygen saturation (O_2 sat) in arterial blood showed better results in e sigh recruitment maneuvers. Partial pressure of oxygen in vena jugularis interna ($SjVO_2$) was also improved but there was not statistical differences in $SjVO_2$ 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 gradualy reduced tidal volumes from 8 to 2 ml /kg and increased PEEP from 10 to 25 cmH_2O.When PEEP of 25 cm H_2O was reached, CPAP of 30 cmH_2O was applied for 30 seconds.This was a succssessful manouver, oxigenation was incresed and patients were hemidinamically stabile. Lots of authors (11, 17, 19) showed that e sigh was safe and efficiant method for improvment in oxygenation. Constantin et al. (28) compared two recruitment maneuvers, e sigh with PEEP 10 cm H_2O above LIP for 15 minutes and CPAP 40 cmH_2O for 40 seconds.

Both manouvers approved oxygenation but CPAP was assossiated 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 oxygenatian but the effect of improvment was limited untill the discoutinuation. Lapinsky et al. (30) applied inflation manouver using 45 cm H_2O or the peak pressure at he tidel volume at the tidel volume of 12ml/kg which was lower.

The manouver was applied for 20 seconds. Improvment in oxygenation occured in 10 minutes .No barotrauma nor nor complications were recoreded. 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 manouvers proved to be essential for ARDS patients .They reopened collapsed alveolli and improved aeration of the lung which was confirmed by x ray and CT scan as an objective methods for verification of lung condition.

Conflict of interest: none declared..

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