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Association of alveolar recruitment maneuvers and prone position in acute respiratory disease syndrome patients

Associação das manobras de recrutamento alveolar e posição prona na síndrome do desconforto respiratório agudo

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ABSTRACT

The acute respiratory distress syndrome is the clinical presentation of acute lung injury characterized by diffuse alveolar damage and development of non-cardiogenic pulmonary edema due to increased pulmonary alveolar-capillary membrane permeability. Alveolar recruitment maneuvers and prone position can be used in the treatment of acute respiratory distress syndrome. The objective of this review of literature was to identify possible benefits, indications, complications and care of the associated recruitment maneuvers and prone position for treatment of the acute respiratory distress syndrome. This national and international scientific literature review was developed according to the established criteria for searching the databases MedLine, LILACS, SciElo, PubMed, Cochrane, from 1994 to 2008 in Portuguese and English, with the key words: acute respiratory distress syndrome, alveolar recruitment maneuver and prone position. Despite advances in the understanding of acute respiratory distress syndrome pathophysiology, mortality is still expressive. Alveolar recruitment maneuvers and prone position significantly contribute to treatment of acute respiratory distress syndrome patient aiming to improve oxygenation and minimizing complications of refractory hypoxemia and reduction of pulmonary compliance. However,as there are few studies in literature associating alveolar recruitment maneuvers and prone position for treatment of acute respiratory distress syndrome, additional research and evidences of clinical application are required.

Keywords: Pronation/methods; Respiratory distress syndrome, adult; Respiration, artificial

Received from the Hospital Physiotherapy Post-Graduate Course of the Universidade de Uberaba - UNIUBE - Uberaba (MG), Brazil.

Submitted on February 16, 2008.
Accepted on May 6th, 2009

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INTRODUCTION

Acute respiratory distress syndrome (ARDS) is the clinical presentation of an acute pulmonary injury. It is pathologically represented by diffuse alveolar damage and pathophysiologically by development of acute non-cardiogenic pulmonary edema due to increased alveolar-capillary membrane permeability.[1,2] It may be due to pulmonary origin, such as diffused lung infection, gastric content aspiration, or to extra-pulmonary causes such as septic syndrome and poly-transfusion, among others.[2,3]

According to the American-European Consensus Conference,[4] ARDS is defined as an acute onset respiratory failure characterized at chest X-ray, by bilateral lung infiltrate compatible with lung edema; severe hypoxemia with the partial oxygen pressure/fraction of inspired oxygen rate (PaO_2/FIO_2) ≤ 200; wedge pulmonary artery pressure ≤ 18 mmHg or lack of left atrial hypertension clinical or echographic signs and presence of one risk factor for pulmonary injury.

Alveolar recruitment maneuvers (ARM) and prone position may be used for ARDS treatment. The first uses sustained increased airway pressure for recruitment of collapsed alveolar units, thus increasing the lung area available for gas exchange and, consequently, arterial oxygenation.[5,6] The second may be considered for patients who need increased positive end-expiratory pressure (PEEP) and FiO_2 in order to keep appropriate oxygen saturation (SaO_2), or patients with acute lung injury (ALI)/severe ARDS, except for those of r high risk of adverse consequences related to posture changes or patients quickly improving.[7]

A literature review was performed, searching books in private collections, and databases MedLine, LILACS, SciElo, PubMed, Cochrane, from 1994 to 2008 in Portuguese and English using the key words: acute respiratory distress syndrome, alveolar recruitment maneuver and prone position. Literature review, systematic review, randomized clinical trials, standardizations and case reports articles were included.

This study purpose was to identify the possible benefits, indications, complications and cares of associated alveolar recruitment maneuvers and prone position for ARDS patients.

ALVEOLAR RECRUITMENT MANEUVERS

Mechanical ventilation (MV) experienced significant progress in recent years, however mortality of ARDS patients remains high.[8] In an attempt to reduce damages by this syndrome, lung protection strategies have been proposed. ARM is a strategy that has been used in MV for ARDS patients. There are several ways to perform ARM, but it basically consists of using high inspiratory pressure for the expansion of collapsed alveoli to increase partial oxygen arterial pressure (PaO_2) and high PEEP levels, required to maintain the accrued benefit.[9-12] The objective is to improve gas exchange by maximum recruitment of alveolar units, to provide a more homogeneous pulmonary parenchyma ventilation.[5]

According to the 3rd Brazilian Consensus on Mechanical Ventilation, ARM has a recommendation level B for ALI/ARDS patients, as there is no consensual opinion on how to perform this maneuver.[7] According to the experts involved in the 3rd Consensus, there is not enough data to identify effects on morbidity and mortality for patients under pressure controlled (PCV) or volume controlled ventilation (CVV). However, they recommend that, whenever possible, ventilation modes limited to pressure be used as they provide more comfort and minimal respiratory work.

Prella, Feihl and Domenighetti[13] compared the potential clinical benefits of PCV versus VCV in ALI/ARDS patients regarding gas exchange, airway pressure and intrapulmonary gas distribution, on CT scans. In this study, no significant difference was found for PaO_2, carbon dioxide partial pressure (PCO_2) and PaO_2/FIO_2 between the PCV and VCV groups. However, airway peak pressure was significantly lower with PCV versus VCV. Further there was a significant increase on not aerated areas of the lung apex under VCV leading to the conclusion that PCV could be used to prevent regional hyperdistension due to a more homogenous gas distribution.

Low tidal volumes are indicated (≤ 6 mL/kg predicted body weight) and maintaining plateau pressure (Pplat) ≤ w 30 cmH_2O. Should hypercapnia be triggered, it can be tolerated (permissive hypercapnia) up to 80 mmHg in ADRS/ALI. Exceptions are patients with severe coronary disease, or cases of concomitant cerebral injury, due to acute intracranial pressure increase, moderate hypertension, increased cardiac work and increased pulmonary vascular resistance.[2,7] A drop in pH is seen with relative safety until 7.20, with slow bicarbonate replacement if indispensable for maintenance of homeostasis.

Repeated alveolar collapse and distension in affected lung parenchyma areas are deleterious, as they create shear forces on the alveolar wall, causing synthesis and release of inflammatory mediators aggravating the alveolar injury and local inflammatory process. Thus, PEEP is the main ventilatory resource used for ventilation/perfusion (V/Q) rate adequation and physiologically protect non-affected exchange areas. It is indicated in ALI/ADRS to minimize the potential lung injury linked to use of toxic oxygen concentrations and prevent end expirator lung collapse d.[2,7,14]

The literature is still controversial on the PEEP values to use in these patients. Several papers show that implementation of the ideal PEEP is more effective when based upon a decreasing assessment, adjusting the PEEP around 20 cmH_2O, then reducing FiO_2 to a lower level while keeping SaO_2 between 90% and 95%. From thereon, reducing the PEEP in 2 cmH_2O steps based upon the best static compliance values.[15] Others propose that the best PEEP level may be chosen by periodical 3-5 cmH_2O increases, analyzing the effects achieved.[2] With appropriate physiologic support, the best PEEP is that associated to best static compliance and less hemodynamic repercussion.

The pressure-volume (PxV) curve graphically displays the lung inflation pressure relative to tidal volume offered during inspiration, and the passive ratio during expiration. Several authors advocate using PEEPs above the lower inflection point of the PxV curve to minimize mechanical ventilation induced injury, caused by alveoli cyclic opening and closing. The upper inflexion point corresponds to the safe pressure threshold for pressures to be tolerated by the lungs, above which hyperdistension would occur.[16]

The 3rd Consensus on Mechanical Ventilation recommendation for ARM in ALI/ARDS patients is still restricted: short periods of high continuous positive airway pressure (CPAP) seem unable to produce sustained oxygenation improvement. On the other hand, short CPAP periods or higher inspiratory pressures (= 40 cmH_2O) followed by PEEP increase and use of prone position may be effective to sustain arterial oxygenation. There is no available evidence that this gas exchange benefit translates into improved clinical outcome.

In a prospective clinical trial, Lim et al.[17] evaluated how PEEP levels changed effects of ARM in ARDS. Patients were allocated into 3 different groups: 1) alveolar recruitment maneuver (ARM) and PEEP (ARM+PEEP); 2) ARM only; and 3) PEEP only. In the 3 groups PaO_2 was increased by the respective maneuver. Fifteen minutes after the intervention, ARM group PaO_2 was lower than PaO_2 immediately after, showing non-sustainability of the maneuver's effects. On the ARM+PEEP group, PaO_2 after intervention was higher at 15, 30, 45 and 60 minutes compared to the ARM group, thus concluding that after alveolar recruitment maneuver, a sufficient PEEP level is required as anti-derecruitment strategy.

Chart 1 presents some alveolar recruitment protocols.

PRONE POSITION

Prone position is a maneuver used for minimizing hypoxemia in ARDS patients by improving oxygenation. However, its physiologic mechanisms are not yet fully understood. This maneuver is also described by several authors as a strategy for preventing derecruitment and sustaining ARM effects, if performed under appropriate conditions and indications.[1,2,7,25]

It may be considered that the weight of structures and organs have a direct influence on alveolar ventilation.[26] However, it is believed that this is one of the reasons of the observed effects on static and dynamic complacency. On the other hand, it is know that if only the alveolar ventilation is incremented, there is no chance of oxygenation levels improvement. Decubitus change also promotes a better redistribution of alveolar fluid contents, and with this a reduction of total alveolar-capillary membrane thickness, making diffusion at this membrane level, reason why a better oxygenation rate is seen in the population treated in prone position. The explanation may reside in the gravitational effect on the hear-lung system, where in supine position, part of the lungs is below the heart submitted to compressive forces. In contrast, in prone position only a small portion of lung area is affected.[27,28]

Chart 1 – Alveolar recruitment protocol models

Authors	Year	Study types	Method
Pelosi et al.[18]	1999	Clinical trial	Consecutive sighs (3) per minute until Pplat 45 cmH_2O (protective ventilation strategy)
Puybasset et al.[19]	2000	Randomized clinical trial	VCV, FiO_2 1.0 and PEEP 10 cmH_2O
Barbas et al.[20]	2001	Randomized clinical trial	3 cycles controlled pressure 40 cmH_2O per 6 seconds every 3 hours
Patroniti et al.[21]	2002	Clinical trial	1 sigh/minute with PEEP about 40 cmH_2O during BIPAP with pressure support
Villagrá et al.[22]	2002	Randomized clinical trial	PEEP 2 cmH_2O above the highest inflexion point (curve PxV) associated to protective strategy
Bugedo et al.[23]	2003	Randomized clinical trial	PEEP increased in 5 cmH_2O steps up to 30-40 cmH_2O (30-40 seconds at each PEEP)
Schreiter et al.[24]	2004	Randomized clinical trial	PEEP 18-26 cmH_2O and high IP, limited to 80 cmH_2O

Pplat – plateau pressure; VCV – volume controlled ventilation; FiO_2 – fraction of inspired oxygen; PEEP – positive end expiratory pressure; BIPAP-biphasic positive airway pressure; PxV – pressure versus volume; IP- inspiratory pressure.

With prone position, a more homogeneous regional ventilation distribution is seen, leading to dorsal regions recruitment. This effects is due to several factors, starting from dorsal segments alveolar decompression and re-expansion, which are areas more affected by atelectasia and edema during the conventional supine position treatment. In prone position the heart region moves toward ventral position (toward the sternum) thus resulting i the volume available for ventilation increase.[29]

There is no absolute contra-indication for prone position. However, there are situations which may represent a problem, such as severe hemodynamic instability, drainage tubes in anterior chest and abdomen, cerebral edema or intracranial hypertension, recent sternum surgery, spinal injuries, cardiogenic lung edema, alveolar hemorrhage, recent abdominal surgery, pregnancy, large skin lesions and abdominal compartmental syndrome. Additionally, cases of face or ventral body area burn.[25]

According to the III Consensus on Mechanical Ventilation,[7] the prone position has grade A recommendation, and should be considered for patients needing high PEEP and FiO_2 values for keeping appropriate saturation, or patients sustaining acute lung injury or severe ARDS. If the main objective is reducing the lung injury induced by mechanic ventilation, the prone position should be used as soon as possible after ARDS/ALI diagnosis.[25]

According to Marini,[30] encouraging results are seen with prone position, as it allows better trans-alveolar forces distribution, thus reducing ventilator-induced injury.

Galiatsou et al.[31] performed a study evaluating and quantifying with CT the regional lung volume changes when diffuse or lobar ALI patients were turned into prone position after ARM. For both maneuvers (alveolar recruitment and prone position) they found increased oxygenation in lobar ALI patients. In addition, prone position also resulted in increased respiratory system complacency and reduced PCO_2 in lobar ALI. The proportion of hyperinsuflated areas, either or not ventilated, declined while the well ventilated areas rate increased in prone position. However, nevertheless ARM and prone position increased oxygenation, there was no PCO_2 effect nor on respiratory system complacency in diffused ALI patients.

In a prospective study, Guerin et al.[32] investigated the prone position effect on alveolar recruitment and oxygenation in acute respiratory failure (ALI/ARDS). Arterial blood gas, respiratory system elastic properties and static PxV curve were measured in supine position (SP1) and after one hour in prone position (PP), and after one hour turned back to supine position (SP2). There was a significant increase on the PaO_2/FiO_2 rate for SP1 and PP. A PP induced alveolar recruitment was identified in five patients. Nevertheless, no correlation was found between the oxygenation changes and chest wall elastic properties.

Rossetti et al.[33] investigated the effect of three hours ventilation in prone position on arterial oxygenation in ARDS patients. Forty one patients with diagnosis criteria for ARDS where included in this trial. PEEP was individually adjusted for each patient according to the best static lung complacency and kept constant, as well as FiO_2 during the entire study. The patients were turned into prone position for three hours, and the PaO_2/FiO_2 values were obtained during the prone position after 30, 60, 120 and 180 minutes in PP and 60 minutes after supine position. A clinically relevant oxygenation improvement was found in 32 patients. Of these, about 65% had this improvement within the first 30 minutes. Of the responders, 21 had maintenance of the reactions even after returning to supine position, some for 24 hours (15%), others for 48 hours (50%) after the maneuver. Two patients had no clinically relevant change, and seven had oxygenation deterioration in prone position, suggesting that although this is an apparently justifiable maneuver for its benefits, not all patients respond as expected.

On the other hand, Lim et al.[17] found that the ARM induced PaO_2 increase was higher in patients in supine position than in those in prone position.

Looking for the prone position effects investigation on final expiratory volume, on chest wall and lung mechanics, and the relationship between oxygenation and respiratory mechanics, Pelosi et al.[34] evaluated 16 ALI/ARDS patients. All of them were ventilated by CVV, constant flow and the measurements were obtained in supine position after 30 and 120 minutes in prone position and 30 minutes after turning into supine position. The investigators found a significant increase on patients' oxygenation level after 120 minutes in prone position. There was no significant difference on the final expiratory volume in both positions; however a consistent increase in total complacency was seen in most patients. Additionally, in 14 of the 16 studied patients, the plateau pressure was reduced after turning back to supine position versus baseline values. This effect also persisted 120 minutes after turning to supine position. The airways resistance was not significantly affected by postural changes and oxygenation changes induced by prone position were not related to final expiratory volume or respiratory system and lung complacency changes.

Although the prone position positive and beneficial results on oxygenation improvement, lung mechanics and gas exchange in ALI/ARDS patients reported by most authors, its efficacy mortality reduction was not yet shown. Gattinoni et al.[35], in a prospective randomized study looked for the impact of prone position evaluation in ALI/ARDS patients, concluding that this strategy improved these patients' oxygenation, however its routine use did not change survival.

PRONE POSITION ASSOCIATED TO ALVEOLAR RECRUITMENT MANEUVERS

Prone position has become an established method for pulmonary recruitment and PaO_2 increase in many ARDS patients. According to Kacmarek,[36] the data suggest that the recruitment maneuver in prone position is more effective for PaO_2 increase, and that the PEEP level requested for sustained PaO_2 increase is lower in prone than in the supine position.

To check if prone position oxygenation differs for PEEP value when used in supine position, Lim et al.[37] performed an experimental trial with seven acute lung injury dog models. They showed that lower PEEP levels are needed for preserving the recruitment maneuvers in prone position.

Yet, studying the oxygenation response in alveolar recruitment maneuvers, prone and supine positions in dog experimental models, Cakar et al.[38] showed that the alveolar recruitment more effectively improves oxygenation with lower PEEP levels in prone position as compared to supine position.

Pelosi et al.[39] ventilated 10 ARDS patients showing that the mechanisms for PaO_2 increases in prone position are different from the ARM mechanisms. In this trial, they correlated the final expiratory lung volume and static lung complacency with PaO_2 increase and found a positive correlation between these and recruitment maneuver, while there was no relationship between increased final expiratory lung volume and significant PaO_2 increase in prone position.

Evaluating the prone position influence on ideal PEEP calculation, Oliveira et al.[40] performed a prospective study comparing prone and supine positions, concluding that there was no difference on the ideal PEEP either for prone or supine position, and that there is no need for PEEP recalculation for every decubitus change.

CONCLUSION

Despite advances in the understanding of ARDS pathogenesis, it still results in significant mortality. The alveolar recruitment maneuver and prone position seem significantly contributive for ARDS patients' treatment, aiming oxygenation improvement and refractory hypoxemia complications minimization, and lung complacency reduction. However there are few papers in the literature evaluating these maneuvers in acute respiratory distress syndrome treatment. As those are mostly experimental, more investigation on this subject is granted, and evidences of its clinical usefulness.

RESUMO

A síndrome do desconforto respiratório agudo é a apresentação clínica de insuficiência respiratória aguda caracterizada por lesão alveolar difusa e pelo desenvolvimento do edema pulmonar não cardiogênico, devido ao aumento da permeabilidade da membrana alvéolo-capilar pulmonar. As manobras de recrutamento alveolar e a posição prona podem ser utilizadas no tratamento da síndrome do desconforto respiratório agudo. O objetivo deste estudo foi identificar os possíveis benefícios, indicações, complicações e cuidados na associação da manobra de recrutamento alveolar e posição prona na síndrome do desconforto respiratório agudo. Realizou-se revisão de literatura científica nacional e internacional conforme os critérios estabelecidos para a pesquisa documental nas bases de dados MedLine, LILACS, SciElo, PubMed, Cochrane, no período de 1994-2008, nas linguagens portuguesa e inglesa, com os unitermos: síndrome do desconforto respiratório agudo, manobra de recrutamento alveolar e posição prona. Apesar de avanços no entendimento da fisiopatologia da síndrome do desconforto respiratório agudo, essa ainda resulta em significativa mortalidade. A manobra de recrutamento alveolar e a posição prona contribuem significativamente no tratamento desses pacientes com a finalidade de melhorar a oxigenação e reduzir as complicações decorrentes da hipoxemia refratária e diminuição da complacência pulmonar. Entretanto, na literatura, há poucos estudos que associam a manobra de recrutamento alveolar e posição prona no tratamento da síndrome do desconforto respiratório agudo, fazendo-se necessária maior investigação sobre o tema e evidências de sua aplicação clínica.

Descritores: Pronação/métodos; Síndrome do desconforto respiratório do adulto; Respiração artificial

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