Comparative analysis between the alveolar recruitment maneuver and breath stacking technique in patients with acute lung injury

ABSTRACT

Objective: To compare the effectiveness of the alveolar recruitment maneuver and the breath stacking technique with respect to lung mechanics and gas exchange in patients with acute lung injury.

Methods: Thirty patients were distributed into two groups: Group 1 - breath stacking; and Group 2 - alveolar recruitment maneuver. After undergoing conventional physical therapy, all patients received both treatments with an interval of 1 day between them. In the first group, the breath stacking technique was used initially, and subsequently, the alveolar recruitment maneuver was applied. Group 2 patients were initially subjected to alveolar recruitment, followed by the breath stacking technique. Measurements of lung compliance and airway resistance were evaluated before and after the use of both techniques. Gas analyses were collected before and after the techniques were used to evaluate oxygenation and gas exchange.

Results: Both groups had a significant increase in static compliance after breath stacking (p=0.021) and alveolar recruitment (p=0.03), but with no significant differences between the groups (p=0.95). The dynamic compliance did not increase for the breath stacking (p=0.22) and alveolar recruitment (p=0.074) groups, with no significant difference between the groups (p=0.11). The airway resistance did not decrease for either groups, i.e., breath stacking (p=0.91) and alveolar recruitment (p=0.82), with no significant difference between the groups (p=0.39). The partial pressure of oxygen increased significantly after breath stacking (p=0.013) and alveolar recruitment (p=0.04), but there was no significant difference between the groups (p=0.073). The alveolar-arterial O₂ difference decreased for both groups after the breath stacking (p=0.025) and alveolar recruitment (p=0.03) interventions, and there was no significant difference between the groups (p=0.81).

Conclusion: Our data suggest that the breath stacking and alveolar recruitment techniques are effective in improving the lung mechanics and gas exchange in patients with acute lung injury.

Keywords: Positive-pressure respiration/methods; Respiratory mechanics; Breathing exercises; Pulmonary gas exchange; Physical therapy modalities

INTRODUCTION

Patients who undergo general surgery have a high incidence of respiratory complications, such as progressive reduction of lung compliance, atelectasis, pneumonia, tracheobronchial infections and prolonged mechanical ventilation.¹⁻³ The incidence of these postsurgical complications ranges from 17% to 88% of the cases.¹ Complications occur due to decreased mucociliary clearance and reduction of lung capacity and volumes.⁴

Conflicts of interest: None.

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These postsurgical complications are usually treated in the intensive care unit (ICU), where the presence of the physical therapist has become common. However, the effectiveness of physical therapy during the postoperative period is still controversial. Some authors have reported only a prophylactic efficacy of the treatment.\(^1\) Conversely, other researchers have demonstrated the effectiveness of treatments such as bronchial hygiene and lung re-expansion for the clinical improvement of atelectasis, pneumonia, lung compliance and lung capacities.\(^6\) Other methods were already considered effective in promoting improvements to collapsed areas of the lung, such as treatment with positive-end expiratory pressure (PEEP), deep-breathing exercises, lung expansion and re-expansion, inspiratory obstruction, intermittent positive pressure, incentive spirometry and chest physical therapy.\(^5\) However, there are few studies proving the efficacy of the individual techniques.\(^5\)

The alveolar recruitment maneuver (ARM) has been used to reverse atelectatic areas.\(^4,8\) ARM can be performed using different techniques, which consist of increasing the lung volume or pressure and inverting the inspiration-expiration ratio (I:E).\(^4,8\) Bittencourt\(^8\) has reported greater effectiveness in increasing the lung volume or pressure when using extrinsic PEEP.

Another technique used in lung re-expansion that has been proven effective is the breath stacking (BS) technique, described by Marini in 1986, which yields good results in terms of improved oxygenation in patients with atelectasis.\(^3\) However, the effects of this technique on respiratory mechanics in patients with severely impaired lung function must still be evaluated, which may contribute to important decisions in clinical practice.

Therefore, the present study aimed to compare, in relation to conventional physical therapy, the effectiveness of the BS and ARM techniques in lung mechanics and gas exchange in patients with acute lung injury.

**METHODS**

The present investigation was a crossover study conducted in the ICU of a public hospital in São Paulo (Hospital Regional Sul), from June 2009 to June 2011. The project was analyzed and the study was approved by the Research Ethics Committee of the hospital (no. 407/13). All family members or guardians of the patients involved in the present study signed an informed consent form after being duly informed of the procedures and interventions performed.

Patients meeting the following criteria were included in the present study: from both genders; over 18 years of age; in the postoperative period of surgery requiring general anesthesia, with involvement of at least two quadrants in the chest radiograph, oxygenation index <200, orotracheal intubation, sedation, indication for respiratory physical therapy and hemodynamically stable without the use of vasoactive drugs; and whose guardian signed the informed consent form.

The exclusion criteria consisted of patients with severe traumatic brain injury with intracranial hypertension, cardiogenic and/or hypovolemic shock, preexisting cardiac disease, renal failure (creatinine >1.3) and cardiac arrhythmia.

The study followed a protocol for recording (on a specific evaluation form) data from all participating subjects, including name, age, gender, weight, height, body mass index (BMI) and diagnosis. All individuals underwent conventional chest physical therapy, using maneuvers to remove bronchial secretions, followed by aspiration of the orotracheal tube using an open and sterile system.

After this procedure and having met all the inclusion criteria, the patients were randomly assigned to two groups. Patients from the first group (BS group) underwent conventional chest physical therapy combined with the BS technique. On the next day, they received conventional chest physical therapy combined with ARM. Patients from the second group (ARM group) were subjected to conventional respiratory physical therapy combined with ARM, and on the next day, they received conventional respiratory physical therapy combined with BS.

During the application of the techniques, the patients received volume-controlled mechanical ventilation, and the following parameters were maintained: tidal volume of 8mL/kg, PEEP of 8cmH\(_2\)O, fraction of inspired oxygen (FiO\(_2\)) of 100% and respiratory rate of 12 breaths per minute.

After conventional respiratory physical therapy, lung mechanics data (static compliance of the respiratory system - Cst, dynamic compliance of the respiratory system - Cdyn and airway resistance - Rsr) were collected using the Dixtal DX3010 device. Concurrently, an arterial blood sample was collected from the radial artery for analysis of arterial blood gases (partial pressure of oxygen - PaO\(_2\) and partial pressure of carbon dioxide - PaCO\(_2\)) and of arterial oxygen saturation (SaO\(_2\)). Subsequently, the patients were randomly subjected to ARM or BS.
To assess the effect of the intervention, the subjects were reassessed after the technique was applied, and lung mechanics data were again collected using the same device. Subsequently, another blood sample was collected for arterial blood gas analysis. The time interval between the blood collections for arterial blood gas analysis and the intervention was 10 minutes. The procedures were performed in reverse order on the next day.

BS was performed at the bedside with the patient in a 45° supine position. The technique consists of occluding the expiratory limb of the mechanic ventilator circuit with the subject performing repetitive inspiratory efforts for 20 seconds; subsequently, the expiratory limb is released, and the subject expires freely. The technique was performed six consecutive times, totaling 120 seconds with an interval of 2 minutes between applications.

ARM was performed at the bedside with the patient in a 45° supine position. The technique consisted of raising PEEP to the optimal level previously determined by calculating the progressive PEEP. Based on the optimal PEEP, PEEP was raised 2cmH₂O at a time until achieving the best lung compliance. The lowest PEEP that produced the best lung compliance was used to perform the ARM, which was applied for 30 seconds in four series, also totaling 120 seconds of recruitment.

To assess the lung mechanics, the individual was precluded from performing spontaneous breaths. If the individual had a respiratory drive, then sedation was increased under medical prescription.

**Statistical analysis**

The data obtained are expressed as the mean and standard deviation. Data symmetry was analyzed using the Kolmogorov-Smirnov test. Lung mechanics variables before and after application of the BS or ARM techniques were analyzed for all patients (n=30) using the paired t test. To compare the delta lung mechanics (pre minus post BS or ARM) between the two groups (n=15), the unpaired t test was used. Differences were considered significant when p<0.05.

The sample was calculated considering α=0.05, with a statistical power of 80% (β=0.20), and considering a difference of 4cmH₂O between the lung compliance before and after application of the technique as improved lung mechanics, with a standard deviation of 5.4 units. To answer the main research question, the sample size calculation revealed that 19 patients per group would have to be evaluated.

**RESULTS**

The sample consisted of 30 patients, distributed into two groups of 15 patients each. The mean age was 49.8 years, and 80% of the patients were male. The groups were homogeneous regarding age, gender, BMI and diagnosis (Table 1). In all cases, there was no need to increase the sedation because the patients did not have a respiratory drive at the moment of data collection.

### Table 1 - Clinical and demographic characteristics of the breath stacking and alveolar recruitment groups on the first day of application of the techniques

<table>
<thead>
<tr>
<th>Variables</th>
<th>BS (N=15)</th>
<th>ARM (N=15)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>49.8±12</td>
<td>47±11</td>
<td>0.99</td>
</tr>
<tr>
<td>Males (%)</td>
<td>80</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>26.4±3.2</td>
<td>25.1±3.5</td>
<td>0.99</td>
</tr>
<tr>
<td>Cst (cm H₂O)</td>
<td>35±5.8</td>
<td>31.9±6.7</td>
<td>0.3</td>
</tr>
<tr>
<td>Cdyn (cm H₂O)</td>
<td>24.4±2.6</td>
<td>23.2±4.3</td>
<td>0.7</td>
</tr>
<tr>
<td>Raw (ml/cm H₂O)</td>
<td>18±8</td>
<td>15±5.2</td>
<td>0.32</td>
</tr>
<tr>
<td>PaCO₂ (mmHg)</td>
<td>41.6±16.2</td>
<td>40.9±11.8</td>
<td>0.6</td>
</tr>
<tr>
<td>A-a (mmHg)</td>
<td>527.7±25.3</td>
<td>527.6±32</td>
<td>0.8</td>
</tr>
</tbody>
</table>

BS - breath stacking; ARM - alveolar recruitment maneuver; BMI - body mass index; Cst - Static compliance; Cdyn - dynamic compliance; Raw - airway resistance; PaCO₂ - partial pressure of carbon dioxide in arterial blood; A-a - alveolar-arterial. Data are expressed as the mean±standard deviation.

Immediately after the BS technique was applied, the patients exhibited an improvement in Cst from 35±5.8mL/cmH₂O to 40.7±7mL/cmH₂O (p=0.021). For ARM, there was an improvement in Cst from 31.9±6.8mL/cmH₂O to 38.6±9.2mL/cmH₂O (p=0.03) immediately after the technique was used. The delta improvement (pre minus post) of Cst was similar for both groups (p=0.95) (Figure 1).

![Figure 1 - Evaluation of static compliance of the respiratory system for the pre- and post-intervention groups. Cst - static compliance.](image)
The mean Cdyn was 24.5±3.4mL/cmH\(_2\)O and 26.2±4.2mL/cmH\(_2\)O before and after BS was used, respectively (p=0.222). Moreover, there was no improvement before and after ARM was applied, with mean of 23.2±4.3mL/cmH\(_2\)O and 26.6±5.8mL/cmH\(_2\)O, respectively (p=0.074). No significant difference was found between the deltas (pre minus post) of the groups (p=0.11).

The mean Rsr before and after the techniques were applied was 18.2±8mL/cmH\(_2\)O and 18.5±8.1mL/cmH\(_2\)O, respectively (p=0.914). For ARM, the mean Rsr decreased from 15±5.3mL/cmH\(_2\)O before the technique was used to 14.6±5.1mL/cmH\(_2\)O after it was applied (p=0.821). No significant difference was found between the deltas (pre minus post) of the groups (p=0.39).

Regarding oxygenation, the use of BS significantly improved PaO\(_2\), from 91.1±19.1mmHg to 113.3±26.2mmHg (p=0.013). Similarly, oxygenation improved significantly after ARM was used, from 84.2±29 mmHg to 102.8±18.7 mmHg (p=0.046) (Figure 2). The delta PaO\(_2\) (pre minus post) was similar between the BS (p=0.073) and ARM (p=0.32) groups.

Regarding PaCO\(_2\), BS caused a non-significant reduction from 41.6±16.2mmHg to 39.7±23.4mmHg (p=0.796). By contrast, after ARM was used, there was a non-significant increase from 40.9±11.8mmHg to 47.2±22.3mmHg (p=0.396). The delta PaCO\(_2\) (pre minus post) was similar between the groups (p=0.117).

The alveolar-arterial oxygen pressure difference (P(A-a)O\(_2\)) decreased significantly after BS was applied, from 527.7±33.8 to 500.1±30.2 (p=0.025). After ARM was used, the P(A-a)O\(_2\) difference decreased from 527.6±34.3 to 501.2±25.7 (p=0.034). The P(A-a)O\(_2\) difference was similar between the groups immediately after the techniques were applied (p=0.813) (Figure 3).

### DISCUSSION

The present study showed that both the BS and ARM techniques led to improved lung mechanics in patients with acute lung injury. However, Cdyn did not improve with the use of these techniques.

The differential of the present study was the adaptation of the BS technique in the orotracheal tube. This technique consists of occluding the patient’s mask at expiration. Thus, the expiratory limb of the ventilator was occluded in the intubated patient. In cases where the threshold pressure was reached, the ventilator cycled continuously for 20 seconds, when the valve was then released. Studies of BS have not evaluated the lung compliance and oxygenation of patients subjected to this technique; the present investigation is the first study to assess these features.

Previous research has revealed that respiratory disorders that occur after surgery with general anesthesia include reduced lung volumes and capacities, progressively reduced lung compliance, atelectasis, pneumonia, tracheobronchial infection, acute respiratory failure, hypoventilation, pleural effusion, bronchospasm, hypoxemia, respiratory failure, bronchitis, decreased effectiveness of cough and prolonged mechanical ventilation.\(^{1-4}\) The Third Brazilian Consensus on Mechanical Ventilation complements these findings by stating that atelectasis occurs in dependent areas immediately after the establishment of general anesthesia.\(^{11}\) These complications are mainly related to decreased mucociliary clearance,\(^{14}\) decreased lung volume and alveolar collapse. The present study used the BS and ARM techniques, aiming to improve the respiratory mechanics by reverting alveolar collapse and increasing the inspired lung volume, thereby improving lung compliance and Rsr, in addition to reverting hypoxemia in patients with...
Comparative analysis between the alveolar recruitment maneuver and the breath stacking technique

ARM not only reverses the atelectasis processes but also decreases the patient’s time on mechanical ventilation, thereby decreasing lung injuries caused by prolonged mechanical ventilation. However, alveolar collapse followed by distension repeatedly causes deleterious effects on the lung parenchyma because it creates shear forces in the alveolar wall, thus increasing the release of inflammatory mediators and aggravating the injury. Therefore, the use of ARM does not have the expected effect unless used with alveolar stabilization techniques. It has also been shown that employing other techniques, such as continuous positive airway pressure (CPAP), also reduces the hospitalization time. A study confirmed this fact by showing that the oxygenation index and shunt values return to baseline values 30 minutes after the application of ARM. Another investigation demonstrated that employing these techniques may reduce the duration of mechanical ventilation and the length of the ICU stay.

The present study has several limitations. The sample was not sufficient to provide statistical power to our results because 19 patients per group were necessary and our groups comprised only 15 patients. Moreover, the study was not blind and was conducted at a single center. The results consist of short-term outcomes and cannot be extrapolated to medium-term periods, especially for the gas exchange and lung mechanics variables. Moreover, no clinical outcome was evaluated. We suggest that additional investigations with larger samples and more comprehensive measures of lung mechanics be performed.

CONCLUSION

The assessment of lung mechanics in a group of acute-lung-injury patients older than 35 years suggested that the breath stacking and alveolar recruitment maneuver techniques are effective in improving lung mechanics and gas exchange.

RESUMO

Objetivo: Comparar a eficácia da manobra de recrutamento alveolar e a técnica de breath stacking, na mecânica pulmonar e na troca gasosa, em pacientes com lesão pulmonar aguda.

Métodos: Trinta pacientes foram distribuídos em dois grupos: Grupo 1 - breath stacking e Grupo 2 - manobra de recrutamento alveolar. Após receberem atendimento de fisioterapia convencional, todos os pacientes receberam ambos os tratamentos, com intervalo de 1 dia entre eles. No primeiro grupo foi aplicada primeiramente a técnica de breath stacking e, posteriormente, a manobra de recrutamento alveolar. Já os pacientes do segundo Grupo 2 foram submetidos inicialmente ao recrutamento alveolar e, após, a técnica de breath stacking. Foram avaliadas as medidas de complacência pulmonar e de resistência de vias aéreas antes e após a aplicação de ambas as técnicas. Foram coletadas gasometrias arteriais pré e pós-técnicas para avaliar a oxigenação e a troca gasosa.

Resultados: Ambos os grupos apresentaram aumento significativo da complacência estática após breath stacking.
Respiração com pressão positiva/métodos;
Nossos dados sugerem que as técnicas de oxigênio aumentou significantemente após breath stacking (p=0,025) e recrutamento alveolar (p=0,03), não sendo diferente entre os grupos (p=0,81).

Conclusão: Nossos dados sugerem que as técnicas breath stacking e de recrutamento alveolar são eficazes em melhorar a mecânica pulmonar e a troca gasosa em pacientes com lesão pulmonar aguda.

Descritores: Respiração com pressão positiva/métodos; Mecânica respiratória; Exercícios respiratórios; Troca gasosa pulmonar; Modalidades de fisioterapia

REFERENCES