Extended prone position ventilation in severe acute respiratory distress syndrome: A pilot feasibility study

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Keywords:
Acute respiratory distress syndrome;
Acute respiratory failure;
Prone position;
Mechanical ventilation

Abstract
Objectives: The aim of the study was to evaluate the safety of extended prone position ventilation (PPV) and its impact on respiratory function in patients with severe acute respiratory distress syndrome (ARDS).

Design: This was a prospective interventional study.

Setting: Patients were recruited from a mixed medical-surgical intensive care unit in a university hospital.

Patients: Fifteen consecutive patients with severe ARDS, previously unresponsive to positive end-expiratory pressure adjustment, were treated with PPV.

Intervention: Prone position ventilation for 48 hours or until the oxygenation index was 10 or less (extended PPV).

Results: The elapsed time from the initiation of mechanical ventilation to pronation was 35 ± 11 hours. Prone position ventilation was continuously maintained for 55 ± 7 hours. Two patients developed grade II pressure ulcers of small extent. None of the patients experienced life-threatening complications or hemodynamic instability during the procedure. The patients showed a statistically significant improvement in PaO2/FiO2 (92 ± 12 vs 227 ± 43, P < .0001) and oxygenation index (22 ± 5 vs 8 ± 2, P < .0001), reduction of PaCO2 (54 ± 9 vs 39 ± 4, P < .0001) and plateau pressure (32 ± 2 vs 27 ± 3, P < .0001), and increment of the static compliance (21 ± 3 vs 37 ± 6, P < .0001) with extended PPV. All the parameters continued to improve significantly while they remained in prone position and did not change upon returning the patients to the supine position.

Conclusions: The results obtained suggest that extended PPV is safe and effective in patients with severe ARDS when it is carried out by a trained staff and within an established protocol. Extended PPV is emerging as an effective therapy in the rescue of patients from severe ARDS.

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1. Introduction

Acute respiratory distress syndrome (ARDS) is highly prevalent in critically ill patients and is associated with elevated long-term morbidity and mortality [1-3]. The subgroup of patients who met the criteria for “severe ARDS” have a predicted mortality of more than 80% [4,5]. In these patients, conventional mechanical ventilation is often insufficient to achieve the target oxygenation level without producing ventilation-induced lung injury (VILI). For this reason, extraordinary means of support are usually required, such as prone position ventilation (PPV), high-frequency oscillatory ventilation, or extracorporeal oxygenation.

In the last years, PPV has been increasingly used in patients with ARDS. Nevertheless, the best moment to apply this ventilatory strategy and the optimum duration have not yet been established. Studies assessing the benefit of PPV in ARDS have included patients with varying degrees of severity and different stages of ARDS. Until now, the intervention has been used for intermittent short doses and with no definite goal to guide therapy [6-12] (Table 1).

Based on the proposed pathophysiologic mechanisms by which PPV improves oxygenation, and its theoretical diminishment in VILI risk, we believe PPV could have a beneficial and “more protective” effect, beyond transitory improvement in oxygenation, if it is applied early and for a prolonged period to patients with the most severe forms of ARDS, until their clinical condition allows safer ventilatory settings. However, the safety of PPV and its impact on mortality when carried out continuously for periods longer than 24 hours remain to be evaluated.

For these reasons, we decided to perform a pilot study to evaluate the feasibility, safety, and effects on respiratory function when PPV is carried out continuously for periods longer than 24 hours (extended PPV) in patients with severe ARDS.

2. Patients and methods

Between September, 2005 and October, 2006, 15 consecutive patients diagnosed with severe ARDS were prospectively recruited in the intensive care unit (ICU) of the University of Chile Clinical Hospital. Acute respiratory distress syndrome was defined according to the American-European Consensus Conference [13]. The inclusion criteria were age of more than 18 years, invasive mechanical ventilation of 72 hours or less, and severe ARDS, defined as persistence of an oxygenation index (OI) of 15 or more and a partial pressure of oxygen in arterial blood/inspired oxygen fraction ratio (Pao2/Fio2) of 100 mm Hg or less, after recruitment maneuvers and positive end-expiratory pressure (PEEP) adjustment (see below). Written informed consent was obtained from each patient’s next of kin.

The exclusion criteria were contraindications to PPV (increased intracranial or intra-abdominal pressure, unstable spinal cord injuries, recent abdominal or thoracic surgery, open thorax or a flail chest, inability to tolerate prone position), hemodynamic disorders (hemodynamic instability, tachyarrhythmia, acute coronary syndrome, and congestive cardiac insufficiency), chronic respiratory insufficiency, indication of limiting therapeutic efforts, and high probability of death during the following 24 hours in the ICU.

Study population characteristics are shown in Table 2. A protocol specifically designed for the care of these patients was implemented (Appendix A). No cushion was used to facilitate abdomen movement. Protective mechanical ventilation was used to ensure a tidal volume of 6 to 8 mL/kg of predicted body weight (calculated according ARDSnet protocol) and plateau pressure of less than 30 to 35 cm H2O (840 Ventilator System, Nellcor Puritan Bennett, Carlsbad, Calif).

The patients were subjected to recruitment maneuvers in the basal state, immediately after the change to prone position and upon returning to supine recumbence according to Hickling’s [14] modified strategy. For this purpose the patients were ventilated in pressure-control mode with an inspiratory pressure of 20 cm H2O, respiratory frequency of 14 per minute, I/E ratio of 1:1, and progressive increments of PEEP from basal, in steps of 5 cm H2O every 15 seconds, until a PEEP of 20 cm H2O (peak pressure 40 cm H2O). These pressure levels were maintained for 2 minutes, after

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Table 1  Summary of prospective studies that have evaluated PPV in ALI/ARDS

<table>
<thead>
<tr>
<th>Trials</th>
<th>Year</th>
<th>Design</th>
<th>Patients (n)</th>
<th>Elapsed time MV (mean)</th>
<th>Time in PPV (media) h/d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beuret et al [9]</td>
<td>2002</td>
<td>RCT</td>
<td>51</td>
<td>14 h</td>
<td>4</td>
</tr>
<tr>
<td>Vieillard-Baron et al [10]</td>
<td>2005</td>
<td>Open prospective</td>
<td>11</td>
<td>3 d</td>
<td>18 a</td>
</tr>
<tr>
<td>Mancebo et al [12]</td>
<td>2006</td>
<td>RCT</td>
<td>136</td>
<td>≈10 h b</td>
<td>17</td>
</tr>
</tbody>
</table>

MV indicates mechanical ventilation; elapsed time MV, time from the initiation of mechanical ventilation until PPV.

a Personal communication (F Jardin).

b Personal communication (J Mancebo).
which the PEEP level was reduced progressively in steps of 2 cm H$_2$O. With each reduction of PEEP, an inspiratory pause of 2 seconds was applied and the static compliance was evaluated. The PEEP level was programmed at 2 cm H$_2$O above the point at which the reduction in PEEP generated a fall in the static compliance.

Sedation protocol based on midazolam and fentanyl was used to achieve a level of 1 to 2 in the Riker sedation-

<table>
<thead>
<tr>
<th>Patients</th>
<th>Age (y)</th>
<th>Sex</th>
<th>Etiology</th>
<th>APACHE II</th>
<th>SOFA</th>
<th>Pao$_2$/FiO$_2$</th>
<th>OI</th>
<th>Elapsed time MV (h)</th>
<th>PPV (h)</th>
<th>DMV (d)</th>
<th>ICU LOS (d)</th>
<th>Outcome (hospital)</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>19</td>
<td>F</td>
<td>CAP</td>
<td>18</td>
<td>10</td>
<td>96</td>
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<td>M</td>
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<td>M</td>
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<td>M</td>
<td>CAP</td>
<td>21</td>
<td>10</td>
<td>100</td>
<td>18</td>
<td>44</td>
<td>56</td>
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<td>12</td>
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<td>53</td>
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<td>AP</td>
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<td>14</td>
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<td>M</td>
<td>AS</td>
<td>24</td>
<td>11</td>
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<td>10</td>
<td>62</td>
<td>14</td>
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<tr>
<td>15</td>
<td>40</td>
<td>F</td>
<td>AP</td>
<td>22</td>
<td>10</td>
<td>96</td>
<td>20</td>
<td>36</td>
<td>56</td>
<td>16</td>
<td>18</td>
<td>S</td>
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<tr>
<td>Mean ± SD</td>
<td>46 ± 17</td>
<td></td>
<td></td>
<td>21 ± 2</td>
<td>10 ± 1</td>
<td>92 ± 12</td>
<td>22 ± 5</td>
<td>35 ± 11</td>
<td>55 ± 7</td>
<td>19 ± 9</td>
<td>23 ± 10</td>
<td></td>
</tr>
</tbody>
</table>

CAP indicates community-acquired pneumonia; AP, aspiration pneumonia; AS, abdominal sepsis; APACHE II, Acute Physiology and Chronic Health Evaluation II; SOFA, Sequential Organ Failure Assessment; DMV, days on mechanical ventilation; ICU LOS, ICU length of stay; D, death; S, survival.

Fig. 1  Severe ARDS algorithm, Clinical Hospital, University of Chile. *PEEP trial indicates set PEEP according to best compliance during decremental PEEP trials, as it suggested by Hickling [14]; protective ventilation, low tidal volume (6-8 mL/kg) and plateau pressure of less than 30 to 35 cm H$_2$O; ECMO, extracorporeal membrane oxygenation; HFOV, high-frequency oscillatory ventilation.
agitation scale [15]. During PPV, all patients received a continuous infusion of rocuronium to achieve a train of four (TOF) of 1 to 2 [16]. Patients were maintained on PPV at least for 48 hours or until they reached an OI of 10 or less in 2 successive measurements (Fig. 1).

### 3. Measurements

The evaluation of cutaneous pressure lesions was carried out daily by the nursing staff, using the classification of the National Pressure Ulcers Advisory Panel (www.npuap.org). According to this score, stage I indicates a reddened of a localized area with intact skin; stage II, a partial thickness tissue loss; stage III, a full-thickness tissue loss with exposed bone, tendon or muscle; stage IV indicates a full-thickness tissue loss with exposed bone, tendon or muscle; slough or eschar may be present on some parts of the wound bed.

The development of barotrauma and/or monobronchial incursion of the orotracheal tube (OTT) was evaluated daily by radiography of the thorax. Displacement and accidental withdrawal of the OTT or the intravascular catheters were registered by the nursing staff.

We recorded arterial and venous blood gas results (Roche OMNI C Blood Gas Analyzer, Indianapolis, Ind), the \( P_{A02} / F\text{io}_2 \), OI, tidal volume and airway pressure (mean and plateau), mean arterial pressure, and norepinephrine (NE) requirements every 6 hours. The OI was calculated according to the formula: mean airway pressure (Paw) × FiO2 × 100/ \( P_{A02} \). The lung static compliance was obtained by dividing the tidal volume by the difference between plateau pressure and PEEP. Data obtained 12 hours after the change to prone position and, 2 hours before to return to supine position. We analyzed the former measurements and data taken 2 hours before and after each change of position (Table 3). The patients were followed throughout their stay in the hospital.

#### 3.1. Statistical analysis

Univariate analysis of variance for repeated measures was used to test for differences in continuous variables at supine –2, supine –12 (parameters 2 and 12 hours before the change to prone position, respectively) and, Proneinitial and Pronefinal (measurements performed 2 hours after the change to prone position and, 2 hours before to return to supine position). To evaluate any change upon returning the patients to the supine position, a new analysis of variance was carried out for the same variables 2 and 12 hours postprone period (supine +2 and supine +12, respectively). Post hoc analysis with Bonferroni correction was used. Statistical calculations were performed using SPSS 14.0 (Chicago, Ill) for Windows XP SP2. Results are expressed as mean (±SD). A \( P \) value of less than .05 indicated significance.

#### Table 3 Respiratory and hemodynamic changes

<table>
<thead>
<tr>
<th>Variables</th>
<th>Supine −12</th>
<th>Supine −2</th>
<th>Prone\text{initial}</th>
<th>Prone\text{final}</th>
<th>Supine +2</th>
<th>Supine +12</th>
</tr>
</thead>
<tbody>
<tr>
<td>( P_{A02} / F\text{io}_2 )</td>
<td>133 ± 24</td>
<td>92 ± 12*</td>
<td>148 ± 25*</td>
<td>227 ± 43*</td>
<td>225 ± 52</td>
<td>227 ± 53</td>
</tr>
<tr>
<td>OI</td>
<td>16 ± 4</td>
<td>22 ± 5*</td>
<td>14 ± 4*</td>
<td>8 ± 2*</td>
<td>9 ± 3</td>
<td>8 ± 3</td>
</tr>
<tr>
<td>( P_{aCO2} ) (mm Hg)</td>
<td>48 ± 4</td>
<td>54 ± 9</td>
<td>45 ± 6*</td>
<td>39 ± 4*</td>
<td>37 ± 3</td>
<td>38 ± 3</td>
</tr>
<tr>
<td>pH</td>
<td>7.32 ± 0.04</td>
<td>7.28 ± 0.05</td>
<td>7.33 ± 0.03*</td>
<td>7.39 ± 0.03*</td>
<td>7.42 ± 0.04</td>
<td>7.42 ± 0.03</td>
</tr>
<tr>
<td>Tidal volume (mL)</td>
<td>479 ± 37</td>
<td>420 ± 34*</td>
<td>444 ± 53</td>
<td>509 ± 94*</td>
<td>540 ± 99</td>
<td>541 ± 88</td>
</tr>
<tr>
<td>Paw (cm H2O)</td>
<td>20 ± 2</td>
<td>21 ± 1</td>
<td>20 ± 1</td>
<td>17 ± 3*</td>
<td>17 ± 3</td>
<td>18 ± 3</td>
</tr>
<tr>
<td>Plateau pressure (cm H2O)</td>
<td>28 ± 2</td>
<td>32 ± 2*</td>
<td>31 ± 1</td>
<td>27 ± 3*</td>
<td>27 ± 3</td>
<td>24 ± 3*</td>
</tr>
<tr>
<td>PEEP (cm H2O)</td>
<td>12 ± 1</td>
<td>12 ± 2</td>
<td>12 ± 1</td>
<td>11 ± 2</td>
<td>11 ± 2</td>
<td>9 ± 1</td>
</tr>
<tr>
<td>Compliance (mL/cm H2O)</td>
<td>30 ± 3</td>
<td>21 ± 3*</td>
<td>25 ± 3</td>
<td>37 ± 6*</td>
<td>39 ± 6</td>
<td>38 ± 5</td>
</tr>
<tr>
<td>Respiratory rate (breaths/min)</td>
<td>23 ± 3</td>
<td>24 ± 2</td>
<td>22 ± 3</td>
<td>22 ± 2</td>
<td>21 ± 3</td>
<td>21 ± 1</td>
</tr>
<tr>
<td>Mean arterial pressure (mm Hg)</td>
<td>80 ± 6</td>
<td>84 ± 8</td>
<td>82 ± 7</td>
<td>82 ± 5</td>
<td>84 ± 7</td>
<td>84 ± 5</td>
</tr>
<tr>
<td>( SvO2 ) (%)</td>
<td>73 ± 4</td>
<td>76 ± 5</td>
<td>79 ± 5</td>
<td>77 ± 5</td>
<td>80 ± 4</td>
<td>78 ± 3</td>
</tr>
</tbody>
</table>

Supine –2 and supine –12 describe parameters 2 and 12 hours before the change to prone position, respectively. Supine –12 included only data from 14 of 15 patients. Supine +2 and Supine +12 described parameters 2 and 12 hours after to return to supine position, respectively. Prone\text{initial} describes measurements performed 2 hours after the change to prone position; Prone\text{final}, measurements performed 2 hours before to return to supine position.

\* \( P < .05 \) comparing measurements made on Supine –2 and Prone\text{initial}.

\** \( P < .05 \) comparing values of Prone\text{final} with Supine +2 and Supine +12.

\§ \( P < .05 \) comparing data between Prone\text{initial} and Prone\text{final}.

\‖ \( P < .05 \) comparing measurements between Prone\text{initial} and Prone\text{final}.

\( b \) \( P < .05 \) comparing data between Supine –12 and Supine –2.
the prone position. Two patients developed grade II pressure ulcers of small extent: one in the nasal septum and the other in the cheek. All patients developed marked facial edema that decreased progressively with supine position.

No patient developed hemodynamic instability during the positional changes. Eight patients who were receiving NE (0.07 ± 0.02 μg/kg per minute) suspended the infusion during PPV.

Before PPV period, patients showed a significant worsening in their variables of oxygenation (PaO2/Fio2 and OI) and respiratory mechanics (compliance and plateau pressure) (Table 3). Twelve hours before the PPV, 11 patients had OI of more than 15. Nevertheless, they were not turned to prone position because they still had hemodynamic instability at this time.

Data analysis showed a statistically significant improvement in PaO2/Fio2 (92 ± 12 vs 227 ± 43, P < .0001) and OI (22 ± 5 vs 8 ± 2, P < .0001), reduction of PaCO2 (54 ± 9 vs 39 ± 4, P < .0001) and plateau pressure (32 ± 2 vs 27 ± 3, P < .0001), and increment of the static compliance (21 ± 3 vs 37 ± 6, P < .0001) with extended PPV. Some of these variables (PaO2/Fio2, OI, and PaCO2) had already experienced significant variations immediately after changing to prone position (Table 3). However, the most important consideration is that all the parameters continued to improve significantly while they remained in prone position and did not change upon returning the patients to the supine position (Table 3). Thirteen patients decreased their plateau pressure throughout the extended PPV, although we increase their tidal volume (from 0.5 to 1.5 mL/kg) if their plateau pressure was lower than 28 cm H2O. Six patients dead, 3 of them required a second extended PPV period because they developed a ventilatory associated pneumonia.

5. Discussion

We found that extended PPV could be carried out without major incidents. According to these findings, other authors have reported that the incidence of displacement of intravascular catheters or accidental extubation is similar to that of patients maintained in supine [8,12,17]. Extended PPV does not include frequent changes from supine to prone position, which is the moment when most complications associated to PPV occur.

The pressure lesions were the most feared complication during this study. However, the incorporation of colloidal patches in pressure zones, air mattress, and frequent changes of position probably explain the low incidence of pressure sores seen in our work. We must point out that, although the PPV protocol was recently implemented in our unit, staffs were already well familiarized with the procedure.

Although hemodynamic instability (perfusion failure or high requirement of vasoactive drugs) is a contraindication for PPV, the use of low doses of vasoactive drugs should not be an impediment to its application, whereas tissular hypoperfusion is ruled out. According to our hemodynamic management protocol [18], we used NE as the drug of choice. At time of the pronation, 8 patients were receiving NE at an average dose of 0.07 μg/kg per minute. They did not experience any worsening of their hemodynamic parameters or perfusion failure with the change of position; in fact, the NE could be suspended during PPV. Nevertheless, it is not possible to make a general recommendation, such that the risk-benefit balance of PPV in this group of patients is a case-sensitive decision.

The benefits of PPV are related to the recruitment of collapsed pulmonary regions in dependent zones, homogenization of the distribution of perfusion and pleural pressure, and consequently, the use of lower concentrations of oxygen [6,10,19,20]. By lowering the pleural pressure gradient, a more homogeneous distribution of the trans-pulmonary pressure occurs, which may be associated with a better strain distribution and reduced risk of VILI [21-24]. In this sense, the improvement in oxygenation, reduction of PaCO2, and the rise in static compliance observed in our series probably reflect recruitment of alveolar units and dead space reduction. To maintain the improvements obtained with PPV, greater PEEP levels are frequently needed when the patient returns to supine position [25]. Nevertheless, according to our results, this effect could be related to the time of permanence in PPV because, in our patients, without change in PEEP levels, oxygenation, and respiratory mechanics did not get worse after prone. The progressive improvement in gas exchange seen in our study is consistent with the report of [26] McAuley and colleagues who observed better results with PPV for long periods. Although ARDS in most of our patients was caused by severe community pneumonia, improvement in gas exchange parameters and respiratory mechanics cannot be totally explained by the antibiotic treatment due to the fact that many of these individuals evolve in an unfavorable manner with slow respiratory function recovery. In fact, patients showed important gas exchange deterioration in the 12 hours before the procedure, a situation that was reversed both rapidly and persistently in time by extended PPV (Table 3).

In patients affected by ARDS, the efficacy of high levels of PEEP depends on the balance between its beneficial and detrimental effects, that is, reduction of intratidal lung opening-closing vs increase of alveolar stress-strain. Higher levels of PEEP appear to be physiologically advantageous only in patients with a more severe disease and higher potential for lung recruitment [27]. However, lung hyperinflation of the nondependent lung regions with PEEP is the “price” in one third of the patients [28].

Our patients had a severe disease and they used high levels of PEEP, so their estimated risk of VILI was significant. Nevertheless, the decrease in plateau pressure, without a change in PEEP level and higher tidal volume,
suggest that extended PPV predominantly induced alveolar recruitment, instead of significant tidal hyperinflation. Perhaps by maintaining tidal volume constant, a greater reduction of the VILI risk could be ensured.

Setting an individualized “best PEEP” according to Hickling’s [14] modified strategy seems a rational and physiologic bedside approach. PEEP and PPV may have synergic effect on oxygenation in some patients [19]. Therefore, we think that the PEEP level must be programmed in supine and prone, independently.

We still do not know for sure how to choose the “best tidal volume” for each patient. Apparently, to select a VT of 6 mL/kg with restriction of the plateau pressure (<30 cm H2O) is not safe in a subgroup of the patients with severe ARDS [29]. While waiting for a better definition of those parameters, we believe that the determination of “best compliance” during decremental PEEP trial, limiting plateau pressure < 30 cm H2O, could be a useful bedside therapeutic intervention in patients with ARDS.

The absence of better results with PPV in larger samples [8,12,30] could be explained by lack of uniformity in the management protocols, varied outcomes, inadequate selection of the study population or intervention timing, insufficient sample size, and, likely a very brief time in the prone position. Nonetheless, post hoc analysis of one of these studies revealed that the most severely ill patients (Simplified Acute Physiology Score II [SAPS II] >49, PaO2/FiO2 <89) and those that showed a PaCO2 reduction with pronation had better survival rates compared to those ventilated in supine position [8,31]. Probably, the complications associated with the necessity for deep sedation and the use of neuromuscular blockade outweighs the benefits of PPV in patients with less severe forms of ARDS. Our inclusion criteria were designed to select a group of severely ill patients (Acute Physiology and Chronic Health Evaluation II [APACHE II] 21 ± 2 and PaO2/FiO2 92 ± 12 after recruitment maneuvers and PEEP adjustment) with the clear objective of maximizing extended PPV benefits. It is possible that organic dysfunctions (Sequential Organ Failure Assessment [SOFA] 10 ± 1) associated with respiratory failure explain the prolonged period on mechanical ventilation.

We believe that the use of OI is preferable for stratification and monitoring patients with ARDS, given that it represents the intensity of pressurized support for a determined oxygenation target, thus better characterizing the process severity [32]. Our patients entered the study with an OI of 22 ± 5, were pronated promptly (<48 hours of ARDS), remained an average of 55 straight hours on PPV, and were returned to supine position with an OI of 8 ± 2. Recently, Mancebo and colleagues [12] found that patients randomized to supine position and those with late recruitment in the study had nearly 3 times greater possibility of dying. We think that if extended PPV is applied early and for a sufficient length of time, it could generate a permanent impact on pulmonary function.

We are aware that our study has some limitations. It represents the experience of a small number of patients in only one center, there is no control group, and only 20% of the individuals were older than 60 years, thus restricting the generalization of results in a younger population. Nonetheless, it represents the first systematic evaluation study for PPV safety for an ongoing period of more than 24 hours and its impact on respiratory function in patients with severe ARDS. Although these results are encouraging, they should be considered preliminary. Further studies examining extended PPV are warranted to clarify its real impact on outcome.

In this small series of selected patients, we found that extended PPV is safe and easy to implement when it is performed by a trained staff and within an established protocol. The improvements in respiratory mechanics and specially the decrease in plateau pressure observed in our series suggest that extended PPV should be considered part of a protective ventilatory strategy. Extended PPV is emerging as an effective therapy in the rescue of patients from severe ARDS.

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Appendix A. Procedure for prone position (PP)

Preparing the patient

1. Obtain chest radiograph and verify that the endotracheal tube is appropriately positioned in the trachea.
2. Ensure security of endotracheal tube, pulse oximeter probe, and all indwelling catheters.
3. Move electrocardiographic electrodes to the lateral aspects of the upper arms and hips.
4. Consider capping nonessential vascular catheters and nasogastric tube.
5. Suction the oropharynx.
6. Apply spongy dressing to pressure point areas.
7. Assign responsibilities to each member of the PP team.

Preparing the patient in PP

Eight members of the staff participated in this maneuver (2 nurses, 3 nursing assistants, 1 respiratory therapist, and 2 physicians). All of the movements and steps during the procedure were directed by only one member of the team each time.

1. Turn the head and body in unison halfway toward the ventilator, and then turn prone. The head should be laterally rotated to face the ventilator.
2. Immediately reassess the security and patency of the endotracheal tube and other indwelling catheters.
3. Assess the need for suctioning the endotracheal tube.
4. Insert bolsters under the shoulders and pelvis (use jell pillow, foam pad, egg crates, etc.), so that the abdomen protrudes off the mattress. The patients remained on air cushions.
5. Flex the arms and position the knees and feet off the bed using an appropriate-sized roll. Cushion the forehead. Pressure points over knees and ears should be protected with control gel formula dressing.
6. Adjust the sedation/analgesia infusion to achieve adequate patient comfort. Neuromuscular blockade was achieved by continuous infusion of rocuronium for a TOF of 1 to 2.
7. Position electrocardiographic leads to obtain a clear monitor waveform.
8. Obtain a chest radiograph to ascertain an adequate endotracheal tube position within the thoracic trachea.
9. Patients may be slightly repositioned every 2 to 4 hours to alleviate pressure points.
10. Leave in prone position for at least 48 hours or until OI is 10 or less.

Preparation in SP

1. Follow similar steps for placing the patient in PP.
2. Once supine, assess the skin for existing wounds or ulcers.
3. Obtain a chest radiograph to verify that the endotracheal tube is within the thoracic trachea and above the carina.
4. If the patient deteriorates, consider using PP again and follow the steps described.

References

[14] Hickling KG. Best compliance during a decremental, but not incremental, positive end-expiratory pressure trial is related to open-lung positive end-expiratory pressure. Am J Respir Crit Care Med 2001;163:69-78.

