High-frequency oscillatory ventilation in neonatal RDS: initial volume optimization and respiratory mechanics

MASENDU KALENGA, ORESTE BATTISTI, ANNE FRANÇOIS, JEAN-PAUL LANGHENDRIES, DALE R. GERSTMANN, AND JEAN-MARIE BERTRAND

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Table 1. Evolution of ventilator settings during lung volume optimization

<table>
<thead>
<tr>
<th>Time Point</th>
<th>CDP, cmH2O</th>
<th>ΔP, cmH2O</th>
<th>FIO2</th>
<th>Crs (ml/cmH2O)</th>
<th>Rrs (cmH2O·ml⁻¹·s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starting Point</td>
<td>7.7 ± 0.8</td>
<td>26.2 ± 4.1</td>
<td>0.73</td>
<td>0.13 ± 0.32</td>
<td>0.12 ± 0.32</td>
</tr>
<tr>
<td>Midpoint</td>
<td>12.4 ± 1.0t</td>
<td>30.5 ± 6.5</td>
<td>0.54</td>
<td>0.17 ± 0.35</td>
<td>0.13 ± 0.35</td>
</tr>
<tr>
<td>OCDP-2 Point</td>
<td>14.2 ± 1.2t</td>
<td>31.8 ± 7.2</td>
<td>0.41</td>
<td>0.19 ± 0.37</td>
<td>0.14 ± 0.37</td>
</tr>
<tr>
<td>OCDP Point</td>
<td>16.5 ± 1.2t</td>
<td>32.7 ± 6.2</td>
<td>0.41</td>
<td>0.20 ± 0.38</td>
<td>0.14 ± 0.38</td>
</tr>
</tbody>
</table>

Data are means ± SD (n = 17 infants). Time points as described in text. OCDP, optimal continuous distending pressure; ΔP, continuous distending pressure; FIO2, inspired O2 fraction. *P < 0.05 and †P < 0.001 vs. starting point; ‡P < 0.001 vs. midpoint; §P < 0.001 vs. OCDP-2 point.

DISCUSSION

Pulmonary function assessment during mechanical ventilation is a question of long-standing interest in clinical practice. In regard to newborns, the single-occlusion technique has proven to be a noninvasive and reliable bedside method of respiratory mechanics evaluation, especially for sick ventilated infants (10, 12, 13, 22). Previous studies on the subject have been essen-
tially conducted under CMV. Using primary HFOV for premature infants with RDS, we found that brief occlusions of airways at the end of spontaneous inspiration were well tolerated and yielded adequate and reproducible flow-volume curves. The computed Crs and Rrs closely approximated those previously reported in similar patients treated with CMV (6, 13, 22). In regard to the main question of the present study, we found that initial stepwise CDP increase to recruit lung volume, while associated with a marked improvement in oxygenation, did not result in any consistent modification of Crs or Rrs.

Several studies using CMV have previously addressed the question of the relationship between the optimal lung inflation and pulmonary compliance. Although controversial results have been reached, some authors have reported lung compliance improvement with positive end-expiratory pressure (PEEP) optimization in both children (20, 21) and adults (11, 21) with various pulmonary diseases. More related to neonatal surfactant deficiency is the study by Mathe et al. (14), who used pressure-volume (P-V) curves to determine the appropriate PEEP in premature infants with hyaline membrane disease. Patients were paralyzed and their lungs continuously inflated beginning at FRC up to a total volume of 10 ml/kg. An inflection of the P-V curve was observed as the inflating pressure approximated 9 cmH\textsubscript{2}O, suggesting an improvement in compliance. In each patient, the pressure at the inflection point was applied as appropriate PEEP, which helped improve oxygenation.

In newborns with surfactant deficiency, lung inflation starting at ambient pressure, like in the paralyzed patients of the study just cited, is characterized by an initial inflection of the P-V curve. This inflection corresponds to the opening of peripheral lung units and is usually observed between 5 and 10 cmH\textsubscript{2}O (14, 17). In our study, it is clear that airway occlusions were performed over the inflation limb of the P-V curve. As Crs did not improve with gradual CDP increase, it is suggested that HFOV optimization was started at a pressure equal to or just above the inflection point, where most peripheral airways were already patent. The rest of volume optimization was then operated over a linear portion of the P-V curve and allowed a further expansion of terminal air spaces. The ensuing increase in gas-exchange surface resulted in an improvement in oxygenation. However, it is important to remember that, based on animal models of surfactant deficiency treated by HFOV, improvement in Crs can be observed if measurements are obtained on the deflation P-V curve following a volume recruitment maneuver such as sustained inflation (1, 2, 23). These interesting observations were not evaluated in our study, as sustained inflation is not part of our current HFOV strategy.

We presumed that in all our patients surfactant deficiency was the main cause of gas-exchange impairment due to collapse of terminal lung units. This was strongly supported by the prompt improvement in oxygenation on LVO as well as by the rapid clearing of chest radiographs. The results of the present study clearly show that optimization of alveolar expansion with HFOV does not favorably influence pulmonary mechanics as long as the underlying cause, i.e., surfactant deficiency, is not reversed. This will occur by a gradual synthesis of endogenous surfactant over hours or days, or after exogenous surfactant instillation. Interestingly, an optimal-volume strategy stabilizing terminal air spaces tends to prolong the effectiveness of exogenous surfactant (8).

It is noteworthy that we found that Crs was inversely related to OCDP and \(\Delta P\). It is unlikely that inadvertent lung overinflation was the reason why patients with high OCDP had low Crs, because CDP was increased in a progressive manner starting from low level. Moreover, lack of progressive Crs deterioration implies that LVO was not operated up to the upper flat portion of the P-V curve, which means that the used LVO procedure induces an appropriate lung expansion. Clearly, low Crs was an indication of the severity of lung disease. In one study using HFOV in a rescue mode, Chan and his colleagues (3) also reported an inverse correlation between OCDP and Crs obtained just before start of HFOV. Relevantly, it has been previously shown that pulmonary compliance measured during artificial ventilation (CMV) was directly related to the surfactant deficit determined by lecithin-to-sphingomyelin ratio in tracheal aspirate (24).

In conclusion, the single-occlusion technique is an applicable and well-tolerated method of determining pulmonary mechanics in infants with RDS, assisted by HFOV. The initial LVO by gradual CDP increase, which markedly improves oxygenation, does not affect pulmonary mechanics. Consequently, optimal lung volume achievement is not detectable by serial Crs measurements during the early phase of HFOV. At the most, low initial Crs appears to indicate that higher distending pressure is needed.

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