One Ventilator and Two Patients: A Laboratory Experiment

By
Hossein Gharanfoli, MA, RRT-NPS, RRT- AACS, RPFT
Associate teaching professor
Bowling Green State University-Firelands College
Huron Ohio 44857

Note to the reader
This is one the experiments in mechanical ventilation course at BGSU-Firelands college respiratory care program. The experiment was devised to give an understanding on how to ventilate two patients with one ventilator. This is not intended to be a scientific paper but a laboratory experiment that would provide an opportunity and insight for students and clinicians on how to apply mechanical ventilation during critical situations where there are not enough ventilators to provide for patients in need of mechanical ventilation.

Abstract
The ventilator shortage during the Covid-19 pandemic has prompted some clinicians to think about using one ventilator on two patients contemporaneously. This idea is a radical departure from norms, but then, Covid-19 era is not a normal time and there are situations that necessitates the use of one ventilator to provide ventilatory support for two patients at the same time.

We, at BGSU-Firelands College respiratory care program conducted a simulated experiment utilizing one ventilator on two patients (two lung simulators). Patient selection for implementing such a procedure is important; patients should have comparable lung injury and similar ventilatory requirements. In this simulation, tidal volume was calculated based on an IBW of 75 kilograms and 6 ml/kg. The volume displacement for each lung simulator was adequate with exhaled volume between 410-450 ml. The volume delivery to each lung simulator varied with degree of changes in resistive and elastic forces that oppose ventilation, in our experiment, the exhaled volume varied between 30-70 ml(an approximate ) in either direction based on the degree of changes in lung characteristics; the purpose of this experiment was not to evaluate the effect of lung mechanics on volume delivery but to assess the potential application of one ventilator to adequately ventilate two patients for the first 24-72 hours of the need for ventilatory support.
Introduction

Corvid’s Patients with lung injury and lung edema (ALI, ARDS) have low FRC and reduced compliance. The resistive forces are also increased due to artificial airway (ET), bronchospasm, inflammation, and high flow rates. Pulmonary and tissue oxygenation are severely impaired which requires ventilatory support.

When selecting patients, the ideal body weight and the extent of lung injury should be similar for both patients for the purpose of setting ventilation and oxygenation parameters. Patient’s pathophysiological acuity and gas exchange abnormalities may be assessed using

- Arterial blood gases
- Chest radiograph
- P/F ratio
- P(A-a) O2

Equipment and supplies

- Adult ventilator circuits
- Inline suction catheters
- Wright respirometers
- PB 840 ventilator
- 22 mm adapters
- Lung simulators
- Wye adapters
- HMEs

Method and setup

The lung simulators were set to mimic a compliance of approximately 20 ml/cmH2O (two loaded springs set at 3); airway resistance was set at level 2. The exhaled volume for each lung was measured by a Wright spirometer. Figures 1 through 5 shows the components of ventilator circuit setup.
Fig 1. Complete ventilator circuits setup with two lung simulators

Fig-2. Ventilator output with Wye adapter attached to the inspiratory limbs of two ventilator circuits
Fig-3. Circuits expiratory limbs connected to the ventilator expiratory filter with inline Wright respirometers. Wright respirometers were used to estimate the returned volume from each lung simulator.

Fig 4. Lung simulator attached to the ventilator circuit with HME and inline suction catheter. Two springs were used for compliance with resistance set at level 2.
Initial settings

An ideal body weight of 75 kilograms and tidal volume of 6 ml/kg were used to calculate the set tidal volume of 450 ml for each lung simulators (simulated patients); the ventilator was set to deliver a tidal volume of 900 ml and 12 bpm. Table 1 and Figure 6 show the initial ventilator settings.

Table 1. Initial ventilator settings

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respiratory rate</td>
<td>12 bpm</td>
</tr>
<tr>
<td>Tidal volume</td>
<td>900ml</td>
</tr>
<tr>
<td>FIO2</td>
<td>Based on ABG</td>
</tr>
<tr>
<td>PEEP</td>
<td>5 CmH2O</td>
</tr>
<tr>
<td>Flow pattern</td>
<td>Decelerating</td>
</tr>
<tr>
<td>I: E</td>
<td>1: 2.5</td>
</tr>
</tbody>
</table>
Fig 6 - ventilator settings to ventilate both lung simulators

**Monitored Parameters**

Table 2. shows the values from figures 7 through 11 during 10:27-10:35 time interval. The values were obtained from monitoring section of the ventilator and the Wright respirometers.

Table 2. summary of patient’s monitored data

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exhaled volume per breath as indicated on the monitor for both simulators (patients)</td>
<td>793-880 ml</td>
</tr>
<tr>
<td>Exhaled volume per breath for each lung simulator as indicted by Wright respirometers</td>
<td>410-440 ml</td>
</tr>
<tr>
<td>Respiratory rate</td>
<td>12 breaths/min</td>
</tr>
<tr>
<td>Parameter</td>
<td>Value</td>
</tr>
<tr>
<td>--------------------------</td>
<td>---------------</td>
</tr>
<tr>
<td>Peak pressure</td>
<td>27-29 cmH2O</td>
</tr>
<tr>
<td>Mean airway pressure</td>
<td>11-12 CmH2O</td>
</tr>
<tr>
<td>PEEP set at 5</td>
<td>5.7-5.8 CmH2O</td>
</tr>
<tr>
<td>I: E</td>
<td>1:2.5</td>
</tr>
</tbody>
</table>

Fig. 7. Monitored parameters at 10:27
Fig. 8. Monitored parameters at 10:28

Fig. 9. Monitored parameters at 10:32
Fig. 10. Monitored parameters at 10:34

Fig. 11. Monitored parameters at 10:35


**Discussion and conclusion**

There may be situations that necessitates application of one ventilator to support two patients, however, there are issues that may challenge clinicians and impede such intervention. Being aware of the problems before implementing the procedure assist clinicians in assessing the risk and benefits of such medical intervention.

The degree of lung recovery and improvement present a challenge for clinicians; the issue is the degree of lung recovery or decline. It is hard to imagine that two sets of lungs, even with the same degree of initial insult would have identical pathophysiological changes in either direction. Airway resistance and compliance were altered on the lung simulators and noted some changes in exhaled volume between the lung simulators; the degree of change in volume distribution is one of the challenges that clinician encounter. All percussions should be taken to avoid injures associated with positive pressure ventilation.

The following are the general conclusions from our experiment.

1. The application of one ventilator on two patients is plausible if patients are heavily sedated or paralyzed in such a way that blunts respiratory efforts; initially this should not pose any problem or concern. We think that 24 to 72 hours of heavy sedation and paralysis is a reasonable, however, the physician will decide the duration of sedation and paralysis.

2. If AC mode is used and one patient has inspiratory effort, such an effort will initiate a patient triggered mechanical breath for both patients

3. If both patients have inspiratory effort, there will be a marked dyssynchrony and increased WOB

4. If SIMV mode with PS is used, an inspiratory effort by one patient will initiate a PS breath for both patients

5. If SIMV mode with no PS is used, there will be a high degree of dyssynchrony and a significant increase in WOB caused by lack of synchronization between patients’ total cycle time.

6. Monitoring patient’s exhaled volume separately is vital, changes in one lung simulator (patient) resistance or compliance altered exhaled volume by approximately 30- 70ml in either direction based on the degree of change, this is only an estimate.

7. Diligent patient monitoring and assessment are imperative to provide safe ventilatory support and avoid additional lung injury.