COVID-19: minimising contaminated aerosol spreading during CPAP treatment

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ABSTRACT

Background The COVID-19 pandemic has raised concern for healthcare workers getting infected via aerosol from non-invasive respiratory support of infants. Attaching filters that remove viral particles in air from the expiratory limb of continuous positive airway pressure (CPAP) devices should theoretically decrease the risk. However, adding filters to the expiratory limb could add to expiratory resistance and thereby increase the imposed work of breathing (WOB).

Objective To evaluate the effects on imposed WOB when attaching filters to the expiratory limb of CPAP devices.

Methods Two filters were tested on three CPAP systems at two levels of CPAP in a mechanical lung model. Main outcome was imposed WOB.

Results There was a minor increase in imposed WOB when attaching the filters. The differences between the two filters were small.

Conclusion To minimise contaminated aerosol generation during CPAP treatment, filters can be attached to expiratory tubing with only a minimal increase in imposed WOB in a non-humidified environment. Care has to be taken to avoid filter obstruction and replace filters as recommended.

INTRODUCTION

The novel severe acute respiratory syndrome coronavirus (SARS-CoV-2) has caused an unpredicted and escalating global pandemic with the disease COVID-19. Virus transmission is considered to be mainly by close person contact or via respiratory droplets when coughing or sneezing and through aerosol-generating healthcare procedures such as continuous positive airway pressure (CPAP), high flow nasal canula and mechanical ventilation.

CPAP is the most common respiratory support used in the neonatal intensive care unit. It is also commonly used in paediatric intensive care units for children with severe lower airway infection. Reports of infants and older children with COVID-19 infection indicate that they rarely get seriously ill. However, infected infants may also need ventilatory support for other conditions such as respiratory distress syndrome. The COVID-19 pandemic has raised a serious concern that viral spreading in intensive care units (ICUs) will increase the risk for healthcare workers to acquire the infection.

Aerosol generation is of particular concern with all non-invasive respiratory support, including CPAP treatment. Evaluating the risk associated with CPAP devices and finding ways to minimise aerosol generation will be of importance to protect medical staff from SARS-CoV-2 exposure.

There are several CPAP devices on the market. The systems classification is not unique, but the CPAP technique can roughly be divided into constant flow devices and variable flow devices. Designated expiratory tubing is a key factor in system design to allow the use of filters. Attaching respiratory filters that remove viral particles in air from the expiratory limb of CPAP devices such as infant flow and bubble CPAP should theoretically decrease the risk of aerosol spreading. Systems that do not have a designated expiratory limb or exhaust tubing (ie, Medijet and the Beneveniste valve) have no option for the attachment of a filter.

Microbial air filters are 99.99% efficient in capturing particles down to 0.3 µm in size according to the manufacturers and are more efficient than for example N95 and KN95 face masks. The SARS-CoV-2 virus particle is approximately 0.125 µm, but as many other viruses, it often travels in biological aerosols from coughing and sneezing that range in size from 0.5 to 3 µm.

A concern when adding filters to the expiratory limb is that it could add to expiratory resistance and thereby increase the imposed work of breathing (WOB). It is essential that any measures introduced do not cause harm to the patient or reduce the efficacy of the treatment. An increase in imposed WOB can have clinical significance for respiratory compromised spontaneously breathing patients in the ICU.

To examine this, we tested the effects on imposed WOB when attaching filters (Intersurgical and Commercial respiratory filters) to CPAP devices.
Short report

Dräger) in a non-humidified environment for three CPAP systems at two levels of CPAP in a mechanical lung model.

METHODS
Breathing was generated by the ASL5000 mechanical lung simulator (IngMar Medical, Pittsburg, Pennsylvania, USA) using a non-compliant and no airway resistance model with 32 mL tidal volume at a respiratory rate of 60 breaths/min with I:E of 1:1. Three CPAP systems were tested: Bubble CPAP (Fisher and Paykel, 5040 prongs, 8 L/min), the original Infant Flow design (NFLOW Intersurgical, L prongs) and Infant Flow LP (Vyair, L prongs). Systems were tested with CPAP 5 and 8 cm H2O, measured at the prongs and adjusted for each experiment. We used no humidification, and the system was attached without leakage using a straight 22 mm connector and putty.

The systems were tested without filter and with Clear-Guard 3 Breathing Filter (Intersurgical) and CareStar Filter (Dräger). Adult filters were used since dead space is not a problem on the expiratory tube. The perforated outlet tubing on the Infant Flow system was replaced with a 40 cm 10 mm disposable tubing (Intersurgical) and on the Infant Flow LP system the existing tube was disconnected, flipped, reattached and split at the midtube connector. Filters were attached at the non-perforated exhaust tube with wide bore disposable connectors (figure 1).

Imposed WOB was calculated (area within the pressure volume loop) for 18 consecutive breaths, and the value means were compared using analysis of variance with Bonferroni correction (SPSS V.26). A p<0.05 was considered statistically significant.

RESULTS
The imposed WOB for the three systems are presented in table 1. There was an increase in imposed WOB when attaching the filters (p<0.01 in all simulations), but the absolute difference was small. Also, the absolute differences between the two filters were small.

DISCUSSION
Our results show that connecting a filter to the expiratory limb of a CPAP system in the absence of humidification only adds minimal resistance during expiration and raises the imposed WOB only marginally. This does not eliminate the risk for aerosol spread because there will always be some leakage besides the nasal interface and through the mouth, and personal protection equipment should be worn at all times by caretakers. The leakage presents a problem, but experienced staff working with CPAP are familiar and used to deal with interface leakage. Our own unpublished data show that the majority of infants breathe in through the Infant Flow device and out via the expiratory limb when leakage is low (ToNIL trial NCT03586856). Thus, a large proportion of the set flow will go out through the expiratory limb and generate a risk for spread of contaminated aerosol.

Attaching a filter on this expiratory tubing is a simple way to reduce the risk for medical staff. The tests were performed without humidification. When using humidification, care has to be taken to avoid filter obstruction and replace filters as recommended by manufacturers.

Both Infant Flow and Infant flow LP have perforated expiratory tubing. This is a safety feature to prevent accidental

Table 1  Imposed WOB when attaching a filter on the outlet tubing of three CPAP systems

<table>
<thead>
<tr>
<th>CPAP and system</th>
<th>Imposed work of breathing (mJ/breath)</th>
<th>No filter</th>
<th>Dräger filter</th>
<th>Intersurgical filter</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 cm Bubble CPAP</td>
<td>5.6 (5.42 to 5.84)</td>
<td>6.2 (6.06 to 6.38)</td>
<td>6.7 (6.33 to 6.99)</td>
<td></td>
</tr>
<tr>
<td>Intersurgical</td>
<td>5.8 (5.75 to 5.82)</td>
<td>6.6 (6.59 to 6.67)</td>
<td>6.9 (6.88 to 6.93)</td>
<td></td>
</tr>
<tr>
<td>Infant flow LP</td>
<td>3.8 (3.77 to 3.81)</td>
<td>4.7 (4.63 to 4.67)</td>
<td>4.9 (4.91 to 4.96)</td>
<td></td>
</tr>
<tr>
<td>8 cm Bubble CPAP</td>
<td>5.5 (5.12 to 5.91)</td>
<td>6.3 (5.88 to 6.66)</td>
<td>6.7 (6.28 to 7.12)</td>
<td></td>
</tr>
<tr>
<td>Intersurgical</td>
<td>8.1 (8.08 to 8.11)</td>
<td>9.3 (9.25 to 9.31)</td>
<td>9.5 (9.43 to 9.46)</td>
<td></td>
</tr>
<tr>
<td>Infant flow low pressure</td>
<td>4.2 (4.21 to 4.27)</td>
<td>4.8 (4.74 to 4.80)</td>
<td>5.1 (5.07 to 5.15)</td>
<td></td>
</tr>
</tbody>
</table>

Adding filters increased imposed WOB in all simulations (p<0.05) but the absolute increase was small. Means (95%CI).

CPAP, continuous positive airway pressure.
occlusion of the expiratory tubing. The perforated part has to be replaced when attaching filters. To maintain safety, a perforated tubing may be added after the filter. The tubing on Infant Flow has to be replaced with solid tubing, and on the LP system, the existing tube can be used by disconnecting, flipping, reattaching and split at the midtube connector. These modifications are currently not recommended by manufacturers and regulations for modifying medical equipment has to be analysed.

The same principles apply to a bubble CPAP system by attaching the filter on the tube leading from the patient before the entrance to the water bottle. Only a minimal resistance will be added to the expiratory limb, and this should not increase the patient’s imposed WOB significantly. This should apply to other systems that use a Y-piece connector and a separate expiratory tubing for example when connecting a filter to the expiratory limb of ventilator derived CPAP. Another aspect of connecting a filter to bubble CPAP must be noted. It has been proposed that bubble CPAP achieves its benefits in part to the oscillations and noise composition of the pressure waveform. Connecting a filter between the patient and the water bottle will affect the pressure waveform and thereby potential treatment efficacy.

The Beneveniste valve has an open design; therefore, there will always be a risk of creating and spreading contaminated aerosol. The Medijet has a unique design with a small hole in the nasal interface/CPAP generator. It is not possible to attach filters on the Medijet to decrease the risk of aerosol spread.

For CPAP drivers with an automatic leakage compensation, turning off this feature could be of value for minimising aerosol spread. These drivers compensate for leakage by increasing the flow and thereby increase the risk of aerosol spreading through leakage. Minimising leakage at the interface has to be performed with care to avoid nasal trauma.

CONCLUSION
To minimise contaminated aerosol generation during CPAP treatment, filters can be attached to expiratory tubing with only a minimal increase in expiratory resistance and imposed WOB in a non-humidified environment. When using humidification, care has to be taken to avoid filter obstruction and replace filters as recommended.

REFERENCES