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Dead in the air- The need to adapt to CoVID adaptations

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A B S T R A C T
During the recent CoVID-19 pandemic, airway management recommendations have been provided to decrease aerosolization and risk of viral spread to healthcare providers. High efficiency particulate air (HEPA) viral filters and adaptors are one way to decrease the risk of aerosolization during intubation. When placed proximal to the ventilator circuit, these viral filters and adaptors can create a significant amount of dead space, which in our smallest patients can significantly impact effective ventilation. We report a case of hypoventilation in a pediatric patient due to lack of provider team appreciation or ventilator sensing of additional dead space due to HEPA viral filter and adaptor.

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1. Introduction
In recent months there has been heightened awareness over provider safety during the CoVID-19 pandemic. Recommendations around appropriate personal protective equipment for high risk aerosolization procedures have been released [1,2]. In addition, practice adjustments such as decreased use of positive pressure ventilation, nebulized therapies, and use of negative pressure room ventilation have been recommended [2,3].

For patients requiring intubation, ventilator adaptations have been devised including HEPA viral filter attachment to self-inflating bags to decrease aerosolization [4]. There is no standard recommendation and different HEPA viral filters vary in volume.

We report a case of a pediatric patient that developed hypercapnia and acute respiratory acidosis secondary to unaccounted for dead space ventilation due to adaptors used during CoVID-19 pandemic.

2. Narrative
A 21 month old, 12 kg patient with history of Hirschsprung disease was transported to our quaternary care facility by air transport due to concern for Hirschsprung enterocolitis. The patient had presented to a local emergency department with 12 h of severe diarrhea and vomiting, and was found to have severe electrolyte abnormalities and hypoglycemia, treated with intravenous fluid resuscitation, and given broad spectrum antibiotics.

On arrival, patient was tachycardic, tachypneic, hypotensive and mildly hypoxic. On exam patient was lethargic and pale appearing, with delayed capillary refill and cool extremities. Fluid resuscitation was initiated to treat shock. Thirteen minutes after arrival the patient became persistently hypoxic to 66% on room air requiring positive pressure ventilation with 100% oxygen.

Initial blood gas drawn just prior to hypoxic episode showed a primary metabolic acidosis with pH: 7.24, pCO2: 35, and HCO3: 14.

Patient was prepared for urgent intubation using video laryngoscopy. Apneic oxygenation and bag ventilation was provided prior to intubation using Bag-Valve-Mask (BVM) ventilation with HEPA viral filter and flexible tubing adaptor. Tube placement was confirmed with colorimetric change, end tidal carbon dioxide recording, and bilateral breath sounds. To reduce aerosolization during the exchange of the BVM for the ventilator circuit, the HEPA viral filter and adaptor remained in-line with the endotracheal tube (ETT) and the ventilator circuit was connected directly to this filter/adaptor unit. Chest X-Ray confirmed appropriate endotracheal tube location.

Initial ventilator settings in SIMV/PRVC mode were: PEEP-5, PS-10, TV-6 cc/kg, 60% oxygen. End tidal carbon dioxide rose to the 70’s over the 30 min after intubation, and venous blood gas showed a new primary respiratory acidosis with pH: 7.24, pCO2: 35, and HCO3: 14.

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3. Discussion

Given the emergence of the 2019 novel Coronavirus, emergency departments have been implementing new practices to maintain staff and patient safety. In addition to appropriate personal protection equipment, HEPA viral filtration to reduce aerosolization with BVM or intubation is recommended [2,3,5,6].

When performing BVM ventilation, the HEPA viral filter is attached directly to the mask, with the bag attached on the opposite side. Given varying mask and bag sizes for infants and smaller children, additional adaptors may be needed. To aid ease of use, additional flexible tubing adaptors can be attached (Fig. 1). At our institution, the HEPA viral filters vary in volume from 10 to 90 mL, and flexible tubing adaptors vary from 5 to 41 mL. The HEPA viral filter and adaptor in Fig. 1 accounted for approximately 95 mL.

Dead space is defined as ventilated area which does not participate in gas exchange. This includes anatomic dead space (oropharynx, trachea, large airways proximal to alveoli), alveolar dead space (ventilated areas of the lung which are not currently perfused), and mechanical dead space (artificial airways past the “Y-connector” on a ventilator circuit). In a typical ventilator-ETT setup, the segment of the ETT distal to the teeth accounts for effective mechanical dead space.

As noted in published guidelines, it is important that the HEPA viral filter be attached to the expiratory limb of the ventilator after intubation. In our case, the HEPA viral filter remained in-line between the endotracheal tube and the ventilator circuit adding significant additional unaccounted for dead space to the system. Therefore, the 6 cc/kg programmed into the ventilator was not the actual effective ventilation to the patient.

In an adult who averages close to 400 cc tidal volume, additional mechanical dead space from the filter/adaptor complex may be detrimental, contributing to respiratory acidosis. In infants and young children, however, whose tidal volumes are often less than 100 cc, this additional dead space can account for >100% of the delivered tidal volume (Fig. 2), and can thus result in ineffective ventilation with potentially deadly consequence.

With the rapidly adapting landscape this case highlights how a well-intended intervention can lead to unexpected consequences and the need for clinicians to consider unaccounted for mechanical dead space in their troubleshooting algorithms of mechanically-ventilated patients.

4. Conclusion

With the requirement to adapt practices to airway management during the 2019 novel Coronavirus pandemic, it is important to be aware of potential iatrogenic complications secondary to equipment error. HEPA viral filters attached to the expiratory limb of a ventilator setup can result in significant mechanical dead space, which in infants and smaller children, has a proportionally larger impact on ventilation.

Fig. 1. Bag-Valve-Mask setup with additional high efficiency particulate air (HEPA) viral filter and flexible tubing adaptor.

Fig. 2. Graph displaying the percent of lung protective tidal volume that the high efficiency particulate air viral filter accounts for by given age. Note the volume and filter/adaptor exceeds the entire lung protective volume until age 4 years [7,8].
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Meetings/presentations

None.

Author contribution

NK drafted this case report and all authors contributed substantially to its revision.

Declaration of Competing Interest

The authors have no conflicts of interest relevant to this article to disclose.

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