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Short Communication

Converting Bi-Level Positive Airway Pressure Machines into Ventilators for Hospitalized Coronavirus Disease-2019 Patients: Emergency Use Protocol

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During March 2020 New York State was facing a shortage of tens of thousands of ventilators. City and state officials were rapidly trying to source more of the machines, which were required in the sickest patients who were critically-ill with coronavirus disease-2019 (COVID-19). In the community hospitals, there were 792,417 beds, with 3532 emergency departments (EDs) and 96,500 intensive care unit (ICU) beds, of which 23,000 were neonatal and 5100 pediatric, leaving just under 68,400 ICU beds of all types for the adult population.[1] Other estimates of ICU bed capacity, which try to account for purported undercounting in the American Hospital Association (AHA) data, show a total of 85,000 adult ICU beds of all types.[2] During this time experts warned that the supply of mechanical ventilators could fall far short of the expected demand. At a webinar convened by the AHA, one researcher projected that 960,000 Americans might need a mechanical ventilator before the pandemic is over. There are approximately 62,000 full-featured ventilators (the type needed to adequately treat the most severe complications of COVID-19) available in the United States.[3] Approximately 10,000 to 20,000 more are estimated to be on call in our Strategic National Stockpile[4] and 98,000 ventilators that are not full-featured but can provide basic function in an emergency during crisis standards of care also exist.[3] At the time, many of those were already in use, or were older, more basic models that hospitals have on hand. Across New York during that time, more than 10,000 people were hospitalized with COVID-19, with more than 2,700 people in intensive care units. During that time several avenues of innovation were being pursued, all of which in our opinion were impractical. The two leading focuses at that time were splitting the use of a single ventilator for two or more patients[5] and the second was using anesthesia machines, which were a virtual unknown to most critical care practitioners, as alternatives to invasive mechanical ventilators.[6,7] These measures were being developed and sometimes used in the setting of a crisis and public health disaster where the two choices were either, no ventilator and the patient dies, or use of alternative methods to mechanically ventilate the patient. It is in this setting of crisis and emergency that our team pursued a third, more practical innovation that our health system implemented.

Bi-level positive airway pressure (BiPAP™) is one type of non-invasive, positive airway pressure (PAP) machine that is commonly used to maintain a consistent breathing pattern at night or during symptom flare-ups in individuals with sleep apnea, congestive heart failure or chronic obstructive pulmonary disease (COPD), a chronic inflammatory lung disease. These devices at the time were not being used, they were basically collecting dust in the hospital since at the time our colleagues in Italy and China were reporting that not only were patients not responding to BiPAP™ machines using the usual face mask, that sleep apnea patients use, but they had preliminary concerns that the virus was being aerosolized and infecting healthcare workers. These two concerns, at the time led to the avoidance of using BiPAP™ *via* the facemask interface in this patient population.

In preparation for the continued patient surge and shortage of critical mechanical ventilators for hospitalized COVID-19 patients in March-April 2020, our team successfully designed a protocol to adapt the more common BiPAP™ machine into a functional invasive pressure control mechanical ventilator through a three dimensional (3D) printed adaptor that we designed

to aid in the conversion. This BiPAP™ device is well-known and commonly used by critical care providers and hence it was a clear, practical innovation to implement.

BiPAP™ is one type of non-invasive, PAP machine that is commonly used to maintain a consistent breathing pattern at night or during symptom flare-ups in individuals with sleep apnea, congestive heart failure or COPD, a chronic inflammatory lung disease.

The key component to converting the BiPAP™ machine is a small, plastic T-piece adapter which was designed in a matter of days in collaboration with Northwell Health's 3D design and Innovation Department who had the capacity to 3D print 150 of these adaptors in 24-hours if needed.

Conversion of the BiPAP™ machine using the standard, non-3D printed, and 3D printed adaptor was tested on both COVID-19 and non-COVID-19 patients during our first surge of COVID-19 in March-April 2020. In addition to the T-piece adaptor, modifications to the BiPAP™ machine include the addition of two high-efficiency particulate air (HEPA) filters at both ends of the oxygen hose to alleviate fears of spreading the virus. A blind reservoir connected to the last HEPA filter in the circuit is also recommended (Figure 1).

During the initial COVID-19 patient surge which occurred from March to May 2020, approximately 28 patients a day were being ventilated in this manner across our health system. At the peak of the pandemic which occurred in mid-April 2020, up to 99 patients a day across our health system were being ventilated using our modified BiPAP™ machine method. To put this number in better perspective, during the height of the pandemic, mid-April 2020, approximately 10% of all invasively mechanical ventilated patients across our health system, with and without COVID-19 induced lung disease were supported using this emergency use method we are reporting in this communication.

In conclusion, this emergency use of converting BiPAP™ machines into invasive pressure control ventilators for intubated hospitalized COVID-19 patients proved to be reliable and help alleviate sporadic short-term ventilator shortages, all while using in house 3D printing technology which avoided any product-supply chain issues with the endotracheal tube adaptor required to utilize this method.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

Figure 1. *Add 2 HEPA Filters, One Immediately Connected to the V60 Main Gas Port Outlet and the Second HEPA Gets Connected to the Exhalation Valve Port Closer to the ET/Trach.To Connect to an ETT Tube You Need to Use the Philips Respironics Conventional Exhalation Valve and/or Circuit Kit.We Recommend that the HEPA Filter on the Exhalation Valve Port be Connected to a Blind Reservoir.Turn on Machine and Hit the Menu Tab. Please Ensure the Patient is not Connected to the V60 Machine*

- *Under the menu tab select the option for Mask/port*
- *Select→ET/trach option (extreme left)*
- *Hit Accept*

Then chose type of exhalation port

- *Select→Other*
- *Hit accept*

Select mode- Batch PCV Place patient on the appropriate pressure settings parameters prior to activating mode as follows;The EPAP will be the same as the PEEP; For IPAP use the plateau pressure measured on the conventional ventilator as a baseline;The FiO_2 would be the same;The ramp should be turned off;The rise time can be adjusted based on patient's demand.We recommend a rise time of 3; Now activate the batch change by hitting select (Active Batch Change).

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