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Correspondence

Desperate times: Repurposing anesthesia machines for mechanical ventilation in COVID-19 *To the Editor:*

In March 2020, the United States Food and Drug Administration (FDA) issued an emergency release authorization [1], allowing anesthesia workstations be modified for use as intensive care (ICU) ventilators during the novel coronavirus (COVID-19) pandemic. We read with interest the guidance laid out by the Anesthesia Patient Safety Foundation and American Society of Anesthesiologists on safely and effectively repurposing anesthesia machines as ICU ventilators [2], and we endorse their recommendations. During the COVID-19 surge in New York City, we managed approximately 50 COVID-19 patients who, for more than two weeks, received invasive ventilation on repurposed anesthesia workstations (GE Healthcare Datex-Ohmeda Avance CS2 Anesthesia Delivery System). In this article, we wish to draw attention to technical limitations of anesthesia ventilator use in long-term mechanical ventilation (MV), based on our collective experiences and in the interest of patient safety.

At first look, the mechanical ventilator within the anesthesia

workstation appears well suited to its new purpose. Similar to an ICU ventilator, it is capable of delivering different types of MV, differentiated by trigger, limit, and cycle variables set by the user. Recruitment maneuvers and high levels of positive end-expiratory pressure (PEEP) can be administered to raise mean airway pressure (Paw) and prevent atelectrauma. Modern day anesthesia ventilators display flow/pressure-time scalars and real time spirometry, facilitating the detection of patient-ventilator dyssynchrony and increased airway resistance. Nevertheless, there are several unique designs in ICU ventilators that anesthesia machines do not possess.

Anesthesia workstations are not intended for continuous operation. They require power cycling and an electronic check of circuit and machine components, at least daily and more often under conditions of heavy usage [3]. This process involves a patient-ventilator disconnect for several minutes, while the patient is hand ventilated with a self-inflating bag, which is quite undesirable given COVID-19's transmissibility and infectivity. Failure to perform periodic system checks may lead to pressure transducers and flow sensors becoming dysfunctional,

Fig. 1. Photograph of a plugged endotracheal tube (red arrow) removed during an emergent tube exchange. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

or even outright anesthesia ventilator failure [3]. In fact, we witnessed 4 cases of spontaneous workstation shutdown at our hospital, which fortunately resolved rapidly without significant sequelae. Anesthesia machine manufacturers expressly recommend that patients prescribed a prolonged period of MV be managed on ICU ventilators [3].

Long periods of MV using dry, cool fresh oxygen and air leads to airway desiccation, mucosal sloughing, and inspissated secretions. Unlike ICU ventilators, anesthesia workstations are not designed to deliver nebulized mucolytics (in-line) and to support active humidification, due to their inability to compensate for added external flow, which could affect ventilation and monitoring [3]. To provide sufficient moisture to breathing gases, we applied two heat and moisture exchanger filters (HMEF) to each breathing circuit, with one filter connected to the endotracheal tube and the other at the expiratory limb. Other mitigation efforts to decrease the likelihood of plugging events included instillation of saline droplets and routine suctioning via the in-line suction catheter every 4 h. Despite this, we observed approximately 29% (14/48) of patients develop endotracheal tube plugging (Fig. 1), causing catastrophic hypoxia and necessitating emergent bronchoscopy, and sometimes tube exchange. Similar to endotracheal intubation, a bronchoscopic exam is an aerosol-generating procedure and poses a significant risk to staff. We strongly recommend prioritizing the transfer of these patients, in whom these events frequently occur, to an ICU for a heated system and inhaled mucolytics.

COVID-19 is associated with a variety of lung pathologies, including diffuse alveolar damage [4]—a hallmark finding in acute respiratory distress syndrome (ARDS). Our COVID-19 patients receive low-stretch (4–8 mL/kg) tidal volumes (VT) with variable PEEP to reduce volutrauma and atelectrauma, while maintaining plateau pressures (Pplateau) less than 30–35 cm H₂O. Unfortunately, anesthesia ventilators do not have an easy method to perform an inspiratory hold or pause to estimate Pplateau. Not knowing the Pplateau presents challenges in providing lung protective ventilation; troubleshooting the etiology of high peak inspiratory pressures (PIP)—compliance versus resistance issue—determined by the gradient between PIP and Pplateau; and calculating driving pressure (Pplateau – PEEP), in minimizing respiratory strain and guiding optimal PEEP titration. If Pplateau cannot be readily obtained, as was the case for us, we recommend utilizing a mode that combines the benefits of volume and pressure-controlled ventilation, to deliver a preset VT at the lowest Paw.

In some COVID-19 ARDS patients, lung compliance is markedly reduced requiring high Paw to deliver desired VT targets [5]. Anesthesia machines have pressure limitations precluding ventilation at high Paw, which could lead to inefficient ventilation and worsening

hypercapnic acidosis. This is problematic in patients with increased physiologic dead space, where adjustments to ventilation is necessary for adequate carbon dioxide clearance. We prioritized this subgroup of patients for transition from an anesthesia workstation to an ICU ventilator.

As we face this pandemic, our aim is not to criticize the ingenuity of those who saw in the anesthesia workstation an ability to fulfill our anticipated lack of ventilators because, in desperate times, innovation is necessary. But ICU ventilators were designed specifically to treat acute or chronic respiratory failure, and as such, are to be preferred.

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