rescue intervention.[1,2] The same message comes from Chinese experience[6] and from worldwide recommendations.[2,8,9] To maximise first-pass success, we recommend a preloaded bougie or stylet, rapid sequence induction with full-dose neuromuscular blockade, preoxygenation by continuation of ongoing noninvasive ventilation, and apnoeic low-flow (1–3 L min^{-1}) oxygen through standard nasal prongs (nasal oxygen during efforts securing a tube [NODESAT]).[2] After two failed laryngoscopies, we recommend rescue use of fibreoptic intubation only through a second-generation intubating supraglottic airway device, which allows ventilation with limited environmental contamination.[2]

Airway management is complex in COVID-19 patients (infection risk, use of personal protective equipment (PPE), difficult communication, rapidly deteriorating patients, and shunt–hypoxaemia). Given the duration, complexity, and aerosolisation potential of fibreoptic intubation and the potential low-efficacy/high contamination profile of HFNO, we strongly discourage the use of the technique proposed by Wu and colleagues[1] in paralysed COVID-19 patients. Awake fibreoptic intubation remains the gold standard for predicted intubation/ventilation difficulty to be used in very selected cases in COVID-19 patients.[2,8,9] Oxygenation, independently of disease, remains the main target of any airway management strategy,[5] and although difficult at times, science and good sense should always prevail.

Declarations of interest

MS has received paid consultancy from Teleflex Medical, Verathon Medical, and DEAS Italia; is a patent co-owner (no royalties; DEAS Italia); and has received lecture grants and travel reimbursements (MSD Italia and MSD USA). IDG has received lecture grants and travel reimbursements from MSD Italia. There are no other competing interests declared.

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"Water, water, everywhere": a challenge to ventilators in the COVID-19 pandemic

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Keywords: COVID-19; pandemic; resource management; ventilator; water trap

Editor—With the spread of coronavirus disease 2019 (COVID-19), intensive care facilities have been rapidly overwhelmed across the UK and elsewhere.[1] In general, the UK has fewer doctors and fewer ICU beds per capita than most of Europe.[2] Many hospitals have spread into the recovery unit of theatres and are using anaesthetic machines to

ventilate patients. We write from a South Wales district general hospital that has moved patients into our recovery facility as an outreach ICU to discuss some of the challenges and potential solutions of the use of anaesthetic machines in long-term ventilation.

The anaesthetic machines used in the expanded ICU within Newport hospital are the Mindray WATO Ex-65 (Mindray). These use standing gas-driven bellows to provide driving pressure and are connected to a heated circle system, and passive humidification and heating are provided by distal and proximal heat and moisture exchange (HME) filters. One of the main issues we have encountered in ventilating these patients for durations outside the routine scope of anaesthetic machines is water condensation within the 22 mm tubing. This condensation has been sufficient to cause almost complete obstruction and create an oscillating obstructive flow trace.

Humidification of inspired air is required in the intubated patient to preserve mucociliary function, clearance of secretions, and gas exchange of the respiratory system. Disruption of these can cause damage and difficulty in ventilation, even in normal lungs. Over 24 h, ~250 ml of water is lost from the respiratory tract,[3] and a portion of this will collect in the breathing system, which requires multiple disconnections to drain water from the breathing circuit. Several methods are proposed to counteract this: increasing fresh gas flow to at least minute ventilation, decreasing breathing circuit length, and introduction of water traps into the breathing circuit.

By increasing fresh gas flow, the relative humidity in the circle system is reduced by increasing circuit gas turnover with dry gas. This was partially effective, but this strategy should be discussed with the works and estates team to ensure that the maximal oxygen flow rates are possible. Increased numbers of ventilated patients and the introduction of CPAP noninvasive ventilation as a viable first-line therapy can exhaust oxygen supplies if all patients require higher flows to match minute ventilation.

Decreasing the length of the breathing circuit partially helps with this issue but can exhaust the proximal HME more rapidly. It is also difficult to achieve once a patient has been admitted, intubated, and connected to the anaesthetic machine.

Water traps act as a reservoir for condensed water within the circuit. There are several models available but, as with many supply chains, they are difficult to purchase in a pandemic scenario. They sit between the patient and the anaesthetic machine on the expiratory limb and act to collect condensation via gravity. A further limitation of many of these water traps is that they do not allow the system to be emptied without disconnection. Several options were explored including the design of water traps that could be 3D printed and attached to the circuit, including a Luer lock system to extract water using a syringe. This would reduce circuit disconnections and create a large reservoir before ventilation became affected, with the caveat of using an untested medical device. The design of this trap went through several stages, from a sealed reservoir with a large volume (Fig 1a) to a smaller reservoir that could be emptied using a Luer lock syringe (Fig 1b).

A final water trap design was created using an HME filter with the filter material removed and connected in the middle of the expiratory limb of the circuit. A needle-free connector was added to the inline sampling port to allow removal of condensation using a syringe without disconnection (Fig 1c). This design is simple, quick to create using available resources, user friendly, and uses the minimal number of connections. A more complex design using a short in-line suction catheter (Fig 1d) was also proposed, however it requires more complex connections that increase the risk of disconnects, turbulent flow, or leaks. An empty HME filter provides around a 55 ml volume reservoir, with the addition of a 15–22 mm connector increasing this to 75 ml. The more complex connection with in-line suction can contain 80 ml.

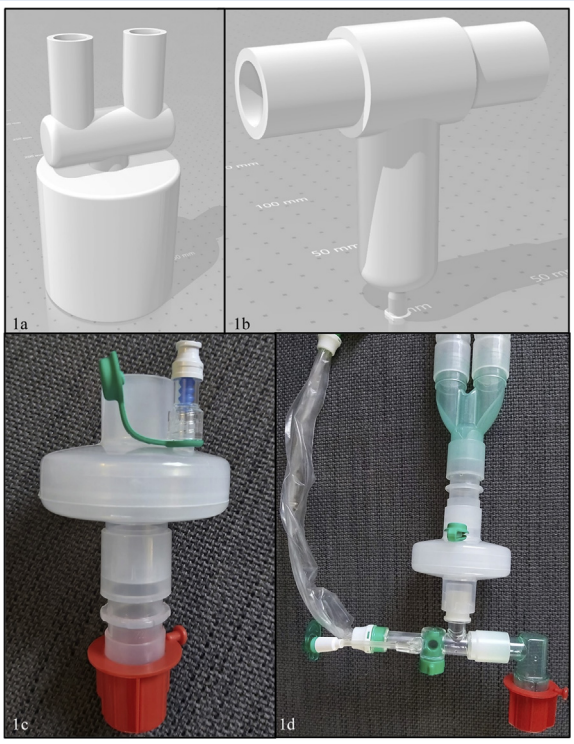

Figure 1. Proposed water trap designs. (a) Initial design using large reservoir of >300 ml. (b) Refined design with Luer lock port for aspirating condensation. (c) Simplified design with available materials using an empty heat and moisture exchange (HME) filter and needle-free connector. (d) Modified HME filter with y-connector and in-line suction.

We submit this as a creative solution to a practical problem encountered in the use of anaesthetic machines as long-term ventilators for COVID-19 patients. Awareness, consideration, and discussion of this and other issues arising should be encouraged to improve the care and safety of these at-risk patients.

Declaration of interest

The authors declare that they have no conflicts of interest.

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Comparison of three tracheal intubation methods for reducing droplet spread for use in COVID-19 patients

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Keywords: aerosol-generating procedure; COVID-19; infection prevention; simulation; tracheal intubation; videolaryngoscopy

Editor—Tracheal intubation is a life-saving procedure for respiratory failure caused by coronavirus 2019 (COVID-19),[1] however it is a high-risk aerosol generating procedure.[2] Healthcare workers have been compelled to discover novel forms of physical barrier and develop specific techniques of tracheal intubation with the least risk of transmission.[3,4] One such barrier method is an 'intubation protection box', a transparent box with openings for the hands that is placed over the patient's head to physically capture droplets and protect the laryngoscopist. Inspired by a previously described design,[5] we created a similar model with some modifications (Supplementary File S1).

We compared three methods of tracheal intubation: direct laryngoscopy, videolaryngoscopy, and video-laryngoscopy with the protective intubation box (see online video and Supplementary File S2). In a simulated intubation, we measured the trajectory and amount of droplet spread. We used an airway mannequin with its airway connected to a laryngo-tracheal mucosal atomisation device (MADgic, Teleflex Medical, Ontario, Canada) to simulate a cough and aerosolisation of droplets, which was attached via a short connector tubing to a 10 ml syringe containing a red-dye solution. The first test with direct laryngoscopy showed a large amount of dye on the laryngoscopist's faceshield, gown, arms, glove, neck, and hair. The second test with the videolaryngoscopy technique showed a significantly lower amount of dye on the laryngoscopist in similar locations, visually less than half the quantity compared with direct laryngoscopy. The third test with videolaryngoscopy and the box showed dye only on the gloves and forearms within the box; no dye was visible on any part of the laryngoscopist located outside the box including gown, face shield, neck, and hair (Fig. 1).

Fig. 1. Videolaryngoscopy with the protective intubation box.

Supplementary video related to this article can be found at https://doi.org/10.1016/j.bja.2020.04.083.

Our simulation method is one of the few simulations to show both large and small droplet trajectory. In the video, it is interesting to note that microdroplets lingered longer. Out of the three methods, videolaryngoscopy, as compared with direct laryngoscopy, was the preferred method of tracheal intubation given the significant decrease in the amount of aerosolised droplets on the laryngoscopist. The box offered an