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Intensive & Critical Care Nursing 60 (2020) 102894

Contents lists available at ScienceDirect

Intensive & Critical Care Nursing

journal homepage: www.elsevier.com/iccn

Letter to the Editor

# Procedures to minimize viral diffusion in the intensive care unit during the COVID-19 pandemic

*Dear Editor,*

Since February 20th, our Intensive Care Unit (ICU) has been converted into a COVID-19 unit and critical care beds in our hospital were increased from 25 to 75 in just a few days. To date (early April 2020), 72 of 75 beds are occupied by intubated patients, who are cared for by 150 nurses, 90 physicians and 25 healthcare assistants, some of whom without prior ICU experience. As the novel coronavirus SARS-CoV-2 can be transmitted from person to person, it represents a potential serious hazard to healthcare providers and unaffected patients (Chirico et al., 2020).

A preliminary report from Italy (Grasselli et al., 2020) suggested that the proportion of intensive care unit admissions were between 5 and 16% of the total positive SARS-CoV-2 cases, similar to the range reported in China (Guan et al., 2020). Recently guidelines from other countries (Respiratory Care Committee of Chinese Thoracic Society, 2020; Sorbello et al., 2020; Wax and Christian, 2020) classify procedures related to airway and ventilation management (High flow nasal cannula, continuous positive airway pressure (CPAP), non-invasive ventilation (NIV), bag-mask ventilation and bronchoscopy) as "High risk for healthcare worker contamination". These interventions generate aerosol and increase the risk of viral transmission to staff. Patients with COVID-19 should ideally be admitted to an airborne infection isolation room inside the ICU, that is at negative pressure relative to surrounding areas. Unfortunately, with the enormous need for new ICU beds in Italy (Grasselli et al., 2020), many of these patients are treated in positive pressure ICU rooms, with a great risk of spreading the virus to the environment and to health care workers. Cabrini and colleagues recently suggested, to increase safety during NIV and avoid viral spread, to use helmets as the NIV interface (Cabrini et al., 2020). With this device, the patient's exhalate can be filtered by applying a high efficiency particulate (HEPA) filter at the helmet outlet (Lucchini et al., 2020). For this reason, this interface may reduce virus spread compared to other interfaces such as face masks or high flow nasal oxygen. HEPA filters meet the highest standards for infection prophylaxis in ventilation (EN ISO 9360-1, 2009). The active medium of these mechanical filters is a hydrophobic membrane of coated glass fibres developed specifically for this purpose. Due to the hydrophobicity, the HEPA filter cannot be passed by potentially contaminated fluids (e.g.: blood, sputum, condensate) under normal pressure conditions of mechanical ventilation (viral filtration efficiency: 99.97%). When filters are placed on the expiratory limb of ventilator breathing circuit to preserve the reusable components, the greatest risk is that moisture accumulating in the device could increase exhalation resistance (Sorbello et al., 2020). This accumulation will affect ventilation effectiveness, as many ventilators have the flow and pressure detector located inside the ventilator For this reason, in order to reduce viral spread, the HEPA filter could be placed after the expiratory valve. When used in this mode, the HEPA filter does not interfere with the ventilator expiratory valve and can be replaced daily without opening the breathing circuit.

A significant proportion of patients with COVID-19 develop acute respiratory distress syndrome (ARDS), often requiring endotracheal intubation and mechanical ventilation. In these patients avoiding ventilator-induced lung injury is crucial (Meng et al., 2020), therefore low tidal volumes (4–6 mL/kg predicted body weight) and low inspiratory pressures (plateau pressure $\leq$30 $cmH_2O$) are recommended. The use of low tidal volumes may increase the risk of hypercapnia, thus the reduction of airway dead space is essential Restrepo and Walsh, 2012). Switching from an heat and moisture exchanger (HME) to a heated humidification system with heated-wired tubes (HH) is associated with a significant decrease in $PaCO_2$ levels (Morán et al., 2006). Moreover, COVID-19 patients have dense and dry bronchial secretions and ineffective humidification may lead to airway obstruction increasing the requirement of airway procedures such as bronchoscopy or endotracheal tube replacement (Meng et al., 2020).

In order to reduce potential virus diffusion, it is crucial to avoid unnecessary disconnection of breathing circuit (Respiratory Care Committee of Chinese Thoracic Society, 2020; Sorbello et al., 2020; Wax and Christian, 2020), thus closed suction devices and in-line adapters for bronchoscopy should be preferred. When it is necessary to open the circuit (manual emergency ventilation, connection of portable ventilator, change of broken parts of breathing circuit) a two-operator technique is recommended: the endotracheal tube should be temporarily clamped after activation of an expiratory hold on the ventilator. This procedure prevents alveolar de-recruitment while minimizing the exposure of the environment to the virus (Respiratory Care Committee of Chinese Thoracic Society, 2020; Sorbello et al., 2020; Wax and Christian, 2020).

A small proportion of COVID-19 patients may require extracorporeal membrane oxygenation (ECMO) (Bartlett et al., 2020). In patients undergoing ECMO support, the available literature does not exclude the spread of COVID-19 from the membrane lung gas outlet port. However, Extracorporeal Life Support Organization guidelines for COVID-19 patients do not recommended routine exhaust gas scavenging (Bartlett et al., 2020). Donning optimal personal protection equipment is required if oxygenator or circuit change is required. No indications are present on the management

https://doi.org/10.1016/j.iccn.2020.102894

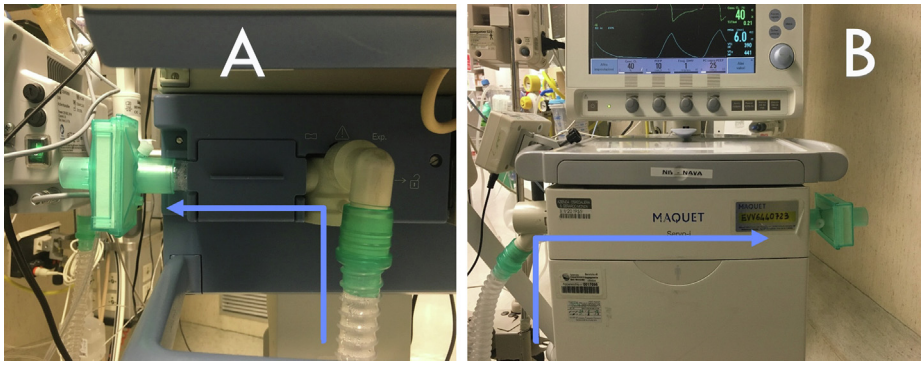


**Fig 1.** High efficiency particulate filters placed after ventilator expiratory valve (A: Drager Evita XL, B: Gettinge Maquet Servo I).

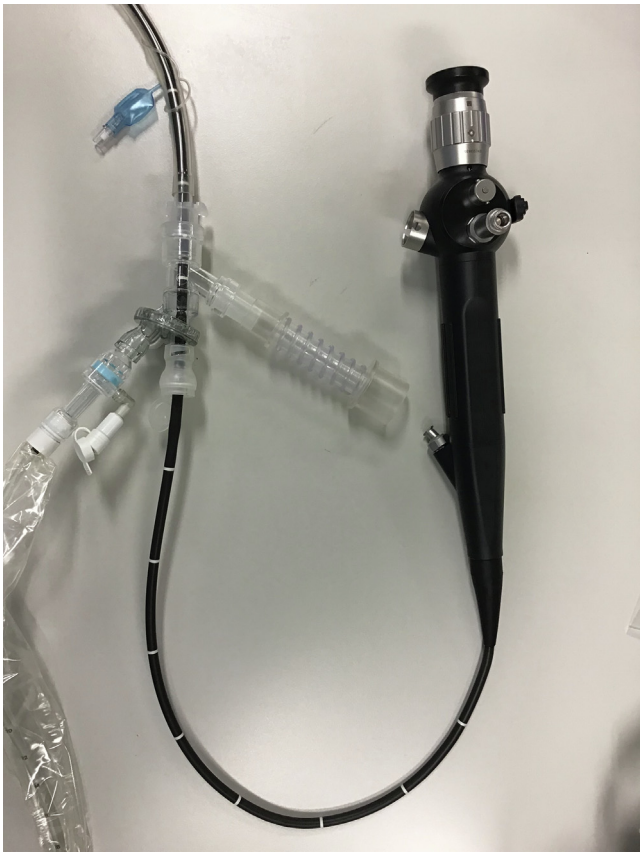

**Fig 2.** 72-hours closed suction system with a valve side port for bronchoscopy.

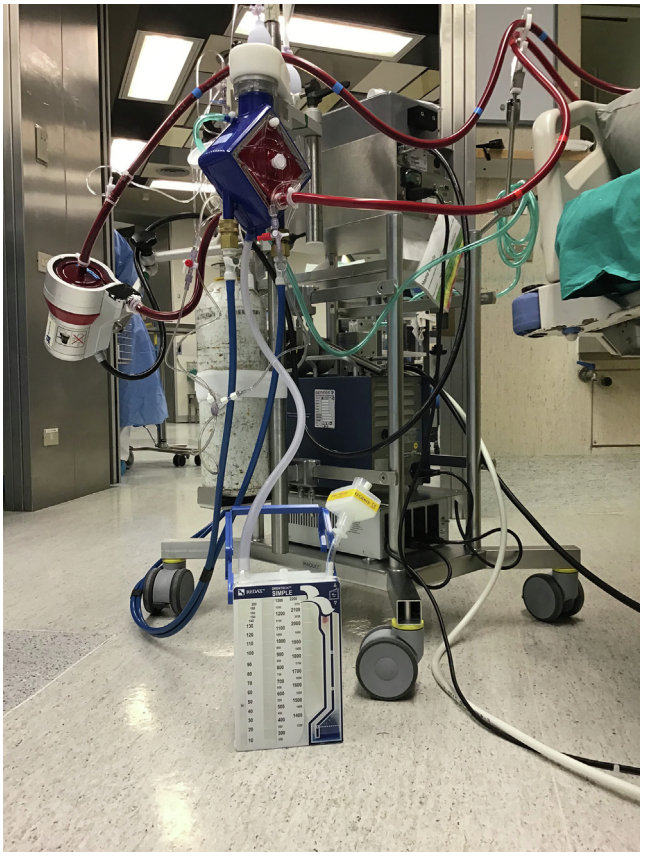

**Fig 3.** Single-chamber thoracic drainage system with a high efficiency particulate filter on the membrane lung air exit port.

of the moisture normally present in the membrane lung gas port, which is usually collected in a glass bottle in ECMO centers. As there are currently no studies in the literature proving that condensation is not contaminated by the SARS-CoV-2, it may be reasonable to collect moisture and exhalate gas from membrane lung into a single-chamber chest drainage system with a HEPA filter on the air exit port, allowing for proper gas filtering and a closed system for moisture drainage.

On the basis of these considerations and available literature on this topic, Institutional Guidelines for airway management and other high-risk procedures in these patients were developed. These recommendations include:

1) Manage non-intubated patients requiring positive end-expiratory pressure with Helmet CPAP.
2) Apply a HEPA filter to the helmet outlet. Tag the HEPA filter with the date and time of installation into the breathing circuit;
3) For patient requiring mechanical ventilation, use only ventilators which feature dual-limb circuits
4) Do not perform routine change of the ventilator circuit (i.e. unless visibly soiled);
5) Use of a heated humidification with HH to minimize airway dead space and provide optimal humidification;
6) Apply an active scavenging system (usually utilized for anesthetic gases) to the ventilator gas outlet, to minimize ICU air contamination;

7) If gas scavenging is not available and active humidification is used, apply a HEPA filter to the ventilator expiratory outlet to reduce environmental dispersion (Fig. 1);
8) If HH is not available, place a filter with both HEPA and HME capability between the Y-connection and the endotracheal tube. In this case, no other filter is required to prevent ICU air contamination on ventilator gas outlet. The HME + HEPA filter needs to be replaced every 24 h;
9) When patients require manual ventilation, position a HEPA filter between the manual resuscitator and endotracheal tube or face mask;
10) For patients requiring endotracheal suctioning, use of a dedicated 72-hours closed suction system with a valve side port (5.0 mm) for bronchoscopy. The system can be used for the patient's entire intubation time (Fig. 2) and may substantially reduce the risk of aerososzation during endotracheal suction or bronchoscopy;
11) Procedures requiring opening of the breathing circuit must be carried out by two operators with full personal protective equipment (tyvek suit, FFP3 mask and eye-protective gear). Before opening the circuit, activate the expiratory hold function on the ventilator and clamp the endotracheal tube;
12) For patients requiring mechanical ventilation during transport, place an HME + HEPA filter between patient and ventilator circuit;
13) In tracheotomised patients requiring T-Tube trial, position the HME + HEPA filter between the tracheostomy tube and the T-piece connector;
14) In ECMO patients, connect the sweep gas outlet port to a single-chamber chest drainage system with a HEPA filter on the gas flow exit port (Fig. 3).

Chirico and colleagues (Chirico et al., 2020) reported that, at April 5th, 12,252 health workers in Italy have tested positive for COVID-19, making up 10% of Italy's COVID-19 cases; furthermore, 80 medical doctors and 25 nurses have died. At our institution, after the first COVID-19 case more than 50 days ago (Giani et al., 2020), we cared for hundreds of patients, up to a maximum of 75 patients on invasive mechanical ventilation and 100 on helmet CPAP in general wards, on the same day. Out of a total of 265 nurses, physicians and other health care personnel involved in the care of ICU COVID-19 patients we have recorded only 4 (1.5%) cases of confirmed COVID-19.

In conclusion, we suggest developing a shared strategy to reduce the virus spread and minimize infections among providers caring for critical COVID-19 patients.

## Financial support

None

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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