Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Heart & Lung 49 (2020) 869–871

Contents lists available at ScienceDirect

Heart & Lung

journal homepage: www.heartandlung.com

Precautions for weaning from invasive mechanical ventilation with critically ill COVID-19

Mengqiang Luo[a], Zubing Mei[b,c], Liqun Wei[a], Shumei Cao[a], Shiheng Su[d], Yingwei Wang, MD, PhD. Professor and Chair[a,*]

[a] Department of Anesthesiology, Huashan Hospital, Fudan University, Shanghai, China
[b] Department of Anorectal Surgery, Shuguang Hospital, Shanghai University of Traditional Chinese Medicine, Shanghai, China
[c] Anorectal Disease Institute of Shuguang Hospital, Shanghai, China
[d] Department of Critical Care Medicine, Huashan Hospital, Fudan University, Shanghai, China

ARTICLE INFO

Article History:
Received 3 July 2020
Accepted 7 July 2020
Available online 9 July 2020

The coronavirus disease (COVID-19) pandemic remains an ongoing threat worldwide. By July 3, 2020 there had been 517,337 confirmed deaths and 216 countries and territories were affected.[1] This has created a major challenge worldwide, especially for patients with limited health care coverage. COVID-19 has a broad spectrum of clinical severity. Approximately 5–20% of those who are hospitalized are admitted to the intensive care unit because of acute respiratory failure, shock, and multiple organ dysfunction.[2] In China, 6–47% of critically ill COVID-19 patients received intubation and invasive mechanical ventilation (IMV) support,[2-3] while this figure goes up to 71–75% in the United States,[4-5] and 88% in Italy.[6] Moreover, the mortality rate among intubated COVID-19 patients is reported to be as high as 97%.[7] An early study conducted in Wuhan reported that 31 of the 32 patients who received IMV support died. Recently, 56.5–62.1% of patients were reported to be successfully extubated eventually, which suggests that better outcomes after intubation are extremely concerning for the survival of critically ill COVID-19 patients.[8-9]

COVID-19 leads to an atypical form of acute respiratory distress syndrome with relatively well-preserved lung compliance despite severe hypoxemia, and no specific antiviral drug has been identified. Extubation is a high-risk procedure in patients with COVID-19 because of direct contact with patients and exposure to airway droplets and aerosols. Therefore, it is critical to ensure that the decision to extubate is appropriate so that the patients are not harmed by extubation, and the hazards related to the cycle of reintubation and extubation are avoided. A protocol that facilitates the decision-making and execution of extubation in COVID-19 patients is warranted.

An important goal of extubation is to ensure that patients tolerate extubation and to minimize the chance that they will require reintubation. High-risk factors for reintubation include age, Acute Physiology and Chronic Health Evaluation (APACHE) II score, Rapid Shallow Breathing Index (RSBI), and positive fluid balance. A low PaO_2/FiO_2 ratio at extubation may be a risk factor for reintubation due to respiratory insufficiency.[10] Hence, patients should have a patent airway, adequate ventilation and gas exchange capacity with minimal or no respiratory stress before extubation. Daily spontaneous breathing trials, with pressure support for 30 min or T-piece ventilation for 2 h should be performed to determine whether patients are ready for discontinuation of IMV support. Progressive reduction of pressure support and daily spontaneous breathing trials are satisfactory methods of weaning in COVID-19 patients. It should be ensured that the established criteria are met before starting spontaneous breathing trials[11] (Table 1). For instance, a chest X-ray is needed to demonstrate remission of the lung disease (Fig. 1) and the PaO_2/FiO_2 ratio should be above 200 mmHg.

Some details need to be highlighted. A humidifier with a virus-filtering function should be used when modified T-piece ventilation is needed. Gentle in-line closed suction should be used to clean airway secretions (Fig. 1). Because the dispersion distance of exhaled air can range from 42 to 99 mm and that from coughing bouts may range up to 460 mm, multiple strategies should be used to reduce droplet spread during extubation. These may include covering the patient's mouth and nose with a wet gauze, plastic drapes, or a box; halting flow of oxygen with gauze; clamping the endotracheal tube; and use of suctioning devices.[12] Furthermore, "Mask-Over Tube Extubation" technique may enable the anesthetist to avoid direct exposure to droplets or aerosols produced by extubation or associated coughing.[13] Measures such as dexmedetomidine or remifentanil infusion and intravenous lidocaine maybe useful to prevent agitation, coughing, and bucking. Supraglottic airways and airway exchange catheter are not recommended in COVID-19 patients due to the potential for coughing.

The planned use of non-invasive ventilation (NIV) after extubation is recommended in high-risk patients to reduce the chance of extubation failure. Strategies for supporting respiration after extubation, such as NIV and high-flow nasal oxygen, are relatively

* Corresponding author.
E-mail address: wangyw@fudan.edu.cn (Y. Wang).

https://doi.org/10.1016/j.hrtlng.2020.07.005

Table 1
Criteria Used in Weaning IMV of COVID-19.

1.1 Clinical criteria to be met before starting SBT for COVID-19[11]	
1.	bedside x-rays suggest lung disease remission or absorption;
2.	adequate oxygenation($PaO_2/FiO_2 \geq 200$, PEEP≤5~8 cmH2O, $FiO_2 \leq 0.4 \sim 0.5$)
3.	stable cardiovascular system (HR≤140 times /min, stable arterial blood pressure, no or minimal pressors ie.dopamine < 5ug/kg/min);
4.	adequate cough;
5.	adequate alveolar ventilation (PH>7.3, PCO2<6.5kpa);
6.	T<38 °C;
7.	hemoglobin ≥8~10 g/dl;
8.	GCS≥13(no continuous sedative infusion);
9.	metabolic stability
1.2 Clinical criteria used to define the failure of an SBT with pressure support for 30 min or T-Piece ventilation for 2 h	
1.	gas exchange deterioration ($SpO_2 \leq 85\% \sim 90\%$; $PaO_2 \leq 50 \sim 60$ mmHg; pH≤7.32;increase in $PaCO_2 \geq 10$ mmHg), duration exceed more than 5 min;
2	hemodynamic instability (HR ≥ 120~140 beats/min; HR changed>20%; systolic BP<90 mmHg or 180~200> or changed>20%, pressors required), duration exceed more than 5 min;
3	instable ventilatory pattern (RR ≥30~35breaths/min; RR changed >50%, duration exceed more than 5 min);
4	change in mental status (eg, somnolence, coma, agitation, anxiety);
5	diaphoresis;
6	onset or worsening of discomfort;
7	signs of increased work of breathing (use of accessory respiratory muscles, and thoracoabdominal paradox)

contraindicated due to their ability to aerosolize viral particles. However, during the severe acute respiratory syndrome epidemic NIV did not appear to be associated with an increased risk of transmission of the virus to healthcare workers.[14] Minimizing unnecessary patient and surface contact, and careful waste management, are essential for risk reduction. Healthcare workers who are involved in the extubation process should wear standard Level 3 personal protective equipment, including a powered air-purifying respirator system.

In conclusion, meticulous considerations are needed to ensure the quality of care, decrease the chance of reintubation, and ensure the safety of healthcare workers when weaning critically ill COVID-19 patients from invasive mechanical ventilation.

Authors' contributions

M. Luo and Y.Wang contributed to the study conception and design. All authors were involved in critically revising the work for important intellectual content and approval of the final manuscript. The corresponding author attest that all listed authors meet the authorship criteria and that no others meeting the criteria have been omitted.

Consent for publication

Written consent for publication was obtained from patient.

Declaration of Competing Interest

None.

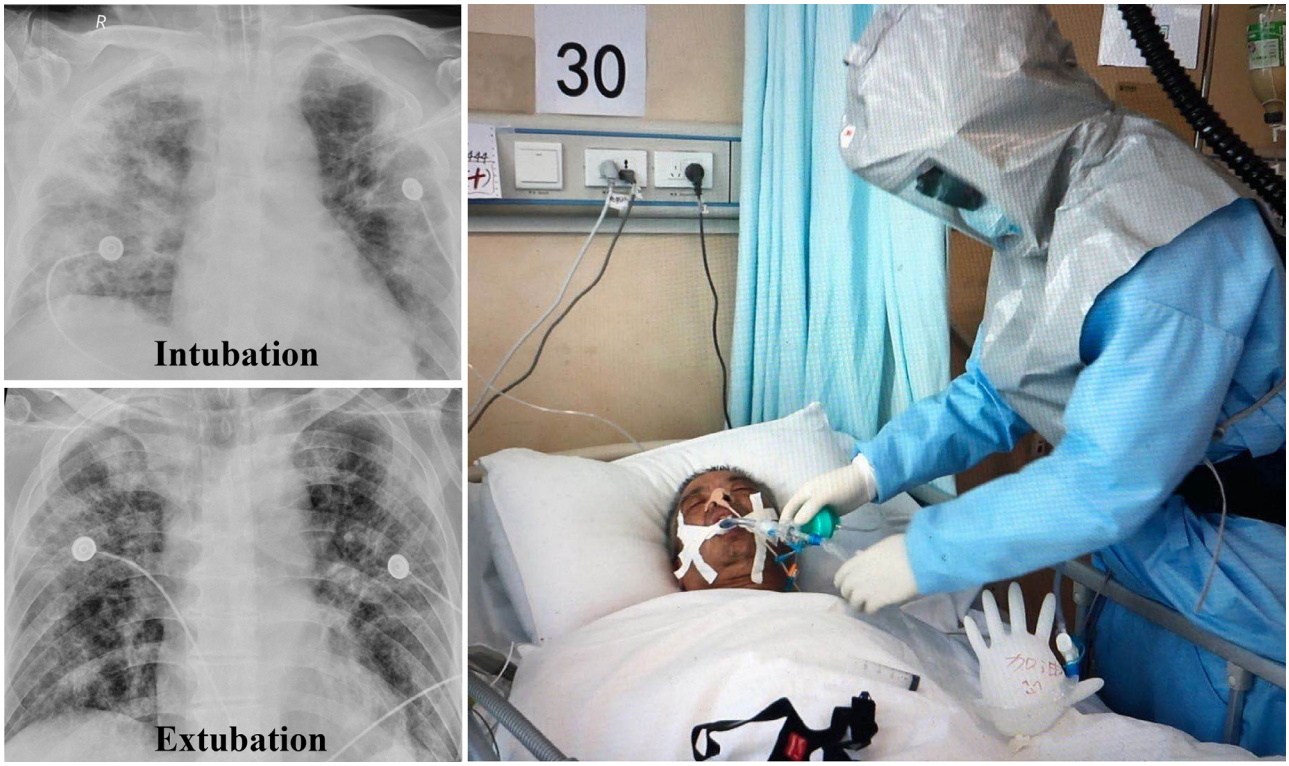

Fig. 1. An extubation scene in the epicenter Wuhan, China. As noted, the individual who was involved in the extubation wore a powered air purifying respirator system. The patient was on a modified T-piece ventilation trial. A humidifier with virus filtering function was used to prevent virus spreading. (Photograph provided by one of our team member Dr. Shiheng Su who volunteered to travel from Shanghai to Wuhan to join forces caring for COVID-19 patients. Written consent for publication was obtained from patient.).

References

1 World Health Organization: Coronavirus disease (COVID-19) dashboard, Last update: 3 July2020. https://covid19.who.int/.
2 Huang C, Wang Y, Li X, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China.. *Lancet*. 2020;395:497–506. https://doi.org/10.1016/S0140-6736(20)30183-5.
3 Wu C, Chen X, Cai Y, et al. Risk factors associated with acute respiratory distress syndrome and death in patients with coronavirus disease 2019 pneumonia in Wuhan, China. *JAMA Intern Med*. 2020.. e200994; https://doi.org/10.1001/jamainternmed.2020.0994.
4 Arentz M, Yim E, Klaff L, et al. Characteristics and outcomes of 21 critically ill Patients With COVID-19 in Washington State. *JAMA*. 2020;323(16):1612–1614. https://doi.org/10.1001/jama.2020.4326.
5 Bhatraju PK, Ghassemieh BJ, Nichols M, et al. Covid-19 in critically ill patients in the seattle region - case series. *N Engl J Med*. 2020;382:(21) 20122022. https://doi.org/10.1056/NEJMoa2004500.
6 Grasselli G, Zangrillo A, Zanella A, et al. Baseline characteristics and outcomes of 1591 patients infected with SARS-CoV-2 admitted to ICUs of the Lombardy Region, Italy. *JAMA*. 2020;323(16):1574–1581. https://doi.org/10.1001/jama.2020.5394.
7 Zhou F, Yu T, Du R, et al. Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study. *Lancet*. 2020;395(10229):1054–1062. https://doi.org/10.1016/S0140-6736(20)30566-3.
8 Ziehr DR, Alladina J, Petri CR, et al. Respiratory pathophysiology of mechanically ventilated patients with COVID-19: a Cohort Study. *Am J Respir Crit Care Med*. 2020;201(12):1560–1564. https://doi.org/10.1164/rccm.202004-1163LE.
9 Hur K, Price CPE, Gray EL, et al. Factors Associated With Intubation and Prolonged Intubation in Hospitalized Patients With COVID-19. *Otolaryngol Head Neck Surg*. 2020;163(1):170–178. https://doi.org/10.1177/0194599820929640.
10 Fujii E, Fujino K, Tanaka-Mizuno S, et al. Variation of risk factors for cause-specific reintubation: a preliminary study. *Can Respir J*. 2018 3654251. https://doi.org/10.1155/2018/3654251.
11 Schmidt GA, Girard TD, Kress JP, et al. Liberation from mechanical ventilation in critically ill adults: executive summary of an Official American College of Chest Physicians/American Thoracic Society Clinical Practice Guideline. *Chest*. 2017;151(1):160–165.. https://doi.org/10.1016/j.chest.2016.10.037. Epub 2016 Nov 3.
12 Matava CT, Yu J, Denning S. Clear plastic drapes may be effective at limiting aerosolization and droplet spray during extubation: implications for COVID-19. *Can J Anaesth*. 2020;67(7):902–904.. https://doi.org/10.1007/s12630-020-01649-w. Epub 2020 Apr 3.
13 D'Silva DF, McCulloch TJ, Lim JS, et al. Extubation of patients with COVID-19. *Br J Anaesth*. 2020;125(1):e192–e195.. https://doi.org/10.1016/j.bja.2020.03.016. Epub 2020 Apr 9.
14 Arulkumaran N, Brealey D, Howell D, et al. Use of non-invasive ventilation for patients with COVID-19: a cause for concern? *Lancet Respir Med*. 2020;8(6):e45. https://doi.org/10.1016/S2213-2600(20)30181-8.