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.

Respiratory Medicine 170 (2020) 106038

Contents lists available at ScienceDirect

Respiratory Medicine

journal homepage: http://www.elsevier.com/locate/rmed

Short review

Safe extubation during the COVID-19 pandemic

Aaron W. Kangas-Dick [a], Bruce Swearingen [a], Elias Wan [a,b], Kabu Chawla [c], Ory Wiesel [a,*]

[a] Department of Surgery, Maimonides Medical Center, Brooklyn, NY, USA
[b] Department of Emergency Medicine, Maimonides Medical Center, Brooklyn, NY, USA
[c] Department of Internal Medicine, Maimonides Medical Center, Brooklyn, NY, USA

ARTICLE INFO

Keywords:
COVID-19
Coronavirus
SARS-CoV-2
Extubation

ABSTRACT

Extubation of patients with Coronavirus Disease 2019 (COVID-19) is a high risk procedure for both patients and staff. Shortages in personal protective equipment (PPE) and the high volume of contact staff have with COVID-19 patients has generated an interest in ways to reduce exposure that might be feasible especially during pandemic times and in resource limited healthcare settings. The development of portable barrier hood devices (or intubation/extubation boxes) is an area of interest for many clinicians due to the theoretical reduction in aerosolization of SARS-CoV-2, the causative virus for COVID-19.

We present a review of the current literature along with recommendations concerning safe extubation during the COVID-19 pandemic. In addition, a focused summary on the use of portable barrier hood devices, during the recent surge of COVID-19 is highlighted.

1. Introduction

The COVID-19 pandemic has resulted in a rapid increase in patients requiring mechanical ventilation. While the true incidence is not yet known, large case series from New York City have suggested that almost a quarter of hospitalized patients may require endotracheal intubation [1,2].

The risk of spreading COVID-19 virus through aerosolizing procedures, such as intubation or extubation, is well documented [3–7]. While the majority of reports and guidelines focus on intubation, many of these same risks apply to extubation. Coughing is common in patients immediately after extubation and may contribute to additional aerosolization of SARS-CoV-2, as seen in simulations for intubation performed by multiple groups [4,5]. Additionally, while the use of Non-Invasive Positive Pressure Ventilation (NIPPV) strategies post-extubation is largely recommended for non-COVID patients with ARDS, there is little guidance on how to balance the clinical benefit of these interventions with the documented risk of viral aerosolization associated with these modalities [8,9].

1.1. Previous reports of safe extubation

Guidelines for extubation of COVID-19 patients are inconsistent and not well defined. Evidence based standards for safe practice under these circumstances are yet to be established. Several publications have emerged recently specifically describing safer techniques and protocols for extubation. D'Silva and colleagues recommend that extubation take place in a negative pressure room, if possible. Adequately trained staff for re-intubation (experienced anesthesia providers, respiratory therapists) be present if an emergency re-intubation is necessary, equipped with personal protective equipment (PPE) and preferably, a powered air-purifying respirator (PAPR). Only minimum staff required for the extubation procedure should be present, with any other staff available outside the room for emergencies. All team members should wear PPE including at minimum an N95 facemask and eye-protection. Orotracheal suctioning should be minimized in order to reduce the number of times this potentially aerosolizing procedure is performed. The authors also recommended the use of supplemental oxygen connected in series to two high efficiency particulate air [HEPA] Viral filters. After extubation, non-rebreathed oxygen at a FiO2 of 100% is provided via the ventilator for post-oxygenation [10].

Asenjo et al., in describing intubation and extubation procedures for the operating room, describe the importance of a sealed mask over the patient's face during the extubation process, in keeping with D'Silva's reccomendations [11].

Au Yong et al., described protocols for intubation and extubation based on the experience of the Singapore General Hospital with COVID-19 patients. The authors aim to describe interventions that might be

* Corresponding author.
E-mail address: owiesel@maimonidesmed.org (O. Wiesel).

https://doi.org/10.1016/j.rmed.2020.106038
Received 18 May 2020; Accepted 19 May 2020
Available online 23 May 2020

applied to resource limited environments, although these primarily focus on intubation. In keeping with other reports, the authors emphasize the provision of only the minimal amount of staff for both intubation and extubation, and the use of a plastic sheet to cover the patient entirely as a means of reducing droplet aerosolization [12].

Consensus guidelines for the management of the airway in patients with COVID-19 were jointly released in the United Kingdom by the Difficult Airway Society, the Association of Anesthetists, The Intensive Care Society, The Faculty of Intensive Care Medicine, and the Royal College of Anesthetists in March 2020. In reference to extubation, the group recommends avoidance of high flow nasal cannula oxygen or other methods of NIPPV in favor of standard low flow nasal cannula. The group recommends a standard surgical face mask be placed on the patient as soon as possible following extubation [13].

Multiple hospital systems have published institutional protocols pertaining to the extubation of COVID-19 patients. The Massachusetts General Hospital provides weaning recommendations for intubated and mechanically ventilated patients. They advise a 24 h trial of pressure support ventilation and recommend extubation to Continuous Positive Airway Pressure for patients with a body mass index over 35 [14] (see Table 1).

1.2. Use of barrier devices

In order to reduce risk of staff exposure to SARS-CoV-2 during high-risk procedures, barrier hood devices have been proposed, with a mixed response in the literature. The first known hood was described as an "Aerosol Box" constructed of durable plexi-glass. This device was intended for use in low resource situations where PPE was not adequately available for healthcare workers involved in high risk procedures [15]. A hood of this type was evaluated by Canelli et al. who concluded in a simulated intubation experiment that such a hood prevented the spread of aerosolized particles [4]. Results were similar in an experiment by Matava et al. who performed essentially the same procedure [16]. Response to this experiment has been mixed, with some authors suggesting that restricted hand movements might result in safety hazards to the patient, as patients with COVID-19 often require rapid intubation, rescue breaths with a mask, and/or suctioning to obtain a clear view of the vocal cords. Other disadvantages of the durable plexi-glass hood device include that it requires meticulous decontamination, and might be difficult to transport from patient to patient in emergent situations [17]. Other groups have suggested the use of a simple plastic sheet covering the entire patient as a barrier protection in high risk airway procedures, which has the theoretical advantage of being cheap and easily replaceable. Decreased access to the patient in emergency settings makes this device less desirable [12,18].

Table 1
Recent publications describing extubation procedures for patients with COVID-19. OR, Operating Room; ICU, Intensive Care Unit; PPE, Personal Protective Equipment; NIPPV, Non-invasive Positive Pressure Ventilation.

Group	Setting	Origin	Key Recommendations
Asenjo et al. *2020* [11]	OR	Canada	• Sealed anesthesia mask over patient's face • Prophylactic suctioning tube placed prior to extubation
Au Yong et al. *2020* [12]	ICU	Singapore	• Minimal Staff present • Barrier plastic sheet
Cook et al. *2020* [13]	ICU and OR	UK	• Minimal Staff present • Mitigate coughing • Avoid NIPPV • Delay extubation as possible
D'Silva et al. *2020* [10]	ICU and OR	UK	• Negative Pressure Room • Key Airway Personnel on hand • Minimum staff, wearing PPE • Extubation to anesthesia mask with "double filter" circuit.

The first case of SARS-CoV-2 in New York City was diagnosed on March 1. Shortly after, New York has quickly become the front line and the epicenter of the nation's fight against the disease. As of May 13th, 2020, there have been approximately 351,535 cases in the state and 26,707 deaths [19].

Our center, an academic tertiary medical center in Brooklyn, New York adapted rapidly and opened 8 Intensive care units to meet the need of the surge in mechanically ventilated patients. As with the majority of the medical centers, we created protocols for safe intubation and extubation to mitigate the high risk of the virus spread.

To further decrease the risk of virus spread during extubation, we designed a portable light hood device to minimize risk to both patients and healthcare workers under COVID-19 surge conditions.

1.3. Hood design

Our hood device is constructed of light PVC tubing, forming a cube, and is covered on four sides with semi-transparent nylon which can be exchanged easily between consecutive procedures. The remaining two sides are left open- one side to allow placement over a patient's torso, head and neck, and one to the rear to allow access for procedures such as intubation and extubation. Five sided full nylon coverage is also feasible with a slit opening at the nylon to allow hand manipulation during selected procedures (given the flexibility of the Nylon coverage) (Fig. 1). Standard cleaning with sani-cloths allow quick decontamination of the PVC tubes and connectors, while the nylon is easily replaceable.

In order to demonstrate the use of this device, we present the case of a morbidly obese 38 year old male without past medical history who was admitted to our institution. The patient initially presented to an outside hospital with shortness of breath, polyuria, and polydipsia. He was transferred to our facility for further workup. He had no prior medical history, but was taking prednisone at home for perceived weakness. In the emergency department, he developed worsening shortness of breath and desaturation which prompted endotracheal intubation. Chest radiograph at presentation demonstrated findings consistent with COVID-19. The patient tested positive for SARS-CoV-2. The patient was further found to be in diabetic ketoacidosis, which was managed with an insulin drip.

His Intensive care unit course was remarkable for methicillin susceptible staph aureus bacteremia, managed with Oxacillin. He was enrolled in a clinical trial for convalescent plasma and received one dose. By Hospital day six, the patient required minimal ventilator support. He was weaned from sedation, and passed a trial of pressure support ventilation. On Hospital day seven he was deemed ready for a trial of extubation.

In order to minimize risk of viral aerosolization multiple precautions

Fig. 1. Lightweight, disposable hood device with and without nylon covering.

were taken prior to an attempt at extubation. The patient was transferred to a negative pressure room. In order to be prepared for a need for rapid re-intubation, the anesthesia team was present outside the patient room in full PPE including PAPR. Respiratory therapist and attending physician both equipped with PPE, performed the extubation (Fig. 2, video).

Supplementary video related to this article can be found at https://doi.org/10.1016/j.rmed.2020.106038

Extubation was performed using a modified version of the "mask over tube" approach described by D'Silva et al. [10] The entirety of this procedure was performed under our barrier hood device. A non-rebreather facemask was placed over the patient's mouth, after all securing tape had been removed from the endotracheal tube. The respiratory therapist removed the endotracheal tube rapidly, and the non-rebreather mask was immediately placed over the patient's mouth. Orotracheal suctioning was performed under the barrier hood. High flow nasal cannula was placed on the patient, as he was high risk for re-intubation due to his morbid obesity. The light hood was left in place for several hours to assist in blocking any aerosolized virus from post-extubation coughing. The patient tolerated the extubation well and reported that the hood did not interfere with his breathing nor communication with the team.

The patient remained further extubated and was transferred out of the ICU after observation for additional 48 h.

1.4. Advantages and limitations of hood devices during extubation

Our light PVC Barrier hood device was designed to address some of the concerns regarding plexi-glass hoods while maintaining the potential benefit to the patient and staff. Replaceable Nylon covering allows for a similar level of barrier protection, but may be easily removed and discarded after use. The covering may be replaced quickly. The PVC structure of the device may be easily cleaned and decontaminated for subsequent use. The hood can be covered with 4 or 5 sided nylon according the hospital protocols or the team preference.

While there has been some empiric investigation concerning the theoretical benefits of a device similar to ours, there are currently no society recommendations specifically endorsing their use. However, similar devices have been independently developed by multiple groups who have published accounts of their use and potential efficacy. Description of these devices and summary of their potential advantages and limitations are listed in Table 2 [12,18,20,21].

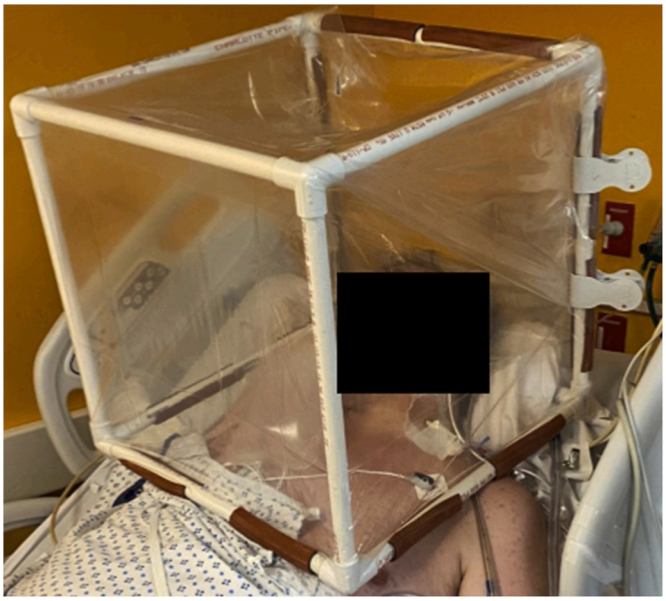

Fig. 2. Video of extubation.

Accumulated data from several groups suggesting that barrier hoods are effective in simulations modeling patient interaction should be validated with human studies. One possible avenue by which this might be explored is the direct testing of expectorated saliva with patient coughing for SARS-COV-2, as to date only simulated experiments have been performed [22]. Additional further studies should investigate the impact of hood devices on hand restriction and emergent intubations.

1.5. Summary of recommendations for safe extubation during COVID19

First, the patient must be considered an appropriate candidate for extubation. Traditional guidelines have been established for the non-COVID patient largely apply, with some centers recommending the following [23].

Patients should be optimized prior to an attempt at extubation, with closed endotracheal and protected orotracheal suctioning. While there is evidence that an appropriate cough effort is associated with decreased rates of re-intubation, excessive coughing should be prevented via pharmacologic means [10,13]. An extended trial of pressure support ventilation, and/or an extended spontaneous breathing trial may be considered [8,14].

In light of the risk to staff associated with re-intubation of COVID-19 patients, the traditionally accepted re-intubation rate of 5–30% may no longer apply. For this reason, it is recommended by several groups that extubation be delayed as long as is feasible, which must be balanced against the need for intensive care unit beds in the setting of a pandemic [13].

If possible, extubation should take place in a negative pressure room [10,13]. In open spaces, HEPA filters should be used to prevent aerosolized viral particle spread.

Only necessary staff wearing adequate PPE consisting of at minimum an N95 respirator, eye protection, and/or PAPR should remain in the room during the procedure [10,13,24].

An oxygen mask should be placed immediately over the patient's mouth and nose immediately following removal of the endotracheal tube [10,12,13,18].

While the use of NIPPV confers a protective effect against re-intubation in non-COVID-19 patients, this has not yet been established in the COVID-19 patient population [9]. It is possible that NIPPV modalities are aerosol generating procedures [25,26]. For this reason, some institutions advise that NIPPV should be employed routinely for high risk patients only [8]. UK Consensus guidelines recommend against the use of NIPPV [13].

The use of barrier hood devices during extubation is feasible, but is neither recommended for or against by any society.

Table 2
Types of Barrier Devices developed for use in aerosolizing procedures for patients with COVID-19.

Device	Citation	Advantages	Disadvantages
Plexi-Glass Hood	**Canelli et al 2020**	• Durable • Reusable • Validated to reduce spread experimentally	• Expensive • Require extensive decontamination procedures • May limit access to airway by staff
Nylon Hood	**Brown et al 2020**	• Easy to replace nylon • Easy to Sanitize • Cost-Effective	• Not separately validated experimentally • May also limit access to airway by staff
Clear Plastic Sheet	**Patino Montoya et al 2020 Au Yong et al 2020 Matava et al 2020**	• Disposable • Available widely • Cost-effective • Validated to reduce spread experimentally	• Extreme limit to access to airway and patient to staff • Difficult and time consuming to apply correctly.

2. Conclusion

In light of the high aerosolization risk during airway procedures of SARS-COV-2 during the COVID-19 pandemic, a lightweight Barrier hood device was designed to benefit patients, and maximize the safety of healthcare workers performing this high-risk airway procedures. While we speculate that its' use mitigates aerosolization, it by no means eliminates it. Institutional safeguards for extubation remain paramount to avert nosocomial transmission of COVID-19. Until then- the true risks of extubation during the COVID-19 pandemic remain unknown.

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.The Authors declare no competing interests, financial or otherwise. None of the authors has any commercial stake in any product discussed in this manuscript.

Acknowledgements

The Authors wish to thank Mr. Pat Masi, Operating Room Biomedical Equipment Specialist for assistance with the procurement and maintenance of our hood devices.

References

[1] C.M. Petrilli, S.A. Jones, J. Yang, et al., Factors associated with hospitalization and critical illness among 4,103 patients with COVID-19 disease in New York City, medRxiv (646) (2020) 2020, https://doi.org/10.1101/2020.04.08.20057794, 04.08.20057794.

[2] S. Richardson, J.S. Hirsch, M. Narasimhan, et al., Presenting characteristics, comorbidities, and outcomes among 5700 patients hospitalized with COVID-19 in the New York city area, J. Am. Med. Assoc. (April 2020), https://doi.org/10.1001/jama.2020.6775.

[3] W. Wang, Y. Xu, R. Gao, et al., Detection of SARS-CoV-2 in different types of clinical specimens, *JAMA*. March (2020), https://doi.org/10.1001/jama.2020.3786.

[4] R. Canelli, C.W. Connor, M. Gonzalez, A. Nozari, R. Ortega, Barrier enclosure during endotracheal intubation, N. Engl. J. Med. (2020) 1–2, https://doi.org/10.1056/nejmc2007589.

[5] D.N. Weissman, M.A. de Perio, L.J. Radonovich, COVID-19 and risks posed to personnel during endotracheal intubation, *JAMA*. April (2020) 19–20, https://doi.org/10.1001/jama.2020.6627.

[6] B.A. Orser, Recommendations for endotracheal intubation of COVID-19 patients, Anesth. Analg. 130 (5) (2020) 1109–1110, https://doi.org/10.1213/ANE.0000000000004803.

[7] L. Berkow, A. Kanowitz, COVID-19 putting patients at risk of unplanned extubation and airway providers at increased risk of contamination, *Anesth Analg*. April (2020) 1, https://doi.org/10.1213/ANE.0000000000004890.

[8] M. Wolf, Ventilator liberation in COVID-19 patients. MGH FLARE, Accessed, https://us19.campaign-archive.com/?u=ef98149bee3f299584374540a&id=3f1e9abc61. (Accessed 13 May 2020).

[9] S.M. Maggiore, F.A. Idone, R. Vaschetto, et al., Nasal high-flow versus venturi mask oxygen therapy after extubation. Effects on oxygenation, comfort, and clinical outcome, Am. J. Respir. Crit. Care Med. 190 (3) (2014) 282–288, https://doi.org/10.1164/rccm.201402-0364OC.

[10] D.F. D'Silva, T.J. McCulloch, J.S. Lim, S.S. Smith, D. Carayannis, Extubation of patients with COVID-19, Br. J. Anaesth. (xxx) (2020) 1–3, https://doi.org/10.1016/j.bja.2020.03.016.

[11] J.F. Asenjo, Safer intubation and extubation of patients with COVID-19, Can J Anesth Can d'anesthésie (2020), https://doi.org/10.1007/s12630-020-01666-9.

[12] Yong PS. Au, X. Chen, Reducing droplet spread during airway manipulation: lessons from the COVID-19 pandemic in Singapore, Br. J. Anaesth. (2020), https://doi.org/10.1016/j.bja.2020.04.007 (January).

[13] T.M. Cook, K. El-Boghdadly, B. McGuire, A.F. McNarry, A. Patel, A. Higgs, Consensus guidelines for managing the airway in patients with COVID-19: guidelines from the difficult airway society, Anaesthesia. (2020) 785–799, https://doi.org/10.1111/anae.15054, the Association of Anaesthetists the Intensive Care Society, the Faculty of Intensive Care Medicine and the Royal College of Anaesthetist.

[14] Massachusetts general hospital. Weaning and extubation guidance. COVID-19 Treatment Guidance: Inpatient Care Reccomendations, Accessed, https://www.massgeneral.org/assets/MGH/pdf/news/coronavirus/weaning-and-extubation-guidance.pdf, 2020. (Accessed 13 May 2020).

[15] K. Everington, Taiwanese doctor invents device to protect US doctors against coronavirus, Taiwan News Published, https://www.taiwannews.com.tw/en/news/3902435. (Accessed 23 March 2020).

[16] C.T. Matava, J. Yu, S. Denning, Clear plastic drapes may be effective at limiting aerosolization and droplet spray during extubation: implications for COVID-19, Can. J. Anesth. (2020) 1–3, https://doi.org/10.1007/s12630-020-01649-w.

[17] W.H. Rosenblatt, J.D. Sherman, P. Kovatsis, C. Matava, J. Peyton, More on barrier enclosure during endotracheal intubation, N. Engl. J. Med. 375 (13) (2020) e69, https://doi.org/10.1056/NEJMc2012960.

[18] M. Patino Montoya, H.V. Chitilian, Extubation barrier drape to minimise droplet spread, Br. J. Anaesth. (2020), https://doi.org/10.1016/j.bja.2020.03.028. January).

[19] Worldometers. COVID-19 Pandemic, Accessed, https://www.worldometers.info/coronavirus/. (Accessed 13 May 2020).

[20] D. Brown, T. Carey, Enhancing safety of clinicians intubating patients with COVID-19. On A mission, Accessed, https://www.brighamhealthonamission.org/2020/04/24/enhancing-safety-of-clinicians-intubating-covid-19-patients/, 2020. (Accessed 5 November 2020).

[21] Y.Y. Lai, C.M. Chang, A carton-made protective shield for suspicious/confirmed COVID-19 intubation and extubation during surgery, *Anesth Analg*. April (2020) 1, https://doi.org/10.1213/ANE.0000000000004869.

[22] L. Azzi, G. Carcano, F. Gianfagna, et al., Saliva is a reliable tool to detect SARS-CoV-2, J. Infect. (xxxx) (2020) 1–6, https://doi.org/10.1016/j.jinf.2020.04.005.

[23] N.R. MacIntyre, Evidence-based guidelines for weaning and discontinuing ventilatory support, Chest 120 (6) (2001) 375S–395S, https://doi.org/10.1378/chest.120.6_suppl.375S.

[24] Centers for Disease Control, Use of personal protective equipment (PPE) when caring for patients with confirmed or suspected COVID-19, Accessed, https://www.cdc.gov/coronavirus/2019-ncov/downloads/A_FS_HCP_COVID19_PPE.pdf, 2020. (Accessed 16 May 2020).

[25] D.S. Hui, B.K. Chow, T. Lo, et al., Exhaled air dispersion during high-flow nasal cannula therapy versus CPAP via different masks, Eur. Respir. J. 53 (4) (2019) 1802339, https://doi.org/10.1183/13993003.02339-2018.

[26] N.-H.W. Loh, Y. Tan, J. Taculod, et al., The impact of high-flow nasal cannula (HFNC) on coughing distance: implications on its use during the novel coronavirus disease outbreak, Can J Anesth Can d'anesthésie (2020), https://doi.org/10.1007/s12630-020-01634-3. March.