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Safety and efficacy of tracheotomy for critically ill patients with coronavirus disease 2019 (COVID-19) in Wuhan: a case series of 14 patients

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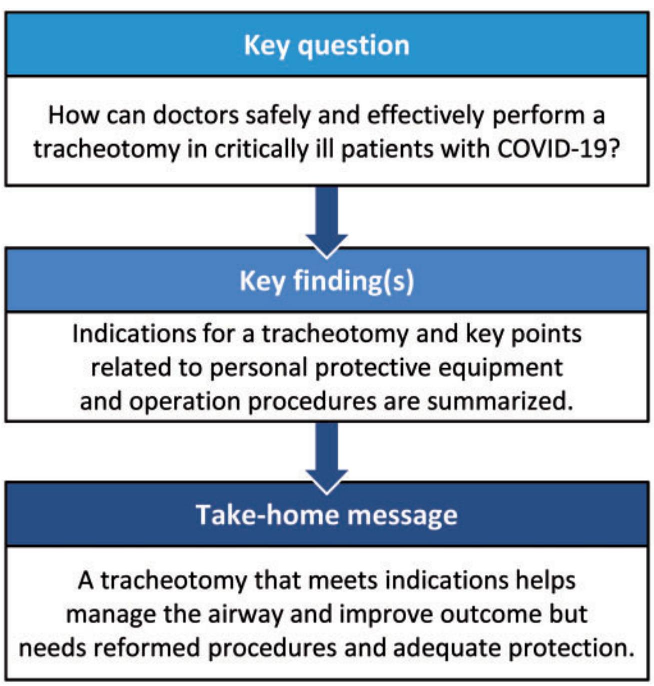

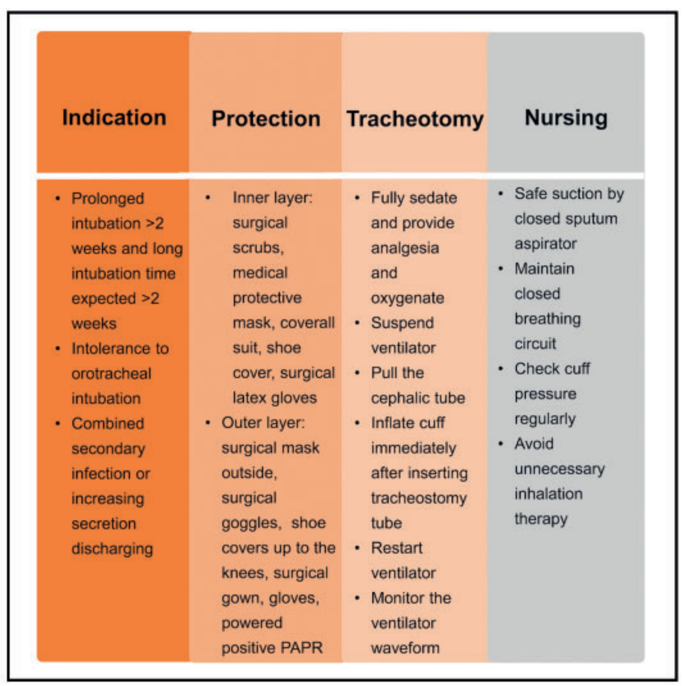

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Abstract

OBJECTIVES: Coronavirus disease 2019 (COVID-19) is a global pandemic. Critically ill patients often require prolonged intubation for mechanical ventilation to support breathing; thus, the artificial airway must be managed by tracheotomy. Therefore, studies exploring appropriate and safe methods for tracheotomy that minimize the risks of nosocomial transmission are important.

METHODS: A retrospective analysis of the clinical characteristics of 14 critically ill patients with COVID-19, who underwent bedside tracheotomy from March to April 2020 was conducted to summarize the indications for tracheotomy and key points related to personal protective equipment and surgical procedures.

RESULTS: All 14 patients were diagnosed with COVID-19 and were critically ill. All tracheotomies were performed in the late phase of the infection course. The interval between the infection and tracheotomy was 33 days, and the median interval between intubation and tracheotomy was 25.5 days. The reverse transcription-polymerase chain reaction results of secretions from the operative incision and inside the tracheotomy tube were negative. Twelve patients improved after tracheotomy, with SpO_2 levels maintained above 96%. One patient died of progressive respiratory failure; another patient died of uncontrolled septic shock. No medical staff who participated in the tracheotomy was infected.

CONCLUSIONS: Tracheotomy in critically ill patients with COVID-19 who meet the indications for tracheotomy potentially represents a safer approach to manage the airway and help improve the treatment outcomes. A tracheotomy performed in the late phase of the disease has a relatively low risk of infection. Adherence to key steps in the tracheotomy procedure and donning adequate personal protection will help medical staff avoid infection.

Keywords: COVID-19 • Critical care • Tracheotomy • Surgical indications • Protective measures

ABBREVIATIONS

COVID-19	Coronavirus disease 2019
ICU	Intensive care unit
PCR	Polymerase chain reaction
PPE	Personal protective equipment
SARS-CoV-2	Severe acute respiratory syndrome coronavirus

INTRODUCTION

Beginning in December 2019, a new form of severe acute respiratory syndrome coronavirus (SARS-CoV-2) caused an outbreak of coronavirus disease 2019 (COVID-19) worldwide. COVID-19 is a contagious pulmonary infectious disease that is transmitted via respiratory droplets and aerosols. Because of its long latency and ability to spread easily among people, COVID-19 has infected more than 2 million people worldwide, causing 160 120 confirmed deaths to date [1].

According to a report from the Chinese Center for Disease Control and Prevention, ∼81% of patients with COVID-19 show mild disease presentation with no or mild pneumonia, while 5–15% of patients with severe symptoms are admitted to the intensive care unit (ICU) in a critical condition [2].

China was the first country to report the COVID-19 pandemic worldwide, with most cases located in Wuhan, Hubei Province. The high rate of hospital and ICU admissions provoked serious overcrowding in hospitals throughout Wuhan [2]. The government completely locked down the city and mobilized tens of thousands of medical practitioners and tons of medical supplies to Wuhan from all over the country to stop the transmission and provide sufficient medical services to the patients.

The quick spread of COVID-19 placed extreme pressure on the healthcare system and led to a personal protective equipment (PPE) shortage, which put medical staff at a higher risk of infection. Various respiratory treatments for critically ill patients, such as intubation, manual ventilation with a resuscitator, non-invasive ventilation, high-flow nasal cannula, bronchoscopy examination, suction and patient transportation, are considered high-risk factors for nosocomial transmission because of their greater possibility of causing or worsening the spread of the virus. According to data from Italy, ∼10% of Italian patients are healthcare workers [3]. Therefore, medical staff must be fully equipped to minimize the possibility of nosocomial transmission.

Critically-ill patients often require prolonged intubation for mechanical ventilation, which requires safer airway management. A recent systematic review revealed that early tracheotomy performed in the first 7 days after orotracheal intubation is associated with reductions in the mechanical ventilation duration, mortality rate and length of stay in the ICU [4]. Although surgical tracheotomy is a routine procedure for otolaryngology surgeons in daily practice, direct access to the trachea and mechanical ventilation during this procedure might spurt tremendous amounts of droplets and aerosols, placing surgeons and ICU workers in the highest risk category [5]. Therefore, surgical tracheotomy is preferable for sedated and intubated patients rather than awake patients. Percutaneous dilatational tracheotomy is not optimal because mechanical ventilation should not be stopped for long periods, and droplet emission inevitably occurs at a higher rate. To date, our team has performed 14 cases of surgical tracheotomy in critically ill patients with COVID-19 in the ICU while employing proper protective measures, with no nosocomial transmission. Due to the increasing number of confirmed COVID-19 cases and the increasing need for tracheotomy in ICU patients, we summarize our experience with tracheotomy to minimize the risk of nosocomial infection and avoid healthcare worker shortages.

PATIENTS AND METHODS

This study was approved by our local ethics committee. Written informed consent was waived by the Ethics Commission of the designated hospital for emerging infectious disease due to the urgent need to collect data.

Figure 1: Two layers of personal protective equipment. (**A**) Inner layer including a N95 medical protective mask and coverall suit. (**B**) Outer layer including surgical goggles, another surgical mask and gown outside. (**C**) Second outer layer with a pressure air-purifying respirator. (**D**) Two otolaryngologists and an anaesthetist performing a tracheotomy.

The clinical data from 14 patients with COVID-19 in our ICU who underwent a tracheotomy from February to April 2020 were retrospectively analysed. This unit, which was established under emergency conditions to accept the most critically ill patients during the outbreak of COVID-19, was managed by a multidisciplinary team from Peking Union Medical College Hospital in the Sino-French New City Branch of Tongji Hospital in Wuhan, China. All patients were evaluated for the clinical course, intubation timing, surgical indications, secondary pneumatic infection and past medical history. Samples from the operative incision and secretions from the endotracheal tube were collected for reverse transcription-polymerase chain reaction (PCR) analyses of the SARS-CoV-2 RNA after the operation. In addition, viral RNAs from oropharyngeal swabs and serum IgM and IgG antibody titres were routinely measured during the disease course.

Tracheotomy was performed in the same manner as the conventional operation beside the ICU bed. The appropriate setting and PPE (Fig. 1A–D) worn during the procedure are described in the discussion section. The anaesthetist maintained the analgesia status of intubated and sedated patients and carefully monitored their vital signs. Furthermore, the dose of the drug used for neuromuscular blockade was adjusted by the anaesthetist to prevent swallowing and cough reflexes. Secretions of the oropharynx and in endotracheal tube were collected before the operation. Oxygenation was achieved with a ventilator. After the tissue at the front of the neck was dissected and the anterior wall of the trachea (2–4 rings) was exposed clearly, the ventilator was suspended. Then, the surgeon quickly completed the tracheal anterior wall incision and inserted the tracheotomy tube. The cuff was inflated immediately and confirmed to avoid leakage, and then the anaesthetist reconnected the ventilator and restarted the assisting breathing. The anaesthetist monitored the ventilator waveform to ensure that the endotracheal tube was placed in the correct position (Fig. 2).

RESULTS

All 14 patients (6 males and 8 females) had a SARS-CoV-2 infection confirmed by reverse transcription PCR for viral RNA in respiratory samples, in combination with the clinical history and pulmonary chest computed tomography findings. All patients were diagnosed as critically ill according to the diagnostic criteria of China's seventh version of the diagnosis and treatment guidelines for COVID-19 (3 March 2020) and treated by our multidisciplinary ICU team. Most patients were senior citizens aged 55–80 years old. All patients had previously been diagnosed with one or multiple chronic underlying diseases, including primary hypertension, type 2 diabetes mellitus and coronary heart disease, among others. Twelve (85.71%) patients had secondary infections with other pathogens in the lung (Table 1).

All tracheotomies were performed in the late phase of the COVID-19 infection (≥15 days). The minimal interval between infection and tracheotomy was 33 days (range: from 33 to 90 days) (Table 1). The median interval between intubation and tracheotomy was 25.5 days (range: from 13 to 33 days) (Table 1). The average operation time was ∼30 min, and the respiratory and circulatory functions were stable during the operation. The wound showed no obvious bleeding after the operation. None of the medical staff who participated in the tracheotomy was infected. Viral RNA reverse transcription PCR analyses of samples from the operative incision and endotracheal discharge were performed on the same day after the operation. The results of all these samples were negative (Table 2). PCR of the oropharyngeal swabs collected before and after the operation and analysed within 1 week all showed negative results. The serum IgM and IgG antibody titres were also measured. In the late phase, all patients showed IgG seropositivity, and most of them even showed strong seropositivity (85.71%), while only a minor proportion of them showed IgM seropositivity (18.57%) (Table 2).

The treatment outcomes of 12 of the 14 patients improved after the tracheotomy to varying degrees. Seven of these patients were removed from mechanical ventilation, and the other 5 patients were receiving anti-infective and supportive treatment with continuous invasive mechanical ventilation until the date our data were collected (Table 1). The conditions of all 12 patients were stable, with SpO_2 levels maintained at >96%. Patient no. 1 died of progressive respiratory failure, and patient no. 9 underwent vein–vein extracorporeal membrane oxygenation treatment after tracheotomy and died of uncontrolled septic shock.

DISCUSSION

In this study, we report the results of 14 critically ill patients with COVID-19 who underwent bedside conventional tracheotomy in the ICU. Tracheotomy was safe when proper biosafety

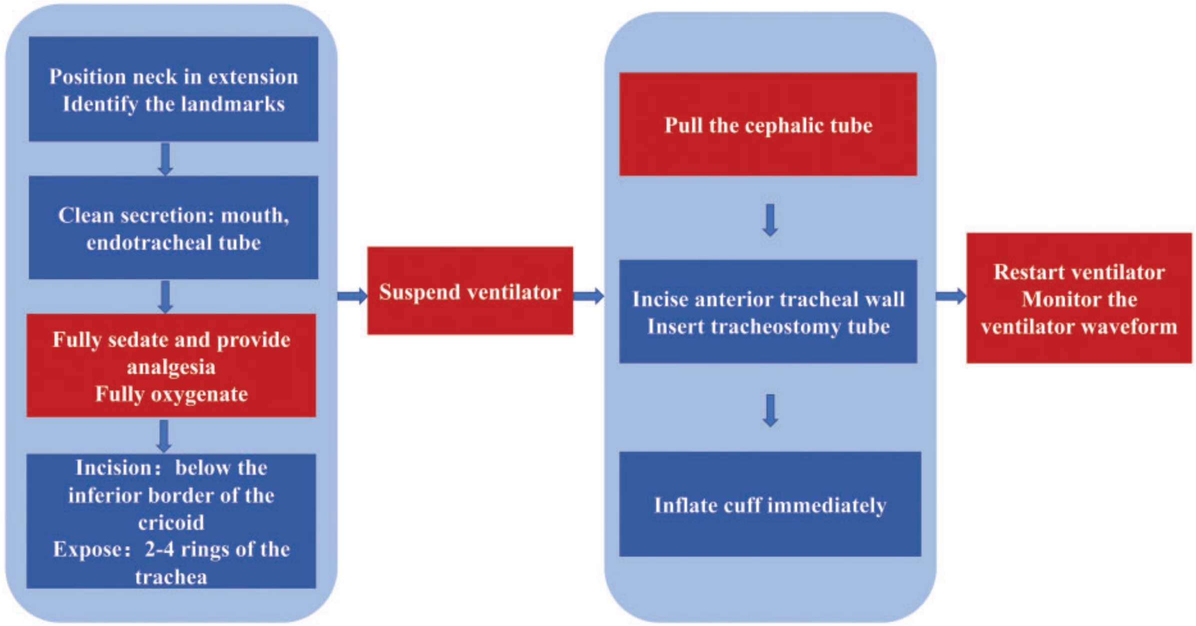

Figure 2: Illustration of the steps for a safe tracheostomy in coronavirus disease 2019-positive patients. Blue steps are performed by an otolaryngologist. Red steps are performed by the anaesthetist.

Table 1: Clinical characteristics of 14 critically ill patients with COVID-19 who underwent a bedside tracheostomy in the ICU in Wuhan

No.	Age/sex	Diagnosis date	Intubation date	Tracheotomy date	I-T interval (days)	Past medical history	Lung infection	Prognosis
1	74/F	D13	D31	D58	27	HTN		Died on D71 due to respiratory failure
2	69/M	D13	D24	D48	24	HTN, T2DM, CI	MDR-PAE	Off ventilator
3	55/F	D3	D24	D50	26	CHD	PAE, MDR-ABA	IMV
4	65/F	D9	D12	D33	21	HTN, T2DM, CHD	MDR-ABA	Off ventilator
5	69/M	D9	D25	D57	32	CHD	MDR-ABA, MDR-PAE	Off ventilator
6	70/M	D8	D10	D37	27	R-NPC, CI	MDR-PAE, Candida	Off ventilator
7	67/F	D7	D24	D41	17	HTN, PPR-breast cancer		IMV
8	55/F	D6	D14	D40	26	HTN, obesity	MDR-KPN	Off ventilator
9	80/F	D12	D41	D56	15	HTN	PAE	Died on D50 due to septic shock
10	66/M	D9	D27	D60	33	CHD	PAE	Off ventilator
11	58/F	D0	D37	D70	33	HTN, T2DM	SM	IMV
12	77/M	D28	D65	D90	25	Bradycardia, CPI	Candida	IMV
13	69/M	D7	D10	D42	32	PP-lung cancer, CPI	MDR-ABA, SM	IMV
14	68/F	D12	D25	D38	13	AICH, HTN, T2DM	MDR-ABA, Candida	Off ventilator

ABA: *Acinetobacter baumannii*; AICH: acute intracerebral haemorrhage; CHD: coronary heart disease; CI: cerebral infarction; COVID-19: coronavirus disease 2019; CPI: cardiac pacemaker implantation; Diagnosis date: diagnosis date after disease onset; HTN: hypertension; ICU: intensive care unit; IMV: invasive mechanical ventilation; Intubation date: intubation date after disease onset; I-T Interval: interval from intubation to tracheotomy; KPN: *Klebsiella pneumoniae*; Lung infection: pathogens causing a secondary lung infection; MDR: multidrug-resistant; PAE: *Pseudomonas aeruginosa*; PP-lung cancer: postoperative for lung cancer; PPR-breast cancer: postoperative for breast cancer; R-NPC: radiotherapy for nasopharyngeal carcinoma; SM: *Stenotrophomonas maltophilia*; T2DM: type 2 diabetes mellitus; Tracheotomy date: tracheotomy date after disease onset.

precautions were implemented to protect medical staff from SARS-CoV-2 infection.

COVID-19 displays viral exuding inflammation with alveolar damage in the early stage [2, 6]. If the patients exhibit respiratory failure or hypoxaemia with signs of severe pulmonary infection, international experts recommend that immediate intubation with mechanical ventilation in the prone position to correct acute respiratory distress syndrome [7–9]. With the progression of the disease, critically ill patients may develop secondary bacterial or fungal infections and the retention of secretions that obstruct the small airways. In our study, 85.71% of patients (12/14) had combined secondary pulmonary infections, including bacterial and fungal infections, which led to increased respiratory secretions and thick sputum. Moreover, many patients are unable to tolerate prolonged orotracheal intubation, which potentially renders the cannula prone to obstruction by secretions and necrosis of the mucosa of the mouth and trachea, even resulting in tracheomalacia and tracheal stenosis. In contrast, tracheotomy may allow the patients to become more comfortable and increase the safety of airway management, including the administration of fewer sedative agent doses, easier secretion suction and drainage and faster recovery of spontaneous breathing. Therefore, tracheotomy does not bring more benefits to patients than orotracheal intubation in the early stage.

The detection of antibodies against SARS-CoV-2 reflects the course of the disease to some extent. It is recommended as an effective supplementary indicator for suspected cases with negative viral RNA detection or in conjunction with RNA detection for disease diagnosis. A retrospective analysis from China revealed that the RNA test for sputum specimens had the highest detectability rate (92.3%), followed by throat swabs (69.2%). Antibody detection showed lower positive rates (IgM, 23.0% and IgG, 53.8%) in the early phase of the disease (<8 days). However, the sensitivity of antibody detection exceeded the RNA test beginning on day 8 after onset (IgM, 50.0% and IgG, 87.5%). In the late phase (≥15 days), the sensitivity of IgM and IgG tests increased to 52.2% and 91.3%, respectively, while the positive rate of throat swabs was only 13.0% [10]. In our unit, the minimal interval between the infection and tracheotomy was 33 days, and the interval between intubation and tracheotomy was ∼2–4 weeks. All patients were in the late phase of COVID-19 infection (≥15 days). During this phase, viral RNA detection (otolaryngeal swabs, endotracheal secretions and operative incisions) was negative, IgG was detected at a 100% positive rate and IgM was only detected at low positive rates.

We recommend indications for surgical tracheotomy in critically ill patients with COVID-19, including (i) mechanical ventilation during a prolonged intubation time (more than 2 weeks) and a long intubation time expected (more than 2 weeks), (ii) intolerance to orotracheal intubation and (iii) combined secondary infection with other pathogens or increasing amounts of secretion discharge.

Because tracheotomy is one of the highest risk procedures during the treatment of COVID-19, medical staff must be appropriately protected from infection when performing this procedure. To date, evidence-based guidelines on the use of PPE are not available. The basic principle of covering should be multilayer donning and doffing to minimize the possibility of contamination. In our practice, medical staff should wear level 3 PPE equipment during the procedure. As the inner layer, we wear surgical scrubs or a work uniform, 1 KN95 (China), N95 (USA) or FFP2 (Europe) medical protective mask, coverall suit, shoe cover and surgical latex gloves (Fig. 1A). As the outer layer, we wear another surgical mask outside, surgical s and another layer of shoe covers up to the knees, surgical gown and gloves, then put on a powered positive pressure air-purifying respirator (Fig. 1B and C). If a pressure air-purifying respirator is not available in some hospitals, it can be replaced with a completely enclosed surgical helmet (Fig. 1D). Uncertainty and variable practices regarding PPE remain worldwide, and some countries recommend lower levels of PPE [7, 11–14]. However, evidence of the association between the level of PPE and coronavirus transmission is currently lacking and requires further investigation. Therefore, we used a higher level of PPE to avoid nosocomial infection. Uncertainty exists regarding whether an N95 mask should be worn if a pressure air-purifying respirator is used [7]. We chose to wear the N95 mask to protect us from self-contamination during the doffing of PPE. Recent studies also confirmed that the risk of disease transmission to healthcare workers is very low when a similar level of PPE as described here is used [15, 16].

After being completely equipped in the buffer room as described above, the surgical team, which was composed of 2 otolaryngology surgeons, 1 anaesthetist and 2 nurses, entered the isolated negative pressure ICU room. Other medical staff remained outside to minimize the infection risk. The procedure was performed at the bedside to minimize the risks of spreading the virus and endangering critically ill patients during the process of transporting them to the operating room [17]. The presence of 2 experienced surgeons ensured a fast and effective tracheotomy compared with less experienced surgeons or residents (Fig. 1D). The anaesthetist administered aesthetic agents to prevent swallowing and cough reflexes, control the ventilator and remove the tube after tracheal incision (Fig. 1D) [17]. The critical and most important steps should be performed by the anaesthetist and the otolaryngologist in skilled cooperation [18]. The anaesthetist stops the ventilator and deflates the cuff, and the surgeon opens the anterior wall of the trachea and quickly inserts the tube. The cuff is then inflated immediately and the lack of leakage is confirmed by the anaesthetist. A scrub nurse and an assistant nurse should handle the surgical table and assist the anaesthetist. In addition to the necessary surgical instruments, a non-fenestrated cuffed tracheotomy tube of the expected diameter should be prepared on the surgical table. After the tracheotomy, reusable medical devices should be disinfected according to the disinfection procedures for SARS-CoV-2, and all surfaces of objects should be wiped with a disinfectant containing 1000 mg/l active chlorine.

Table 2: Results of PCR analyses of otolaryngeal swabs and serum IgM and IgG antibody titres

No.	Tracheotomy date	Swab	Antibody type	Level (AU/ml)	
1	D58	D54 Neg	IgM	2.33	–
			IgG	17.79	↑
2	D48	D48 Neg	IgM	29.04	↑
			IgG	97.07	↑↑
3	D50	D53 Neg	IgM	0.33	–
			IgG	20.78	↑
4	D33	D33 Neg	IgM	1.51	–
			IgG	117.7	↑↑↑
5	D57	D57 Neg	IgM	4.57	–
			IgG	96.97	↑↑
6	D37	D39 Neg	IgM	6.27	–
			IgG	79.48	↑↑
7	D41	D39 Neg	IgM	20.69	↑↑
			IgG	389.66	↑↑↑
8	D40	D40 Neg	IgM	45.12	↑
			IgG	220.13	↑↑↑
9	D56	D50 Neg	IgM	2.3	–
			IgG	49.6	↑↑
10	D60	D66 Neg	IgM	17.38	↑
			IgG	101.46	↑↑↑
11	D70	D68 Neg	IgM	0.74	–
			IgG	46.42	↑↑
12	D90	D92 Neg	IgM	2.74	–
			IgG	84.47	↑↑
13	D42	D36 Neg	IgM	5.39	–
			IgG	104.24	↑↑↑
14	D38	D35 Neg	IgM	0.43	–
			IgG	62.62	↑↑

'-': <10 AU/ml (normal range); '↑': ≥10–50 AU/ml; '↑↑': ≥50–100 AU/ml; '↑↑↑': ≥100 AU/ml; Neg: negative; PCR: polymerase chain reaction; Swab: date of the PCR test and result of oropharyngeal swab after disease onset; Tracheotomy date: tracheotomy date after disease onset.

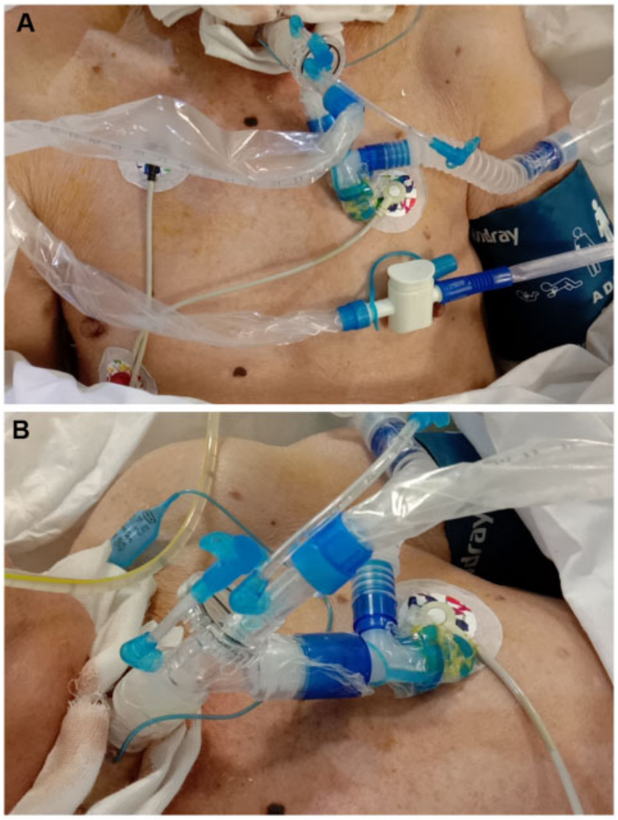

Figure 3: Completely enclosed sputum aspirator. (**A**) Anterior view. (**B**) Lateral view.

The nurses providing care to patients after tracheotomy also face an exposure risk. We chose a completely closed sputum aspirator to prevent the airway from directly opening and generating droplets and aerosol contamination, which will promote virus spread (Fig. 3). In addition, the breathing circuit should be maintained in the closed position during mechanical ventilation, and virus filters are inserted in both the inhalation and expiration ends. If no obvious contamination is detected, the breathing circuit does not need to be replaced routinely. In terms of airway protection, the cuff pressure should be maintained at 25–30 cmH_2O (1 cmH_2O = 0.098 kPa), and it should be monitored every 6–8 h after the artificial airway (orotracheal intubation or tracheotomy) is established. We recommend that cannula management should be performed by trained nursing staff [19]. With this range of cuff pressures, we are able to ensure effective ventilation, reduce air leakage contamination caused by inadequate cuff sealing and avoid airway mucosal compression injury caused by the overinflation of intubation cuffs [20]. Because airborne transmission is presumed to occur when respiratory particles <5 µm in diameter are inhaled and deposited in the lungs [21], we recommend that patients with COVID-19 avoid unnecessary inhalation therapy as much as possible for airway humidification. The results of aerosol aerodynamic transmission studies of influenza virus (another airborne RNA virus) showed that 65% of the influenza RNA was contained in particles ≤4 µm in aerodynamic diameter (23% in particles 1–4 µm and 42% in particles <1 µm), indicating that most of the viral RNA is contained within particles in the respirable size range and the airborne route may be a transmission pathway [22]. Although the drug aerosol diffused during airway humidification has a lower risk of spreading the disease than the aerosol particles discharged from the patient, the aerosol generated during atomization may still carry the virus expelled in the patient's exhaled air. Therefore, unnecessary inhalation therapy should be avoided during the pandemic. Regarding ventilation in the prone position, 1 staff member should stand at the head of the bed, handle the tracheal intubation, and place the U-shaped pillow cushion on the pressure side to prevent the tracheal tube from being compressed. Changes in the waveform, tidal volume and minute ventilation volume must be monitored, and an arterial blood gas analysis could be performed if necessary. Patients who have undergone a tracheotomy may need to retain the cannula for a period of time after being weaned from mechanical ventilation, and thus we recommend the use of a filter to provide airway warming and humidity. The dressing of the wound should be changed daily to prevent infection, and the tightness of neck fixation should be monitored routinely.

Due to the recent COVID-19 pandemic, several studies on tracheotomy management in patients with COVID-19 have been published [18, 19, 23, 24], with the aim of providing helpful information to minimize the risks of nosocomial transmission. To our knowledge, we are the first group to summarize our own experiences with an open bedside tracheotomy at a centre in the hardest-hit region of China. Compared with open tracheotomy in the operating room, open bedside tracheotomy might reduce potential exposure risks associated with transport between the ICU and operating room. Additionally, we systematically described the procedures for donning PPE in detail, which will allow medical staff to easily follow the instructions. Nursing work, particularly work related to airway humidification and ventilation in the prone position, was also reported. Importantly, our study described and analysed the PCR results for SARS-CoV-2 and serum IgM and IgG antibody titres, which might be valuable for evaluating the infection risks of these invasive procedures and assessing clinicians in determining the indications for and timing of tracheotomy.

CONCLUSIONS

A tracheotomy performed in the late phase of COVID-19 in critically ill patients has a relatively low risk of infection. Proper extension of the intubation time (2–4 weeks) of patients who require invasive mechanical ventilation is acceptable. If the patient shows intolerance to orotracheal intubation or has a secondary lung infection, tracheotomy might represent a safer method to manage the airway and help improve the treatment outcomes. Compared with conventional tracheotomy, the modified tracheotomy procedure should include the use of neuromuscular blockade to completely sedate the patients, along with the suspension of ventilation before opening the airway. Donning adequate personal protection will help medical staff avoid infection.

Conflict of interest: none declared.

Author contributions

Surita Aodeng: Data curation; Project administration; Writing—original draft. **Weiqing Wang:** Data curation; Investigation; Writing—original draft. **Yu Chen:** Project administration; Resources. **Guodong Feng:** Formal analysis; Investigation; Writing—review & editing. **Jian Wang:** Formal analysis; Investigation; Writing—review & editing. **Wei Lv:** Formal analysis;

Investigation; Writing—review & editing. **Hua Yang:** Formal analysis; Investigation; Writing—review & editing. **Xin Ding:** Project administration. **Kaicheng Song:** Project administration. **Sirui Zhao:** Project administration. **Jiazhen Liu:** Project administration. **Shuyang Zhang:** Project administration; Supervision; Writing—review & editing. **Zhiqiang Gao:** Project administration; Supervision; Writing—review & editing.

Reviewer information

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REFERENCES

[1] World Health Organization (WHO). Coronavirus Disease (COVID-19) Pandemic. 2020. https://www.who.int/emergencies/diseases/novel-coronavirus-2019 (26 April 2020, date last accessed).
[2] Wu Z, McGoogan JM. Characteristics of and important lessons from the coronavirus disease 2019 (COVID-19) outbreak in china: summary of a report of 72314 cases from the Chinese Center for Disease Control and Prevention. JAMA 2020;323:1239.
[3] Istituto Superiore di Sanitaà (ISS). Integrated Surveillance of COVID-19 in Italy. 2020. https://www.epicentro.iss.it/coronavirus/bollettino/Infografica_28marzo ENG.pdf (26 April 2020, date last accessed).
[4] Adly A, Youssef TA, El-Begermy MM, Younis HM. Timing of tracheostomy in patients with prolonged endotracheal intubation: a systematic review. Eur Arch Otorhinolaryngol 2018;275:679–90.
[5] Tran K, Cimon K, Severn M, Pessoa-Silva CL, Conly J. Aerosol generating procedures and risk of transmission of acute respiratory infections to healthcare workers: a systematic review. PLoS One 2012;7:e35797.
[6] Huang C, Wang Y, Li X, Ren L, Zhao J, Hu Y *et al.* Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. Lancet 2020;395:497–506.
[7] Yao W, Wang T, Jiang B, Gao F, Wang L, Zheng H *et al.* Emergency tracheal intubation in 202 patients with COVID-19 in Wuhan, China: lessons learnt and international expert recommendations. Br J Anaesth 2020;125:e28–37.
[8] Alhazzani W, Moller MH, Arabi YM, Loeb M, Gong MN, Fan E *et al.* Surviving sepsis campaign: guidelines on the management of critically ill adults with coronavirus disease 2019 (COVID-19). Crit Care Med 2020;48:e440–69.
[9] Bajwa AA, Arasi L, Canabal JM, Kramer DJ. Automated prone positioning and axial rotation in critically ill, nontrauma patients with acute respiratory distress syndrome (ARDS). J Intensive Care Med 2010;25:121–5.
[10] Gao Y, Yuan Y, Li T, Wang X, Li X, Li A *et al.* Evaluation of the auxiliary diagnostic value of antibody assays for the detection of novel coronavirus (SARS-CoV-2). J Med Virol 2020; 10.1002/jmv.25919.
[11] The First Affiliated Hospital, Zhejiang University School of Medicine. Handbook of COVID-19 Prevention and Treatment. 2020. https://gmcc.alibabadoctor.com/prevention (26 April 2020, date last accessed).
[12] European Centre for Disease Prevention and Control. Infection Prevention and Control for COVID-19 in Healthcare Settings. 2020. https://www.ecdc.europa.eu/sites/default/files/documents/COVID-19-infection-preventionand-control-healthcare-settings-march-2020.pdf (26 April 2020, date last accessed).
[13] World Health Organization. Clinical Management of Severe Acute Respiratory Infection When Novel Coronavirus (nCoV) Infection Is Suspected: Interim Guidance. 2020. https://www.who.int/publications-detail/clinical-management-of-severe-acute-respiratoryinfection-when-novel-coronavirus-(ncov)-infection-is-suspected (26 April 2020, date last accessed).
[14] Public Health England. COVID-19: Infection Prevention and Control. 2020. https://www.gov.uk/government/publications/wuhannovel-coronavirus-infection-prevention-and-control (13 March 2020, date last accessed).
[15] Meng L, Qiu H, Wan L, Ai Y, Xue Z, Guo Q *et al.* Intubation and ventilation amid the COVID-19 outbreak: Wuhan's experience. Anesthesiology 2020;132:1317–32.
[16] Chen X, Liu Y, Gong Y, Guo X, Zuo M, Li J *et al.* Perioperative management of patients infected with the novel coronavirus: recommendation from the Joint Task Force of the Chinese Society of Anesthesiology and the Chinese Association of Anesthesiologists. Anesthesiology 2020;132:1307–16.
[17] Tay JK, Khoo ML, Loh WS. Surgical considerations for tracheostomy during the COVID-19 pandemic: lessons learned from the severe acute respiratory syndrome outbreak. JAMA Otolaryngol Head Neck Surg 2020; doi: 10.1001/jamaoto.2020.0764.
[18] Broderick D, Kyzas P, Sanders K, Sawyerr A, Katre C, Vassiliou L. Surgical tracheostomies in Covid-19 patients: important considerations and the "5Ts" of safety. Br J Oral Maxillofac Surg 2020;58:585–9.
[19] Pichi B, Mazzola F, Bonsembiante A, Petruzzi G, Zocchi J, Moretto S *et al.* CORONA-steps for tracheotomy in COVID-19 patients: a staff-safe method for airway management. Oral Oncol 2020;105:104682.
[20] Respiratory Care Committee of Chinese Thoracic Society. Expert consensus on preventing nosocomial transmission during respiratory care for critically ill patients infected by 2019 novel coronavirus pneumonia. Zhonghua Jie He He Hu Xi Za Zhi 2020;43:288–96.
[21] Wilson NM, Norton A, Young FP, Collins DW. Airborne transmission of severe acute respiratory syndrome coronavirus-2 to healthcare workers: a narrative review. Anaesthesia 2020;75:1086–95.
[22] Lindsley WG, Blachere FM, Thewlis RE, Vishnu A, Davis KA, Palmer JE *et al.* Measurements of airborne influenza virus in aerosol particles from human coughs. PLoS One 2010;5:e15100.
[23] Prabhakaran K, Malcom R, Choi J, Chudner A, Moscatello A, Panzica P *et al.* Open tracheotomy for COVID 19 positive patients: a method to minimize aerosolization and reduce risk of exposure. J Trauma Acute Care Surg 2020;89:265–71.
[24] Turri-Zanoni M, Battaglia P, Czaczkes C, Pelosi P, Castelnuovo P, Cabrini L. Elective tracheostomy during mechanical ventilation in patients affected by COVID-19: preliminary case series from Lombardy, Italy. Otolaryngol Head Neck Surg 2020;163:135–7.