Am J Transl Res 2020;12(10):6655-6664
www.ajtr.org /ISSN:1943-8141/AJTR0113898

Original Article

Clinical experience with emergency endotracheal intubation in COVID-19 patients in the intensive care units: a single-centered, retrospective, descriptive study

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Received May 6, 2020; Accepted October 8, 2020; Epub October 15, 2020; Published October 30, 2020

Abstract: Few studies have reported the implications of performing endotracheal intubation for critically ill COVID-19 patients admitted to intensive care units (ICUs). Therefore, this study aimed to summarize the outcomes of COVID-19 patients in the ICU following endotracheal intubation and provide a clinical reference for the high-risk procedure. From February 1 to February 18, 2020, we enrolled 59 critically ill COVID-19 patients who received emergency endotracheal intubation in the ICUs of Tongji Hospital. We recorded demographic information, laboratory parameters, comorbidities, changes in vital signs pre- and post-intubation, the airway grade, intubation success rate using three types of laryngoscopes, and the experience of intubators. Follow-up evaluations were performed for all proceduralists to monitor nosocomial infections. The majority of the patients requiring intubation were elderly and had at least one comorbidity. Of the patients, 86.4% developed hypoxia before intubation. The first and second attempts of successful endotracheal intubation with the Macintosh laryngoscope (70.0% and 83.3%), Airtraq videolaryngoscope (93.5% and 80%), and UE videolaryngoscope (88.9% and 100%) were performed. Notably, SpO_2 <93% and hypotension were observed 3 min after intubation in 32.2% and 39% patients, respectively. With the proper use of personal protective equipment (PPE), no nosocomial infections were observed among proceduralists. Full PPE increased the occurrence of fogging on goggles and myopia glasses. Overall, a higher success rate of intubation was achieved by senior intubators using a videolaryngoscope. Although inconvenient, appropriate ensembles of PPE could prevent nosocomial infections.

Keywords: COVID-19, pneumonia, acute respiratory distress syndrome, critically ill, airway management, endotracheal intubation, videolaryngoscope

Introduction

In December 2019, a local outbreak of a novel coronavirus, now known as severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), first occurred in Wuhan City, Hubei Province of China, and eventually caused the ongoing global pandemic [1, 2]. The highly infectious respiratory disease caused by SARS-CoV-2 has been termed coronavirus disease 2019 (COVID-19) by the World Health Organization (WHO) [3]. As of August 20, the cumulative number of confirmed COVID-19 cases was over 22 million globally and remains on the rapid increase.

Angiotensin converting enzyme 2 (ACE2), widely detected in the airway and type II pneumocytes in the lungs, has been deemed as the target for SARS-CoV-2 attack and thus the cause of COVID-19 [4]. The fundamental pathophysiology of severe viral pneumonia is severe acute respiratory distress syndrome (ARDS) [5]. Recently, 17% of COVID-19 patients developed ARDS [6]. To date, there are no specific preventative measures or treatment for COVID-19. However, the supportive therapy for infection prevention is recommended to relieve symptoms and hypoxic injury to vital organs [7, 8]. A previous report showed that, overall, 2.3% to 8% of the patients required tracheal intubation and invasive mechanical ventilation [9, 10]. However, 71% to 88% of the critical COVID-19 patients required invasive mechanical ventilation, according to previous studies [10, 11].

Considering that critical COVID-19 patients accounted for 5% of infected patients overall [12] and the increasing number of infected patients globally, health care personnel are vulnerable to several risks during endotracheal intubation.

Previous retrospective analyses have demonstrated that early mechanical ventilation for critically ill patients is beneficial in improving the prognosis and survival of the patients [5, 13]. Although a series of consensus guidelines for endotracheal intubation of COVID-19 patients have been issued, limited studies have reported the indications of performing endotracheal intubation for critically ill COVID-19 patients admitted to intensive care units (ICUs). Therefore, this study aimed to summarize the outcomes of endotracheal intubation for patients with severe COVID-19 in ICUs and provide a clinical reference for the high-risk procedure.

Methods

Ethics approval and consent to participate

The present study was approved by the Institutional Review Board of Tongji Hospital of Tongji Medical College of Huazhong University of Science and Technology (TJIRB-C20200346) and was also registered at the Chinese Clinical Trial Registry (ChiCTR2000031439). The requirement for informed consent was waived by the Ethics Commission due to the rapid emergence of this infectious disease.

Study design and participants

All patients were informed of the necessity and possible complications of endotracheal intubation, and informed consent was obtained from the patients' family members by telephone. Tongji Hospital was officially designated as a hospital for the treatment and surgical care of critically ill COVID-19 patients during late January 2020. As of February 18, 2020, 59 patients were enrolled in the present study. The diagnostic criteria and classification of COVID-19 were according to the WHO interim guidance [14].

In this study, the clinical data and personal protection characteristics related to endotracheal intubation for these 59 patients were retrospectively compiled. These data were analyzed to provide a clinical reference for the management of critically ill COVID-19 patients requiring endotracheal intubations.

Personal protective equipment (PPE) of proceduralists and detailed procedures of endotracheal intubation

Full PPE was used by all personnel performing the intubation including assistants involved in the peri-intubation procedure. Full PPE included a respirator (N95 or equivalent, inside), a surgical mask (outside), a pair of goggles, a face shield, a full hood, and a protective suit. To facilitate the wearing and removal of gloves, a layer of transparent polyethylene gloves was worn under sterile gloves, and a layer of ordinary gloves was then added during the endotracheal intubation procedure. After the completion of intubation, the gloves were immediately discarded and replaced with ordinary gloves.

The endotracheal intubation tools included a single-use Macintosh direct laryngoscope (Zhejiang Sujia Medical Device Co., Ltd., China), Airtraq videolaryngoscope (Prodol Meditec Ltd., China), and UE videolaryngoscope (Zhejiang Lingyang Medical Apparatus Co., Ltd., China). These are intubation tools commonly used during routine intubation procedures requiring anesthesia for the patient. From February 1 to February 4, 2020, the ICU was only equipped with single-use Macintosh direct laryngoscopes and Airtraq videolaryngoscopes as there was a shortage of UE videolaryngoscope in Wuhan. Subsequently, UE videolaryngoscopes were then made available for the ICU from February 5 onwards. The intubators (anesthesiologists or physicians) were free to select their intubation tools based on tool allocation and their personal preference.

Pre-intubation induction protocol

A modified rapid sequential induction (mRSI) protocol was adopted in the present study [15]. An appropriate dose of propofol (0.5-1.5 mg/kg) or etomidate (0.1-0.2 mg/kg) was administered by titration until the loss of consciousness. This was followed by the bolus administration of rocuronium (1 mg/kg) and sufentanil (0.2-0.5 μg/kg).

Endotracheal intubation process

Approximately 60 s after drug administration and once the cessation of spontaneous breath-

ing of the patient was confirmed, the position of the patient for intubation was adopted and the patient's mask was swiftly removed. The laryngoscope was then positioned for a direct view of the glottis, and the endotracheal tube was inserted to complete the endotracheal intubation process. For patients with a full stomach, cricoid force by an assistant was used after sedation to prevent regurgitation and aspiration. If positive pressure ventilation was required, the maximal pressure of the ventilator was set at ≤12 cm H_2O [16]. For all patients, intubation preparations were performed in accordance with the procedures for difficult airway management [17]. Supraglottic airway devices and equipment for emergency access to the front-of-neck were made available at the bedside, and an emergency airway management team was on standby. Each endotracheal intubation was performed by an experienced anesthesiologists. Drug administration, observation of the monitoring devices, and assistance during the intubation process were performed by an assistant. Intubation failure was defined as three consecutive failed intubation attempts using the same intubation apparatus followed by successful intubation using a different type of intubation apparatus. Regardless of whether the peripheral oxygen saturation (SpO_2) level was maintained, following a second failed intubation attempt, the emergency airway management team intervened to provide a rapid decision on whether a third intubation attempt should be made.

Data collection

A team of experienced physicians reviewed and analyzed the electronic medical records and nursing records. Two physicians independently reviewed the data collection forms. The information regarding demographics, medical history, underlying comorbidities, symptoms, signs, laboratory parameters, and clinical oxygenation therapy was extracted and collected. In addition, vital signs of the patients before and after intubation (SpO_2 [%], heart rate [HR, bpm]), mean arterial pressure (MAP, mmHg), Cormack-Lehane grades with the use of different intubation tools, and number of successful first-, second-, and third-pass intubation attempts and failed intubation attempts were recorded.

Statistical analysis

Continuous and categorical variables were presented as median (interquartile range [IQR]) and n (%), respectively. Non-parametric tests including the Mann-Whitney U test or χ^2 test were used to compare differences between variables where appropriate. A two-sided α of less than 0.05 was considered statistically significant. Statistical analyses were done using the SPSS software (version 22).

Results

Clinical characteristics

A total of 59 critically ill COVID-19 patients (37 [62.7%] men and 22 [37.3%] women) who underwent endotracheal intubation at ICUs between February 1 and February 18, 2020, were included in the present study. The median age was 74 (range, 54-81) years, and 42 (71.2%) patients were over 65 years old. Forty-seven (79.7%) patients had a comorbidity, with hypertension being the most common (24 [40.7%]), followed by diabetes (12 [20.3%]) and coronary heart disease (10 [16.9%]).

Common abnormalities following laboratory tests included lower lymphocyte counts, lower albumin levels, higher procalcitonin and D-dimer levels, and longer prothrombin time (PT) as shown in **Table 1**. In addition, following laboratory tests, organ injuries included acute kidney injury, acute cardiac injury, and coagulopathy. Overall, 53 (89%) patients received chest computed tomography (CT) scanning. Results from the scans showed bilateral pulmonary infiltration (10 [18.9%]) and CT manifestation of COVID-19 as ground-glass opacity (24 [45.3%]) and manifested as consolidation (19 [35.8%]) (**Table 1**). Due to the limited healthcare resources during the early epidemic of COVID-19 in Wuhan, these data indicated that the lung injury was already severe when patients were admitted to the ICU.

Before intubation, 55 (93.2%) and 4 (6.7%) patients required non-invasive mechanical ventilation and received high-flow nasal oxygenation therapy, respectively. Four (6.8%) patients had a full stomach. Eight (13.6%) and 18 (30.5%) patients were sedated and in a coma, respectively.

Table 1. Demographics and clinical characteristics of patients infected with COVID-19 (n=59)

Patients characteristics	
Age (years)*	74 (54-81)
<65 years old	17/59 (28.8%)
≥65 years old	42/59 (71.2%)
Gender	
Male	37/59 (62.7%)
Female	22/59 (37.3%)
Comorbidities	47/59 (79.7%)
Hypertension	24/59 (40.7%)
Diabetes	12/59 (20.3%)
Coronary heart disease	10/59 (16.9%)
Laboratory findings	
WBC count, × 10^9/L	8.2 (5.0-12.3)
>10	18/59 (30.1%)
Hemoglobin, g/L	123.0 (114.6-141.5%)
<110	31/59 (52.5%)
Platelet count, × 10^9/L	154.0 (104.3-200.4)
<100	12/59 (20.3%)
Lymphocyte count, × 10^9/L	0.6 (0.4-0.9)
>0.8	11/59 (18.6%)
0.5-0.8	20/59 (33.5%)
<0.5	28/59 (47.5%)
Albumin, g/L	31.5 (28.2-34.9)
<35	46/59 (78.0%)
ALT, U/L	51.0 (13.1-84.2)
>50	45/59 (69.5%)
AST, U/L	41.0 (17.5-65.5)
>50	38/59 (64.4%)
Total bilirubin, μmol/L	16.6 (11.0-22.5)
>20	20/59 (33.9%)
Direct bilirubin, μmol/L	6.2 (4.3-9.1)
>6	29/59 (49.2%)
Indirect bilirubin, μmol/L	11.4 (8.8-18.0)
>20	9/59 (15.3%)
BUN, mmol/L	8.3 (6.0-11.6)
>8.2	32/59 (54.2%)
Creatinine, μmol/L	68.7 (71.2-128.5)
>120	22/59 (37.3%)
CK, U/L	145.0 (58.5-228.5)
>190	11/59 (28.2%)
CK-MB, U/L	21.0 (15.0-52.5)
>25	17/59 (43.6%)
Troponin I, ng/mL	0.4 (0.0-0.7)
>0.5	35/59 (59.3%)
Procalcitonin, ng/mL	0.4 (0.2-1.9)
>0.1	56/59 (94.9%)
PT, seconds	12.5 (11.9-13.5)
>12	34/59 (57.6%)

Intubation success rate with different intubation tools

Grade I-II glottic exposure for the intubations were achieved with the Macintosh laryngoscope (60.0%), Airtraq videolaryngoscope (83.3%), and UE videolaryngoscope (93.5%). All 59 patients received orotracheal intubation. Unexpected difficult airways were encountered in five patients (8.5%). Successful first-attempt intubation with the Macintosh laryngoscope, Airtraq videolaryngoscope, and UE videolaryngoscope were achieved for 9, 16, and 31 patients, respectively. In addition, there was one case of intubation success using the Airtraq videolaryngoscope following intubation failure by the Macintosh laryngoscope and two cases of failed intubation with Airtraq videolaryngoscope but success with the Macintosh laryngoscope and UE videolaryngoscope, respectively.

The proportions of successful intubation procedures using the Macintosh laryngoscope, Airtraq videolaryngoscope, and UE videolaryngoscope were 70.0%, 83.3%, and 93.5% of first attempts, respectively, and 80.0%, 88.9%, and 100% of second attempts, respectively (**Table 2**).

Vital signs of patients before and after intubation

Before intubation, the median SpO_2 of the 59 critically ill COVID-19 patients was 85% (IQR, 76-98%), and the proportions of patients with SpO_2 ≤93% and HR of ≥120 bpm were 86.4% and 64.4%, respectively. After intubation, the median SpO_2 was 92% (IQR, 82-97%), and the proportions of patients with SpO_2 of >93% and HR of ≥120 bpm decreased to 67.8% and 47.5%, respectively. As arterial blood gases had only been recorded for a limited number of patients, the SpO_2 instead of partial pressure of oxygen was used to estimate the ARDS. The proportions of patients who experienced hypotension and received vasoactive agents to maintain hemodynamic stability before and after intubation were 16.9% and 39%, respectively, (as shown in **Table 3**).

APTT, seconds	32.1 (23.4-37.5)
>42	3/59 (5.1%)
D-dimer, ng/mL	621.3 (245.1-3340.3)
>243	34/59 (57.6%)
FDP, μg/ml	6.5 (2.7-32.6)
Imaging features of chest CT scanning	
Ground-glass opacity	10/53 (18.9%)
Bilateral pulmonary infiltration	24/53 (45.3%)
Consolidation	19/53 (35.8%)
Organ injury	
Acute cardiac injury	35 (59.3%)
Acute kidney injury	22 (37.3%)
Coagulopathy	34 (57.6%)
ARDS	59 (100%)
Full stomach	4 (6.8%)
Mental state	
Sedation	8 (13.6%)
Coma	18 (30.5%)
Oxygen therapy	
Bi-pap ventilation	55 (93.2%)
High-flow oxygen therapy	4 (6.8%)

*Presented as median (IQR). COVID-19, Coronavirus disease 2019; WBC, white blood cell; ALT, alanine aminotransferase; APTT, activated partial thromboplastin time; AST, aspartate aminotransferase; BUN, blood urea nitrogen; CK, creatine kinase; CK-MB, creatine kinase MB; FDP, fibrinogen degradation products; PT, prothrombin time.

The practicing experience and nosocomial infections of proceduralists involved in intubation of patients

All intubation procedures were performed by the healthcare personnel wearing full PPE. After each intubation, the disposal of medical waste and doffing PPE were carried out in strict accordance with relevant guidelines for the prevention and control of COVID-19 infections. As of April 20, 2020, the nine proceduralists who performed the endotracheal intubations for the 59 patients were followed up, and no sign or symptom of COVID-19, positive SARS-CoV-2 detection, or classical changes of viral pneumonia in chest CT scans were observed (**Table 4**).

Discussion

Owing to the COVID-19 epidemic and relatively limited medical resources at the beginning of the epidemic, several challenges were experienced by healthcare personnel. Firstly, SARS-CoV-2 infection was prevalent among older patients with an increased number of comorbidities such as coronary heart disease, hypertension, and diabetes, and the infection generally developed into critical COVID-19 [6, 12, 20]. Secondly, the elderly patients were more likely to have multiple organ failure, as a result of ARDS, sepsis, acute kidney injury, acute cardiac injury, and acute liver injury [10, 11, 18, 19, 21]. Thirdly, a difficulty lies in precisely evaluating and assessing the airway of a patient before emergency intubation [16, 22, 23]. Lastly, although the mechanism of COVID-19 transmission during aerosol-generating procedures is unknown, performing endotracheal intubation is of high-risk nosocomial infection to the intubators [24, 25]. However, although full PPE reduced the risk of infection, difficulties and inconveniences were reported by numerous health care workers required to perform intubation and auscultation by stethoscope procedures [15, 25].

In the present study, patients diagnosed with COVID-19 that required invasive mechanical ventilation were predominantly male, older, and had more comorbidities including hypertension, cardiovascular disease, and diabetes. Consequently, hypoxia and hypotension frequently occurred, peri-intubation and during treatment decisions, thus appropriate precautionary measures should thus be considered. Following the mRSI protocol, the highest percentage of successful first-attempt intubations was with video laryngoscopy. In addition, the experienced intubators (anesthesiologists or physicians) had higher first-attempt success rates. With the appropriate PPE, no cases of nosocomial infections were reported for the physicians and assisting staff in the hospital. However, the PPE reduced the convenience to perform the necessary procedures and physicians' vision owing to the fogging of goggles. This problem may be addressed by using anti-fogging solutions including commercially available gels and sprays.

ACE2, widely attached to cells in the lungs and cardiovascular system, has recently been confirmed as the SARS-CoV-2 internalization receptor causing COVID-19 [27]. SARS-CoV-2-induced down-regulation of ACE2 compromises its function, diminishes its anti-inflammatory role, and

Table 2. Airway management of patients with COVID-19 (n [%])

Observation index	Macintosh laryngoscope	Airtraq videolaryngoscope	UE videolaryngoscope	Total
Number of cases	10	18	31	59
Unexpected difficult airway	2 (20.0%)	2 (11.1%)	1 (3.2%)	5 (8.5%)
Cormark-Lehane grade				
I-II	6 (60.0%)	15 (83.3%)	29 (93.5%)	50 (84.7%)
III-IV	4 (40.0%)	3 (16.7%)	2 (6.5%)	9 (15.3%)
Results of intubation				
Successful intubation at the first attempt	7 (70.0)	15 (83.3)	29 (93.5)	51 (86.4)
First-attempt intubation success	7 (70.0%)	15 (83.3%)	29 (93.5%)	51 (86.4%)
Second attempt cumulative intubation success	8 (80.0%)	16 (88.9%)	31 (100%)	58 (93.2%)
Third attempt cumulative intubation success	9 (90.0%)	16 (88.9%)	31 (100%)	59 (94.9%)
Replacement of intubation tools	1 (1/10, 10.0%)	2 (2/18, 11.1%)	0 (0/31, 0%)	3 (3/59, 5.1%)

Table 3. Physical status during the oxygen therapy of critical COVID-19 patients (n=59)

Vital signs	Before intubation	After intubation
SpO_2 (%)*	85 (76-98)	92 (82-97)
≤93%	51 (51/59, 86.4%)	19 (19/59, 32.2%)
>93%	8 (8/59, 13.6%)	40 (40/59, 67.8%)
SpO_2/FiO_2 ratio*	87.1 (76.1-120.4)	110.4 (83.2-200.5)
HR ≥120, beats per minute	38 (64.4%)	28 (47.5%)
MAP ≥65, mmHg	49 (83.1%)	36 (61.0%)
MAP <65, mmHg	10 (16.9%)	23 (39.0%)
Vasopressor used	10 (16.9%)	23 (39.0%)
Airway pressure ≥30 cm H_2O	/	47 (79.7%)

*presented as median (interquartile range, IQR). Data shown as n (%). HR, heart rate; MAP, mean arterial pressure.

heightens angiotensin II effects in the predisposed patients [4]. In accordance with previous studies [10, 11, 18, 19], ARDS, sepsis, acute kidney injury, acute cardiac injury, and coagulopathy were observed in the present study. These complications of COVID-19 reduced the reserve of oxygen and vital organ function and increased the risk of endotracheal intubation failure.

Airway assessment is key in determining the intubation method and tools to be used in the endotracheal intubation process [17, 28]. When performing intubation on critically ill patients, intubators (anesthesiologists or physicians) may not be able to precisely evaluate the airways. This is mainly due to two reasons: (1) patients were extremely hypoxic and thus required immediate emergency intubation and (2) patients may be sedated or unconscious, resulting in the inability to communicate or cooperate for an airway assessment. Therefore, the assessment can only be empirically performed through the comprehensive consideration of the medical history and facial appearance of the patient.

The progress of COVID-19 from moderate to severe or critical was usually precipitous. Therefore, fasting was not performed among most of the patients. In the current study, four patients had a full stomach. Non-invasive mechanical ventilation or high-flow oxygen therapy for patients that have not fasted leads to gastric distention, and the administration of other drugs may result in gastric retention. These factors markedly increased the risk of regurgitation and aspiration during the peri-intubation period [29]. To reduce this lethally adverse event, measures were taken as advised by previous guidelines [28], including a head-up position, cricoid force after sedative administration, and following the mRSI protocol.

The mRSI protocol is recommended for intubation of critically ill patients [16, 28]. The mRSI protocol provides advantages such as minimizing peri-intubation stress, improving preoxygenation and oxygen reserves, optimizing intubation conditions, and reducing the incidence of regurgitation and aspiration [15, 17]. Using the mRSI protocol, in the present study, no malignant arrhythmias or cardiac arrests were observed during the peri-intubation period. How-

Table 4. Endotracheal intubation information, PPE ensembles, and nosocomial infections of the proceduralists

Intubators No.	1	2	3	4	5	6	7	8	9
Practicing experience (years)	≥15	≥10	≥10	≥5	≥5	≥5	≥5	≥5	≥5
Full PPE	Y	Y	Y	Y	Y	Y	Y	Y	Y
First-attempt success/total cases	2/2	2/2	6/7	11/13	7/9	6/7	5/6	6/7	5/6
Felt stress after failure	N	Y	N	Y	Y	Y	Y	Y	Y
Inconvenienced by PPE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Foggy myopia glasses or goggles	Y	Y	N	N	Y	Y	Y	Y	Y
Nosocomial infection									
Follow-up days	≥28	≥28	≥28	≥28	≥28	≥28	≥28	≥28	≥28
Infected symptoms	N	N	N	N	N	N	N	N	N
Chest CT scanning	N	N	N	NP	N	N	NP	N	N
SARS-CoV-2 test	N	N	N	N	N	N	N	N	N

Y, indicates yes or positive; N, indicates no or negative; NP, not performed.

ever, 39% of patients experienced post-intubation hypotension and required use of vasopressor. Previous reports have suggested preemptive intravenous infusion of low doses of norepinephrine or the appropriate supplementation of crystalloids to maintain hemodynamic stability and reduce the incidence of adverse events during the peri-intubation period [16].

Of the intubation tools, the videolaryngoscope was the preferred option for endotracheal intubation for critically ill COVID-19 patients [15, 16, 30, 31]. Several advantages have been reported. Firstly, a clear view field is provided, and the inconvenience of fogging of goggles is reduced. Secondly, the glottis is directly viewed during the insertion of the endotracheal tube. Thirdly, a safe distance from the patient can be maintained to avoid the proceduralists' contact with the infected patients. Our results indicated that the first-attempt intubation success rate was only achieved for 70% of the cases using the Macintosh laryngoscope. In contrast, 83.3% and 93.5% of the cases were successful with first-attempt Airtraq videolaryngoscope and UE videolaryngoscope usage, respectively. Critical COVID-19 patients presented symptoms including edema of trachea [32, 33], coagulopathy, and poor oxygen reserves [10, 11, 18, 19], and multiple attempts to intubate were detrimental to the patients as the procedure aggravated tracheal injury, induced bleeding, and severe hypoxia [34]. Therefore, using the videolaryngoscope and limiting the number of attempts to intubate is recommended.

In the operating room, several methods used to check whether the endotracheal tube is in the trachea include auscultation of both lungs by a stethoscope, witnessing the endotracheal tube pass through the glottis, the end-tidal CO_2 waveform (golden standard), and examination with a fiberoptic bronchoscope [17, 28]. However, full PPE decreases the convenience and precision of stethoscope auscultation by healthcare workers. In addition, lung complications of COVID-19 patients and ARDS further reduced the precision of auscultation. With the limited amount of monitoring devices during the pandemic, monitors with end-tidal CO_2 waveform sensors were usually unavailable [25]. In the present study, the tube location was comprehensively determined by the proceduralists directly witnessing the endotracheal tube pass through the glottis, bilateral chest expansion during ventilation, and monitoring of the SpO_2 levels. The use of a portable detector of end-tidal CO_2 with a filter or lung ultrasonography may be a more reliable way to detect the location of the endotracheal tube [35-37].

Due to limited resources and emergent conditions, the procedures including airway assessment, the selection of intubation procedures and tools, and the judgment of tube location, to a large degree, were dependent on the experience of the proceduralists. Consequently, senior experienced intubators are reported to be beneficial in improving the success of endotracheal intubation [15, 16].

Previously, increased viral loads of SARS-CoV-2 were found in the sputum and upper respiratory secretions of patients with COVID-19 [38]. Therefore, endotracheal intubation should be considered as a high-risk procedure for expo-

sure to and transmission of SARS-CoV-2 [16, 24, 39]. Two simulations of endotracheal intubation suggested that the ensemble of full PPE may not totally prevent the exposure of personnel performing endotracheal intubation (intubators and assistants) in emergency department settings. For these studies, a fluorescent marker was used to visualize the deposition of simulated exhaled respiratory secretions and material from the body surfaces of manikins onto health care personnel performing or assisting in endotracheal intubation procedures [39, 40]. Of note, previous studies found that doffing PPE was another high-risk step for nosocomial infection [41, 42]. However, in our study, the donning and doffing of full PPE at our hospital was performed in strict accordance with the Guidelines for the Prevention and Control of COVID-19 Infections in Medical Institutions in China [43].

Limitations

There were several limitations to the present study: (1) As the data used in the present study were obtained from a tertiary hospital in Wuhan, China, during the peak COVID-19 pandemic period, the sample size was relatively small. (2) Data on the incidence of regurgitation and aspiration with the mRSI method as well as the pre- and post-intubation oxygenation index were unavailable. (3) Complications of endotracheal intubation were not statistically analyzed. Further studies are required to address these limitations.

Conclusions

Overall, critically ill COVID-19 patients that required endotracheal intubation were more likely to show comorbidities before SARS-CoV-2 infection and experience complications including multiple organ injury after the virus attack. The use of the videolaryngoscope, experienced intubators, and the mRSI method were important factors associated with the increased first-attempt success of intubation. Although full PPE increased the inconvenience of intubation, it effectively provided adequate protection to the healthcare workers.

Acknowledgements

We would like to thank Editage (www.editage.cn) for English language editing.

Disclosure of conflict of interest

None.

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