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Australasian Emergency Care 24 (2021) 235–239

Contents lists available at ScienceDirect

Australasian Emergency Care

journal homepage: www.elsevier.com/locate/auec

Research paper

Impact of personal protective equipment on prehospital endotracheal intubation performance in simulated manikin

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ARTICLE INFO

Article history:
Received 20 August 2020
Received in revised form
10 November 2020
Accepted 25 November 2020

Keywords:
Goggles
Prehospital healthcare professionals
Prehospital emergency care
Respirator mask
Video laryngoscopy

ABSTRACT

Background: Tracheal intubation in COVID-19 patients is a potentially high-risk procedure for healthcare professionals. Personal protective equipment (PPE) is recommended to minimize contact with critical patients with COVID-19 infection. This study aimed to primarily examine the effect of PPE use on intubation time and success rate among prehospital healthcare professionals; additionally, we compared intubation times among prehospital health care professionals using PPE with direct laryngoscopy and video laryngoscopy assistance.

Methods: In this prospective simulation study, we compared the intubation times and success rates among prehospital healthcare professionals who were or were not using PPE. Furthermore, demographic data, previous intubation experience, and previous intubation experience with PPE were recorded.

Results: Overall time to intubation with PPE use was 51.28 ± 3.89 s, which was significantly higher than that without PPE use (33.03 ± 2.65 s; $p < 0.001$). In addition, the overall success rate with PPE use was 74.4%, which was significantly lower than that without PPE use (93%;$p < 0.001$). PPE use increased the average intubation time by 19.73 ± 2.59 s with direct laryngoscopy and by 16.81 ± 2.86 s with video laryngoscopy ($p < 0.001$).

Conclusions: PPE use is associated with increased intubation time and decreased success rate. Video laryngoscopy assistance in cases where PPE use is required facilitates faster endotracheal intubation than does direct laryngoscopy assistance.

1. Introduction

The 2019 novel coronavirus (COVID-19) outbreak poses a great risk to healthcare professionals. Person-to-person transmission mainly occurs through direct contact and indirectly through contact with contaminated surfaces [1,2]. Tracheal intubation for airway management in COVID-19 patients poses high risk of transmission to healthcare professionals [3].

Ensuring the safety of healthcare professionals necessitates the use of personal protective equipment (PPE) as demonstrated during the Sarin gas attack (1995), SARS epidemic (2003), Ebola epidemic (2014), and finally, COVID-19 outbreak [4–7]. It is recommended to use an enhanced PPE in high-risk procedures such as tracheal intubation [7,8]. PPE use introduces several challenges in conducting critical patient interventions [9,10]. For example, PPE use is known to increase intubation times and lower success rates [9,11].

Prehospital healthcare professionals usually provide emergency care to critical patients for limited periods, in the narrow space confines in an ambulance, or at the patient's residence amidst the patient's relatives. Operating under such confines can hinder PPE use for prehospital healthcare professionals, thereby increasing the risk of transmission. Furthermore, specific challenges of using PPE, such as fogging of goggles, can prevent effective patient care [12]. Video laryngoscopy (VL) has been shown to facilitate improved glottic visualization compared to direct laryngoscopy (DL) [13]. Video laryngoscopy assistance can help prehospital healthcare professionals conduct required interventions appropriately [12].

The primary aim of this study was to examine the effect of PPE use on intubation time and success rate among prehospital healthcare professionals. The secondary aim of the study was to compare the effect of DL or VL assistance in intubation when using PPE.

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https://doi.org/10.1016/j.auec.2020.11.003
2588-994X/

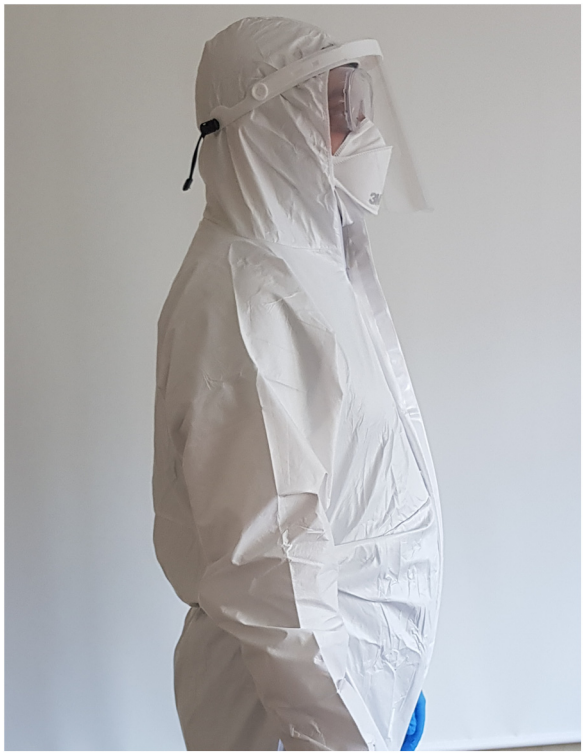

Fig. 1. Participant wearing personal protective equipment.

2. Material and methods

This prospective simulation study was conducted in the training area of an academic hospital that provides tertiary health care services in Aksaray city, in the Central Anatolian region of Turkey. The study complied with the Declaration of Helsinki and was approved by the regional ethical committee (decision number 2020/06-75).

2.1. Study participants

Eligible participants were healthcare professionals (physicians, nurses, and paramedics) who (a) were working at prehospital emergency health services in the city center, (b) would perform tracheal intubation as part of their job responsibilities, (c) were actively engaged as a prehospital healthcare professionals for at least 1 year, (d) had no contraindication to PPE use, e.g., comorbidities that may induce shortness of breath or palpitations, and (e) had used both DL or VL at least once. Participants were invited to the study by contacting the institutions. The participants provided written informed consent and were not paid any compensation.

2.2. Study design

Safety protocols for routine intubation before the pandemic in the study region required using gloves, with enhanced PPE use indicated only for treating patients with known infectious respiratory tract disease. Since the onset of the COVID-19 pandemic, which is primarily transmitted through aerosolization, enhanced PPE use has been mandated [14]. The PPE kit included an isolation coverall (Safetouch TP63 5/6 Classic Disposable protective coverall, Safetouch Ltd., Istanbul, Turkey), nonsterile gloves, goggles (Pulsafe LG20 Goggle, Bacou-Dalloz Company, Paris, France), and a respirator mask (3M Disposable mask, N99/FFP3, without valve, Aura 9330+, 3M Company, St. Paul, USA) (Fig. 1). During the procedure, an endotracheal tube of 7 mm diameter was used, and the manikin was positioned at the ground level in accordance with the conditions of prehospital emergency medical services. The intubation procedures were performed using either a DL (Green Spex 2 Model, Mach blade, Truphatek Int Ltd., Netenya, Israel) or a VL (McGRATH MAC Video Laryngoscope, Aircraft Medical Ltd., Edinburgh, UK) that were routinely used by prehospital healthcare professionals.

The study was designed to compare the intubation time and success rates of prehospital health care professionals with and without PPE, who performed tracheal intubation on a simulated manikin (Resusci Anne QCPR with Airway Head, Laerdal Medical Ltd, Orpington, UK). The study was conducted over four days for four different combinations of PPE use and laryngoscopy (DL without PPE, DL with PPE, VL without PPE, and VL with PPE). The participants were numbered randomly at the time they reached the training area. The sequence of the combinations was determined randomly for each participant. Participants were asked not to talk to each other about the procedure.

The participants were asked to perform tracheal intubation and announce completion by saying "the manikin was successfully intubated." Intubation time was measured as the duration from the time the participant picked up the laryngoscope till announcing completion for all attempts (successful and unsuccessful). The procedure was repeated after a 10-min break for a second attempt in each combination. In total, eight measurements were obtained for each participant (two attempts for each of the four combinations). An emergency medicine specialist confirmed the success of intubation using a device connected to the manikin (SimPad PLUS with SkillReporter, Laerdal Medical Ltd., Orpington, UK). The primary outcome was the intubation time, and the secondary outcome was the intubation success rate.

2.3. Data collection and analysis

In addition to the intubation times and success rates, demographic data such as age, sex, body mass index, previous experience in using PPE (Fig. 1), and previous intubation experience while using PPE (in suspected COVID-19 patients) were recorded.

Data were analyzed using SPSS version 22.0. Visual (histogram and probability graphs) and analytical methods (Kolmogorov–Smirnov or Shapiro–Wilks tests) were used to determine distribution normality. Descriptive statistics were expressed as mean ± standard deviation for normally distributed variables.

The mean intubation time with each device was compared between the standard uniform and PPE groups by using the paired-sample *t*-test. The differential effect of PPE on the two devices was compared using the paired-sample t test. In addition, the mean intubation time with each device was compared between the first and second attempts using the paired-sample *t*-test. Successful intubation rates with each device were compared between the standard uniform and PPE groups using the McNemar test. A p value of <0.05 was considered statistically significant.

3. Results

A total of 43 prehospital healthcare professionals participated in the study, and their characteristics are summarized in Table 1. Of these, most were female (n = 25, 58%) and had previous experience of using PPE (n = 39, 90.7%).

Participants with prior experience in wearing PPE and intubating while using PPE had significantly shorter intubation times with both DL and VL. In addition, doctors had better intubation times with both VL + PPE and DL + PPE compared to nurses and paramedics. Table 2 presents comparison of average intubation times while using PPE according to demographics.

Table 1
Demograhic characteristics of the study participants.

Age, years, mean ± SD	27.37 ± 2.52
Male gender, n (%)	18 (41.9)
Profession, n (%)	
Physician	13 (30.2)
Nurse	11 (25.6)
Paramedic	19 (44.2)
Body mass index, kg/m^2, mean ± SD	25.73 ± 2.75
Prior PPE experience, n (%)	
No	4 (9.3)
Yes	39 (90.7)
Prior intubation experience with PPE, n (%)	
No	22 (52.1)
Yes	21 (48.8)

PPE: personal protective equipment.

Table 3 summarizes the main results of the study. The overall intubation time with PPE was 51.28 ± 3.89 s, which was significantly longer than with standard uniform (33.03 ± 2.65 s; p < 0.001). In addition, the overall success rate with PPE use was 74.4%, which was significantly lower than that with standard uniform (93%; p < 0.001).

PPE use increased the average intubation time by 19.73 ± 2.59 s with DL and by 16.81 ± 2.56 s with VL. The effect of PPE use was significantly more pronounced when using DL (p < 0.001); Table 4).

Table 5 summarizes the comparison between the first and second attempts across the four combinations. In the second attempt, intubation times using both laryngoscopes significantly reduced (p < 0.001).

4. Discussion

Our study confirms that PPE use increases intubation time and decreases the intubation success rate compared to the standard uniform; this observation is consistent with that of previous studies [9–11]. The increase in intubation time with PPE use was less with VL assistance than with DL assistance, and the success rate was higher with VL assistance. These findings support the use of VL in prehospital emergency medical services during the pandemic.

Participants intubated the manikins placed on the ground. This may have caused difficulties [15]. For example, the rescuer is forced to assume crouching or lying positions to obtain adequate visualization of the larynx [15]. In addition, intubation on the ground would favour VL use [16]. We believe that the effect of these issues in our study is limited, given that the participants were prehospital healthcare professionals working under such conditions and were trained to operate in such conditions. However, our findings show that prior experience with PPE in the field, even if once, significantly decreased intubation times. In addition, in the second intubation attempts, intubation times reduced and the success rates increased as compared to that in the first attempts across all combinations. This could be attributed to participants learning the procedure in their first attempts. Doctors' intubation times were significantly shorter than those of the paramedics and nurses. While PPE use

Table 2
Comparison of average intubation times in PPE according to demographics.

	Average time for DL	p Value	Average time for VL	p Value
Gender		0.462		0.933
Male	53.75 ± 2.39		49.13 ± 1.42	
Female	54.3 ± 2.39		49.1 ± 1.53	
Profession		0.000***		0.03*
Doctors	52 ± 1.89		48.46 ± 1.08	
Others	54.96 ± 1.99		49.4 ± 1.53	
Body mass index		0.544		0.261
<25	53.8 ± 2.45		49.41 ± 1.44	
≥25	54.26 ± 2.36		48.9 ± 1.47	
Prior PPE experience		0.001**		0.01*
No	57.62 ± 1.31		50.87 ± 1.97	
Yes	53.7 ± 2.16		48.93 ± 1.31	
Prior intubation experience with PPE		0.016*		0.004**
No	54.9 ± 2.15		49.72 ± 1.58	
Yes	53.19 ± 2.33		48.47 ± 1.03	

Data were presented as mean ± SD. DL: direct laryngoscopy, PPE: personal protective equipment, VL: video laryngoscopy.
*p < 0.05, **p < 0.01, ***p < 0.001.

Table 3
Comparison of standard uniform and personal protective equipment.

	Standard uniform	PPE	Difference	*p* Value
Time to intubation, seconds, mean ± SD				
DL-1st attempt	35.05 ± 1.58	55.58 ± 2.28	20.60 ± 2.45	<0.001
DL-2nd attempt	33.63 ± 2.01	52.49 ± 2.46	18.86 ± 2.46	<0.001
Average time for DL attempts	34.33 ± 1.93	54.06 ± 2.89	19.73 ± 2.59	<0.001
VL-1st attempt	33.42 ± 1.88	50.02 ± 2.34	16.60 ± 2.62	<0.001
VL-2nd attempt	30.02 ± 2.13	47.05 ± 2.13	17.02 ± 2.52	<0.001
Average time for VL attempts	31.72 ± 2.62	48.53 ± 2.68	16.81 ± 2.56	<0.001
Overall	33.03 ± 2.65	51.28 ± 3.89	18.25 ± 2.92	<0.001
Success rate, n (%)				
DL-1st attempt	39 (90.7)	30 (69.8)	9 (20.9)	0.022
DL-2nd attempt	40 (93)	32 (74.4)	8 (18.6)	0.021
Average success rate for DL attempts	79 (91.9)	62 (72.1)	17 (19.7)	<0.001
VL-1st attempt	40 (93)	33 (76.7)	7 (16.2)	0.039
VL-2nd attempt	41 (95.3)	33 (76.7)	8 (18.6)	0.021
Average success rate for VL attempts	81 (94.2)	66 (76.7)	15 (17.4)	0.001
Overall	160 (93)	128 (74.4)	32 (18.6)	<0.001

DL: direct laryngoscopy, PPE: personal protective equipment, VL: video laryngoscopy.

Table 4
Comparison of PPE impact between direct laryngoscopy and video laryngoscopy.

	DL	VL	p Value
Average time difference with PPE, seconds, mean ± SD	19.73 ± 2.59	16.81 ± 2.56	<0.001
Average success rate difference with PPE, n (%)	17 (19.7)	15 (17.4)	<0.001

DL: direct laryngoscopy, PPE: personal protective equipment, VL: video laryngoscopy.

Table 5
Comparison of intubation times between the first and second attempts.

	DL-1st	DL-2nd	p Value	VL-1st	VL-2nd	p Value
Without PPE	35.05 ± 1.58	33.63 ± 2.01	<0.001	33.42 ± 1.88	30.02 ± 2.13	<0.001
With PPE	55.58 ± 2.28	52.49 ± 2.46	<0.001	50.02 ± 2.34	47.05 ± 2.13	<0.001

Data were presented as mean ± SD. DL: direct laryngoscopy, PPE: personal protective equipment, VL: video laryngoscopy.

was rare for prehospital intubations in our region before the pandemic, it has now become a routine procedure [14]. Although PPE use and tracheal intubation are included in the standard training curriculum, the benefits of such training are reportedly lost within 6 months [17]. We believe that training should be conducted repeatedly for healthcare professionals working in the field, particularly nurses and paramedics.

Tracheal intubation is a high-risk procedure posing physiological difficulty; 10% of the patients develop severe hypoxemia (SpO_2 < 80%) and 2% develop cardiac arrest [12,18,19]. Success rate on initial attempts in critical patients is <80%; repeated attempts are required [18]. These figures are likely to be worse in patients with severe COVID-19 manifestations [12]. Early intubation in patients with COVID-19 is recommended to prevent aerosol production and transmission [12]. Therefore, it is necessary to use airway management techniques that maximize success in the first attempt.

In patients with COVID-19, the highest viral load is in the sputum and upper airway secretions [2]. Tracheal intubation poses a risk of exposure to high viral load, and if transmission occurs, higher viral load is associated with more severe illness [3]. In particular, the use of PPE is necessary when performing aerosol-generating medical interventions to prevent transmission to healthcare professionals and while ensuring continued medical care in pandemic. Despite its benefits, PPE use can negatively affect healthcare professionals. The use of N95 masks increases the body temperature, pulse, respiratory count, and PCO_2 pressure [20–23]. Fogging of goggles during intubation is observed in up to 80% cases [12]. Liquid-proof isolation suits reduce users comfort [24].

PPE use is associated with increased intubation times and higher failure rates [10]. Castle et al. reported that <50% of the first-attempt endotracheal intubations were successfully completed within 60 s [10]. Weaver et al. reported that endotracheal intubation is 27 s slower when using PPE with DL [11]. In a study where goggles were not used, the increase in intubation time with PPE use was nonsignificant [9]. In past reports, the simulation manikin was positioned at waist height, usually on a table; this contrasts with prehospital conditions [9–11,25]. In the present study, the manikin was placed on the ground. Findings of the study show that intubation time with PPE in the first attempt increased by 20.6 ± 2.4 s for DL and 16.6 ± 2.6 s for VL. However, in our study, all attempts were performed within one minute, in contrast to past reports. In a real clinical situation, time to intubation may increase. In addition, the time to wear PPE also contributes toward the delay in intubation. This situation may lead to an increase in mortality rates in patients who need immediate respiratory support.

The technological advancements in VL offer many advantages over DL. Disposable blades can be invaluable when faced with epidemic diseases. Video recordings of intubations can be used for documentation and teaching purposes. VL provides visualization of the glottis regardless of the presence of secretions in the airway and possible anatomic differences. It offers a short learning time and reduced need for manipulation [13,26–28]. Using VL may be the solution of difficulties caused by the PPE such as fogging. Results of this study show that VL should be used in prehospital emergency medical services, regardless of the use of PPE, to maximize success in the first intubation attempt.

An important limitation of the study is the simulation with a manikin; our results cannot be generalized to a real clinical environment. The study was performed using a manikin with a normal anatomic structure and in a calm environment; in contrast, healthcare professionals face diverse operating conditions and patients. As with all simulation studies, participants might not have performed the tasks as they would in a real clinical situation. However, we think this bias would have affected our results only minimally because the study did not require clinical decision-making, and it involved a single psychomotor process. Another limitation of the study is that intubation was performed on the ground, and this may have contributed to shorter intubation times with VL. Requiring two attempts is another limitation of our study. The effect of further trials on the results needs to be investigated. Further detailed studies can guide training programs on PPE use for prehospital healthcare professionals specifically for ambulance services.

Using PPE is necessary to protect healthcare professionals in epidemic situations such as COVID-19. We studied the effects of PPE use among prehospital healthcare professionals with regard to tracheal intubation. Intubation times between conditions significantly differed; the intubation time with PPE is higher than that with a standard uniform. Using VL shortens the endotracheal intubation time compared to using DL. We recommend providing further training to healthcare professionals for PPE use to increase success rates during difficult procedures such as intubation.

Conflicting interests

The authors declare that they have no conflict of interest.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Acknowledgements

The authors would like to thank physicians, nurses, and paramedics who participated in this study.

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