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The effects of personal protective equipment on airway management: An in-situ simulation

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ABSTRACT

The novel coronavirus disease (COVID-19) was declared a pandemic by the World Health Organisation on 11th March and has led to over 41,000 deaths in the UK. Public Health England guidance for aerosol generating procedures (AGP) requires the donning of personal protective equipment (PPE). We evaluated airway management skills using an in-situ emergency simulation. The scenarios were video recorded and scored by two independent assessors using a skill specific checklist. A total of 34 airway management procedures were evaluated. The checklist involved 13 steps with a maximum score of 26. The median (IQR [range]) checklist score was 25 (24–25 [20–26]). Four teams failed to intubate the trachea and proceeded to manage the airway using a supraglottic airway device. The mean (SD) intubation time was 47.9 (16.5) seconds and two anaesthetists (7%) required a second attempt. Our results show that airway management can be carried out successfully whilst donned in PPE. However, additional training in using newly introduced devices such as a McGrath® video laryngoscope is of paramount importance.

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1. Introduction

The novel coronavirus disease 2019 (COVID-19) was declared a pandemic by the World Health Organisation on 11th March 2020 and since then there have been over 7 million confirmed cases Worldwide and over 41,000 deaths in the UK [1]. An effective treatment for COVID-19 pneumonia does not exist and many deteriorating patients require mechanical ventilation [2,3]. The primary practitioners involved in intubation for supportive mechanical ventilation and for surgical procedures are anaesthetists and operating department practitioners (anaesthetic assistants). In a theatre environment, the disease prevalence dictates that all patients should be treated like they have suspected COVID-19. Any aerosol generating procedure (AGP) requires the donning of

personal protective equipment (PPE) which includes a FFP3 mask, a face visor, long sleeve fluid repellent gown and multiple pairs of gloves [4]. This has led to a paradigm shift in protocols and working practices. Any change in practice leads to anxiety and increased stress levels. Communication is vital in such situations and this has been shown to be suboptimal or even forgotten in stressful situations [5]. PPE has been shown to limit effective communication which is crucial to safe difficult airway management [6,7]. Managing a difficult airway whilst donned in PPE may result in an increased time to intubation and potentially poorer performance due to increased stress levels and difficulty in visualisation [8].

The primary aim of the study was to evaluate airway management procedure using a skill specific checklist score during a simulated emergency difficult airway scenario. The secondary aim of the study was to evaluate the time to successful tracheal intubation.

2. Methods

The study protocol was reviewed by the local research,

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development and innovation department. As the study involved National Health Service (NHS) staff recruited as research participants by their professional role, the committee deemed that formal national research ethics approval was not required. A participant information sheet was provided to all participants and written consent for participation including video recording of the scenarios was obtained. The study was conducted in March 2020, during which time anaesthetists of all grades at the University Hospitals Coventry and Warwickshire NHS Trust participated in pre-COVID-19 intubation training.

These sessions took place over a two-week period, utilising an in-situ, high fidelity simulation using SimMan® manikin (Laerdal Medical, Stavanger, Norway) and a computer screen displaying standard anaesthetic monitoring. The monitoring displayed included electrocardiogram (ECG), heart rate (HR), invasive blood pressure (IBP), oxygen saturations (SpO₂), end tidal carbon dioxide (EtCO₂), respiratory rate (RR), temperature and end-tidal oxygen (EtO₂).

A structured scenario was designed to be a realistic representation of a deteriorating COVID-19 patient requiring emergency intubation in a theatre environment and subsequently to be transferred to intensive care for mechanical ventilation. A COVID intubation checklist that was locally adapted from national guidelines and a locally designed COVID airway trolley were readily available for the participants [9]. A McGrath® video laryngoscope (Aircraft Medical, Edinburgh, UK) with a size 4 MAC blade was used as the primary laryngoscope. The airway trolley also included a bougie, a size 3 and 4 i-gel® supraglottic airway device (Intersurgical, Berkshire, UK), two oro-pharyngeal airways and a Mapleson C breathing circuit with an EtCO₂ adapter. The intubation team included three members, the primary intubator - team leader (most experienced anaesthetist), secondary intubator - checklist reader (second anaesthetist) and an anaesthetic assistant.

The intubation team was introduced to the airway trolley and local intubation checklist at the start of the simulation. As part of this process they rehearsed donning in the anaesthetic room prior to entering the operating theatre where the SimMan® was positioned on an operating theatre trolley; 15L/min oxygen connected via non-rebreather mask, two 18G cannulas in-situ and standard monitoring attached.

The vital parameters were pre-programmed with starting SpO₂ of 90%, HR of 135 bpm in sinus rhythm and IBP of 100/70 mmHg. The SpO₂ was programmed to drop by 10% every 30s, HR falling 20 bpm every 30s and IBP systolic and diastolic falling by 10 mmHg every 30s. All alarms were active from the beginning of the scenario.

The intubation team was instructed to perform a rapid sequence induction (RSI) and manage any difficult intubation as per the Difficult Airway Society (DAS) guidelines [10].

The checklist and training reinforced the need to pre-oxygenate patients for 3 min and to aim for an EtO₂ of 80%.

The session was completed with additional training provided for doffing of PPE. All teams were then provided with a detailed debrief, including an opportunity for the secondary intubator to practice intubation on the manikin and focussed training on use of the McGrath® video-laryngoscope.

At the beginning of the training session, participant data, including age, gender, seniority and previous experience of using a McGrath® video-laryngoscope were collected.

The scenarios were video recorded, and care was taken only to record the manikin and the participants hands whilst they performed airway interventions. The video recordings were later arranged into two duplicate sets, both of which featured the complete set of recordings, but in differing orders. Individual videos were coded, and the copies of the recordings were transferred to a

portable solid-state data storage device before handing over to the evaluators. This ensured that each evaluator assessed them in a random order. Each set was evaluated independently by one of two expert evaluators (RD, CM), who were not involved in the design of the training session. The evaluators used a skill specific checklist score to assess the technical steps involved in airway management (Table 1). There were a total of 13 steps grouped under three categories: pre-intubation checklist, induction of anaesthesia, laryngoscopy and intubation. Each step was scored as follows: zero if it was not performed, one if it was inadequately performed or two if it was correctly performed.

The intubation time was measured from the video footage as the time when the laryngoscope was inserted into the mouth to the first display of EtCO₂ on the monitor. If the duration of intubation was more than 120s, or the intubator removed the laryngoscope without intubating the trachea or abandoned the intubation attempt and proceeded to plan B, it was considered a failed intubation. Agreement between the two assessors was assessed using the intra-class correlation coefficient. Analysis was carried out using statistical software SPSS (Version 18, SPSS Inc, Chicago, IL, USA).

3. Results

A total of 36 intubation teams participated in the study. Two videos were incomplete and hence excluded from the analysis. The demographic data and experience of the primary intubator for each team is shown in Table 2.

In total 34 complete videos were analysed. Agreement between the evaluators, as assessed using intraclass correlation, was 0.555 (95% CI 0.279–0.749). Fig. 1 shows the total checklist score from each participant and the distribution of the mean checklist scores is presented in Fig. 2.

The median (IQR [range]) checklist score was 25 (24–25 [20–26]). Of the 34 intubation teams, four teams (12%) failed to intubate the trachea and proceeded to plan B. Among 30 successful intubations, all intubations were performed by the primary intubator with 93% of them being successful in first attempt and two anaesthetists (7%) requiring a second attempt at intubation. The mean (SD) intubation time was 47.9 (16.5) seconds with a 95% CI of 41.8–54.1 seconds. A bougie was used in 9 of the 30 successful intubations. We identified two poorly performed steps, namely palpation of the cricothyroid membrane (14 participants scored one, one participant scored zero) and technique of laryngoscopy (14 participants scored one).

4. Discussion

The emergence of COVID-19, a requirement for PPE and the use of a COVID specific airway trolley and equipment, necessitated additional training for all theatre staff. The high checklist scores obtained by participants indicate that following a structured training session, an intubation team can perform the procedure to an acceptable level of competence, including pre-intubation preparation, induction of general anaesthesia and tracheal intubation whilst donned in full PPE. However, we observed a 12% failure rate in tracheal intubation and longer time for intubation as compared to previously published studies from the same department using a videolaryngoscope, where the success rate for tracheal intubation was 100% [11,12]. In another manikin study using McGrath® videolaryngoscope, novices were able to intubate with a 3% failure rate and with a median (IQR) intubation time of 14 (9–31) seconds [13]. Sakles et al. similarly found a failure rate of 1.1% for tracheal intubation using rapid sequence induction in an emergency department [14].

The increased intubation time and failure rate seen in our study may be due to several reasons. Firstly, the use of PPE including three

Table 1
Skill specific checklist score for airway management.

Task 1 – Pre-Intubation Check	0	1	2
1 Intubation checklist	Didn't use the check list	Partly used the check list	Went through the list in full detail
2 Checks ventilator settings	Didn't check	Only partially checked	Went through full set up of ventilator
3 Airway strategy discussed	Not discussed	Partial discussion	Full discussion
4 Preparation of drugs	Not performed	Incomplete and not in correct order	Prepared all essential drugs
5 Preparation of equipment	Not prepared	Incomplete assembly	Correctly assembled all components
6 Ergonomics of equipment	Not considered	Needs improvement	Well organised
Task 2 – Induction of anaesthesia	0	1	2
7 Optimises head & neck position	Not optimised	Not satisfactory	Satisfactory positioning prior to pre-oxygenation
8 Identifies CTM	Not palpated	Incorrect method or just felt cricoid	Correctly identified CTM
9 Pre-oxygenation started (6L, APL open, EtO ₂ >85% confirmed)	Not performed	Inadequate pre-oxygenation	Correctly performs with tight fitting face mask and checks EtO ₂
10 Drugs administration	Both doses and sequence of administration incorrect	Either doses or sequence of administration incorrect	Correct dosages and correct sequence
Task 3 – Laryngoscopy and intubation			
11 Technique of Laryngoscopy	Unsatisfactory laryngoscopy	Required some assistance	Correct technique, no assistance required
12 Insertion of Tracheal tube	Failed attempt	Required some assistance	Correctly intubates the trachea
13 Inflation of cuff	Needed prompting	Inflated after ventilation	Inflates the cuff prior to commencing ventilation
Total score			

CTM = cricothyroid membrane, APL = adjustable pressure relief valve.
EtO₂ = End-tidal oxygen concentration.

Table 2
Demographic data and previous experience of videolaryngoscopy for the primary intubator.

Grade	(n = 34)
Junior Trainee (≤Year 4)	4
Senior Trainee (≥Year 5)	4
Non-Consultant Career Grade	7
Consultant	17
Gender	(n = 34)
Male	20
Female	14
Previous experience of McGrath videolaryngoscopy	(n = 34)
Not answered (unknown)	7
0 intubations	11
<10 intubations	3
11-50 intubations	6
>50 intubations	6

pairs of gloves could have adversely affected the procedure of laryngoscopy and tracheal intubation. Secondly, the intubation team were presented with an emergency scenario where the starting saturation was only 90%, with saturation alarms sounding at the start of the scenario. Therefore, we assume the primary intubator was under psychological stress to secure the airway quickly. It has been shown that psychological stress can affect physical performance [15]. In addition, the wish to secure the airway as quickly as possible can lead to impaired dexterity and increase the time taken to perform a procedural skill [16]. Thirdly, being in PPE could create a degree of anxiety for the primary intubator. In the midst of a pandemic, with anaesthetists well aware of the risks of contracting COVID-19, physical and mental fatigue, stress and anxiety may play a role in decreased performance [17]. Finally, the McGrath® video laryngoscope was introduced as a primary laryngoscope on the COVID airway trolley and lack of experience in using McGrath video laryngoscope could also contribute to failure and a longer intubation time.

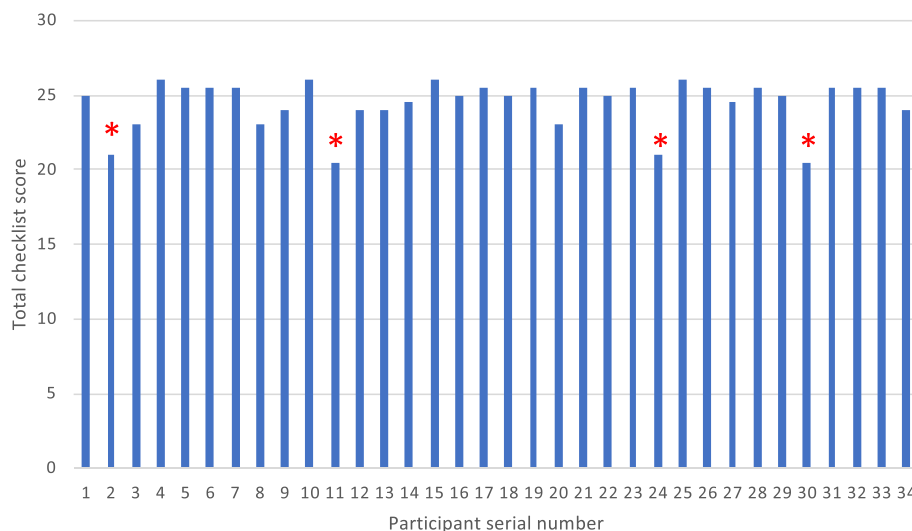


Fig. 1. The mean of total checklist score for each participant.
*failed to intubate the trachea.

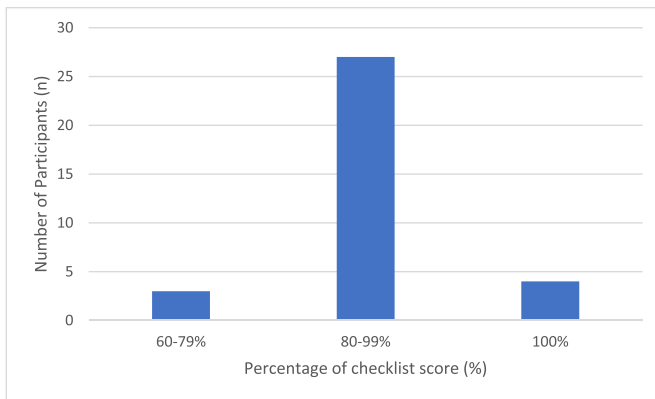


Fig. 2. Total checklist score expressed in percentages.

Castle et al. studied the impact of chemical, biological, radiation and nuclear personal protective equipment (CBRN-PPE) on airway and vascular access. Their results support that high dexterity procedural skills are achievable but can be associated with increased failure rate and prolonged procedural time [18]. Shin et al. studied tracheal intubation using different laryngoscopes whilst wearing CBRN-PPE and reported a significantly increased time for tracheal intubation [19]. However, our study is unique in that, in addition to the effect of PPE and anxiety, participants were subjected to the psychological stress of an operating theatre environment.

The use of a bougie in our study was as an emergency adjunct for rescuing the airway. The primary intubator used the bougie to rescue the airway when experiencing difficulty in advancing the tracheal tube towards the glottis. We acknowledge that routine use of a bougie is likely to improve the success rate of intubation [20]. However, the removal of a bougie needs to be carefully managed to prevent spraying of tracheal secretions on the intubating team [21].

We identified two poorly conducted steps during the simulation. They were palpation of the cricothyroid membrane and the technique of laryngoscopy. Correct identification of the cricothyroid membrane is essential in preparation for emergency front of neck access (eFONA) as part of plan D. Repeated attempts at palpation of the cricoid region may precipitate coughing, which is likely to increase viral spread in COVID-19. Although the participants were presented with a scenario requiring rapid sequence induction, the use of cricoid pressure is controversial, as it may lead to a poor laryngoscopic view and failed attempt at intubation [22]. A lower score for technique of laryngoscopy in our study is likely due to the unfamiliarity with the McGrath® video laryngoscope, as 62% of our participants had limited experience in using the McGrath®. The key principle of airway management in a COVID-19 situation is ensuring success at first attempt of tracheal intubation and minimising aerosolization. This can be achieved by pre-emptive optimisation of haemodynamics, effective pre-oxygenation, rapid sequence induction, minimising facemask ventilation, intubation attempt by most skilled operator, use of videolaryngoscope and bougie or stylet to improve the success of tracheal intubation [23].

There were several limitations to our study. The rapid escalation of the need for training in this pandemic necessitated designing and starting the training and simulations within a very limited time frame. Therefore, we could not plan a randomised comparative study as we were time limited. Similarly, we didn't measure the anxiety level amongst the participants either objectively or qualitatively. Along with several other channelled and non-channelled video laryngoscopes, the McGrath® video laryngoscope was also available in the department and we assumed that all participants would be familiar with the McGrath® videolaryngoscope and

hence didn't arrange prior training in its use. Participants were offered additional training during the debrief session.

In conclusion, this study demonstrated that, following structured training, the overall procedural steps can be performed to an acceptable level of competence. We have identified that additional training in using newly introduced devices such as a McGrath® video laryngoscope is of paramount importance.

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CRediT authorship contribution statement

Umair Ansari: Conceptualization, Data curation, Investigation, Methodology, Visualization. **Cyprian Mendonca:** Formal analysis, Visualization. **Ratidzo Danha:** Formal analysis, Validation, Writing - review & editing. **Richard Robley:** Data curation, Investigation, Validation, Writing - review & editing. **Tim Davies:** Methodology, Project administration, Investigation, Writing - review & editing, Supervision.

Declaration of competing interest

CM has received equipment to conduct airway workshops from Karl-Storz, AMBU, Fannin UK, Free-lance Surgical, Smiths Medical and Verathon.

Declaration of Interest: None (UA, RD, RR, TD).

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.tacc.2020.07.003>.

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