




Orotracheal intubation incorporating aerosol-mitigating strategies by anaesthesiologists, intensivists and emergency physicians: a simulation study

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ABSTRACT

Background Orotracheal intubation (OTI) can result in aerosolisation leading to an increased risk of infection for healthcare providers, a key concern during the COVID-19 pandemic.

Objective This study aimed to evaluate the OTI time and success rate of two aerosol-mitigating strategies under direct laryngoscopy and videolaryngoscopy performed by anaesthesiologists, intensive care physicians and emergency physicians who were voluntarily recruited for OTI in an airway simulation model.

Methodology The outcomes were successful OTI, degree of airway visualisation and time required for OTI. Not using a stylet during OTI reduced the success rate among non-anaesthesiologists and increased the time required for intubation, regardless of the laryngoscopy device used.

Results Success rates were similar among physicians from different specialties during OTI using videolaryngoscopy with a stylet. The time required for successful OTI by intensive care and emergency physicians using videolaryngoscopy with a stylet was longer compared with anaesthesiologists using the same technique. Videolaryngoscopy increased the time required for OTI among intensive care physicians compared with direct laryngoscopy. The aerosol-mitigating strategy under direct laryngoscopy with stylet did not increase the time required for intubation, nor did it interfere with OTI success, regardless of the specialty of the performing physician.

Conclusions The use of a stylet within the endotracheal tube, especially for non-anaesthesiologists, had an impact on OTI success rates and decreased procedural time.

INTRODUCTION

The COVID-19 caused by the SARS-CoV-2 is highly contagious. Patients who are COVID positive may require oro-tracheal intubation (OTI) because of respiratory failure or for surgery.^{1–3} OTI often triggers coughing and the dispersed aerosols pose a serious risk to personnel managing the airway or in proximity.^{1–6} Several guidelines have been proposed to reduce the risk of infection during OTI through

Key messages

What is already known on this subject

- ▶ The COVID-19 pandemic is caused by a coronavirus that is transmitted primarily via aerosol, droplets or direct contact. This may place anaesthesiologists, intensivists and emergency physicians at a higher risk of infection due to their frequent involvement in aerosol-generating airway interventions.
- ▶ Simulation-based training and preparedness testing activities are vital in identifying gaps to apply corrective actions immediately.
- ▶ Orotracheal intubation (OTI) in patients with COVID-19 should be performed by the most proficient practitioner immediately available, using the most efficient technique.

What this study adds

- ▶ Direct laryngoscopy is a more reliable technique than videolaryngoscopy for non-expert practitioner on the last method.
- ▶ Aerosol-mitigating strategies that do not allow stylet usage negatively affect the procedure success.
- ▶ The use of a stylet within the endotracheal tube, especially for non-anaesthesiologists, had an impact on OTI success rates and decreased procedural time.

limiting and isolating the sphere of aerosolisation, preventing aerosolisation, minimising the number of attempts at OTI and using personal protective equipment.^{4–7} Notably, whether the primary cause of aerosolisation during airway management is the OTI procedure itself and/or patient cough (both volitional or during OTI due to insufficient muscle relaxation) or during rescue manoeuvres (eg, face mask ventilation), or both, remains a subject of debate.

In terms of limiting the sphere of aerosolisation during airway management, there is the aerosol box,⁸ antiaerosol igloo⁹ and the portable negative pressure chamber.¹⁰ Unfortunately, the aerosol box (and by extension, any similar tent devices)



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is associated with longer intubation time and higher failure rate.¹¹

The recommendation that, with patients with COVID-19, OTI should be performed by the most experienced professional using the best equipment⁴⁻⁷ is premised on the need to reduce the number and duration of intubation attempts such that aerosolisation can be minimised, and to quickly provide ventilation to patients. Anaesthesiologists are the most proficient in OTI, while intensive care and emergency physicians are probably, on average, competent but not quite as proficient. The best equipment involves videolaryngoscopy (VL).⁴⁻⁷ For non-anaesthesiologists, however, experience with VL may be limited as direct laryngoscopy (DL) is usually used in most non-COVID intubations. One important question to ask is whether the use of a superior laryngoscopy technique (ie, VL) actually facilitates OTI by clinicians who are less experienced with the technique. In terms of limiting/preventing aerosol spread, British and Canadian COVID-19 guidelines suggest the use of a hydrophobic heat and moisture exchanger (HME) filter to block aerosols at the endotracheal tube (ETT) opening.^{4 5} Unfortunately, the HME filter can only be applied after the stylet used to bend the ETT (useful in difficult DL and with videolaryngoscopes that have a hyperangulated blade) has been removed after ETT placement, thus creating a time gap when aerosol can disperse. Our group has adopted a different technique to achieve uninterrupted blocking of the ETT at all times, one which is compatible with use of a stylet in DL and VL. The purpose of this study was to evaluate, through simulation, the success rate and procedural time of two aerosol-mitigating strategies (AMS) during OTI under DL and VL performed by airway clinicians: anaesthesiologists, and intensive care and emergency physicians.

MATERIALS AND METHODS

This was a cross-sectional study in which volunteer physicians performed OTI on a standard airway simulation manikin using two different AMS. A total of 27 physicians—9 anaesthesiologists, 9 intensivists and 9 emergency physicians—were randomly selected from their respective departments. Notably, at the very beginning of this COVID-19 pandemic, all physicians enrolled in this study had previously received specific institutional simulation training on VL as part of a hospital-wide campaign. In addition, for the purposes of this study, clinicians were deemed experts in VL if they had performed ≥ 10 OTIs under VL in the previous 12 months of their clinical practice. Furthermore, prior to beginning this study, all chosen participants were provided with standard instructions for the direct laryngoscope and the videolaryngoscope used in the study, including a demonstration of the intubation methods and the use of enhancement manoeuvres (eg, head position readjustment) to facilitate OTI. The participants were then allowed up to five practice attempts with the direct laryngoscope and the videolaryngoscope on a manikin (QCPR Resusci Anne model with airways: Laerdal).

A McGrath videolaryngoscope (for VL) and a Macintosh laryngoscope (for DL) with size 4 blades were used in this study. Unlike most other videolaryngoscopes, the McGrath MAC blade used in this study is less hyperangulated and routine use of a hyperangulated stylet within the ETT is not needed. As such, the HME could be attached to the ETT during placement, thus eliminating the time gap between removal of the stylet and the attachment of the HME when aerosol can disperse, as explained earlier. All intubations were performed with a 7.5 mm internal diameter Portex ETT on the standard airway training manikin.

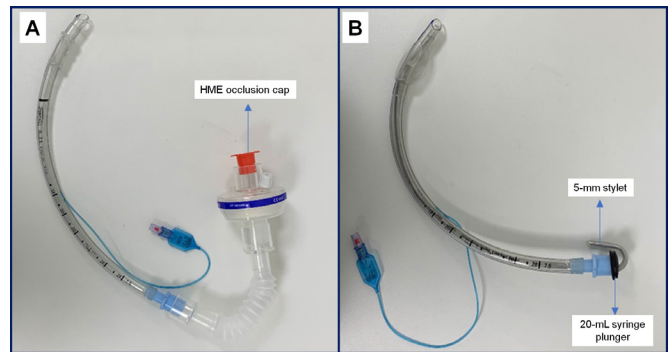


Figure 1 Aerosol-mitigating strategies. (A) Heat and moisture exchange (HME) filter connected to the endotracheal tube (ETT) and occluded with its original occlusion cap. Note that this assembly does not allow for the use of a stylet. (B) A 20 mL syringe plunger is used to occlude the ETT connector through which a 5 mm stylet is inserted.

Two AMS, both without a time gap when aerosol can escape, were studied. (1) The first AMS involved use of an HME filter without stylet: the ETT (prior to intubation) was connected to an antibacterial hygroscopic condenser HME (Gibeck) occluded proximally with its own original occlusion device (figure 1A). This technique does not allow for the use of an ETT stylet (as mentioned earlier). After successful intubation, the participant instructed an assistant to inflate the ETT cuff, clamped the ETT, removed the filter occlusion device (figure 1A), connected to the ventilator and removed the clamp prior to initiation of mechanical ventilation. The ETT curvature was adjusted (without a stylet) at the participant's discretion during the intubation attempt. (2) The other AMS (stylet) was previously described by our group¹²: the ETT-stylet assembly was moulded prior to the procedure to follow the curvature of the blade used, which resulted in $\sim 60^\circ$ angle at the distal third of the ETT.¹³ This technique was performed with the ETT connector occluded by a 20 mL syringe plunger through which a 5 mm malleable stylet was passed (figure 1B). After successful intubation, the participant instructed an assistant to inflate the ETT cuff and partially remove the stylet while keeping the ETT occluded with the syringe plunger. At this point, the ETT was clamped distal to the stylet tip and proximal to the pilot cuff tubing, the stylet-plunger assembly removed, the ventilator connected and the clamp removed prior to initiation of mechanical ventilation.¹²

For all participants, the first intubation attempt was carried out using a standard DL technique (without either AMS) with a

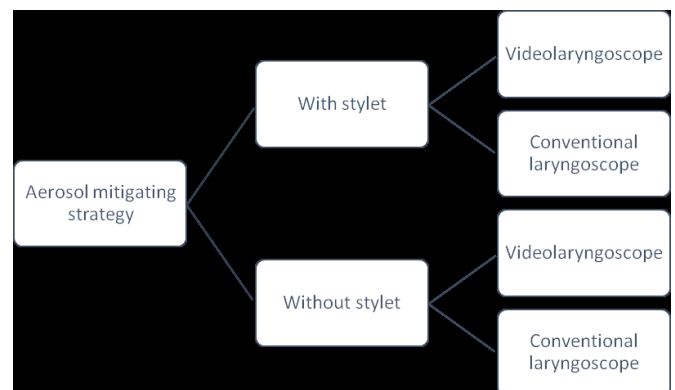


Figure 2 Techniques used in the random intubation sequence on a manikin.

Table 1 Successful (first attempt) orotracheal intubation (OTI) by specialty (anaesthesia, intensive care and emergency medicine) by OTI technique

Techniques used for OTI (T)	Successful first OTI attempt, % (n)				P value
	Overall	Anaesthesia (A)	Intensive care (IC)	Emergency (E)	
DL+styletno AMS (1)	77.8 (21)	100 (9)	66.7 (6)	66.7 (6)	0.14
DL+AMS (HME filter without stylet) (2)	66.7 (18)	100 (9)	44.5 (4)	55.5 (5)	0.03; A>IC
DL+AMS (stylet) (3)	85.2 (23)	100 (9)	88.9 (8)	66.7 (6)	0.12
VL+AMS (HME filter without stylet) (4)	29.6 (8)	88.9 (8)	0.0 (0)	0.0 (0)	0.001; A>IC, A>E
VL+AMS (stylet) (5)	77.8 (21)	100 (9)	77.8 (7)	55.5 (5)	0.07

Values expressed in % (n). Analysis between techniques (T1–T5) by medical specialty— χ^2 test: for anaesthesiologists ($p=0.39$); for intensivists T4<T1–T3 ($p=0.001$); for emergency medicine physicians T4<T1–T3 ($p=0.02$); overall T4<T1–T3 ($p<0.0001$).

AMS, aerosol-mitigating strategy (during OTI); DL, direct laryngoscopy; HME, heat and moisture exchanger; VL, videolaryngoscopy.

Macintosh 4 blade and an ETT over a stylet. The sequence of the remaining four attempts (all of which included an AMS) was at random for each participant (figure 2).

The primary outcome was successful first OTI attempt with each of the five attempts: (1) DL without AMS, (2) DL with AMS (HME filter without stylet), (3) DL with AMS (stylet), and (4, 5) likewise for VL. Secondary outcomes were degree of airway visualisation and the time required for intubation. The time taken for all intubations was measured by the same investigator, and was defined as the time lapse between when the laryngoscope was inserted between the manikin's teeth and when the first breath occurred. The degree of airway visualisation was reported by the participant after each attempt, and was classified according to the Cormack and Lehane grading system as easy (grades I and II) or difficult (grades III and IV).

Intubation failure was considered when the laryngoscope was removed from the oral cavity due to poor visualisation, an intubation time greater than 120 s or oesophageal intubation.

Statistical analysis

The time required to perform OTI on a manikin has been reported to be between 12 and 70 s.¹⁴ For sample size calculation, a difference of 10 (mean) \pm 7.5 (SD) s between the time taken to perform the OTI with different devices was considered significant in a simulated study, with a 95% test power and a difference at a significance level of 0.05. This would require nine physicians from each specialty. Histograms and the Shapiro-Wilk test were used to verify the symmetry of data distribution. Analyses of variance were performed with the Kruskal-Wallis test, followed by the Dunn's post hoc test in case of $p<0.05$. The χ^2 test was used to analyse the categorical variables, and the partitioning χ^2 was used when the p value was less than 0.05. The Fisher's exact test was used when one of the expected frequencies was lower than 5. P values <0.05 were considered statistically significant.

RESULTS

The age of the participants included in the study was 33.8 (mean) \pm 7.6 (SD) years. The median postcertification clinical experience was 3 (range 2–6) years for anaesthesiologists, 7 (3–13) years for intensivists and 3 (2–3) years for emergency physicians ($p=0.18$). There was no significant relationship between OTI success and the age or clinical experience ($p>0.05$).

The overall success rates (defined as first attempt successful intubation) for each technique are shown in table 1. The intubation technique using VL with an AMS (HME filter without stylet) had a lower overall success rate compared with the other techniques ($p<0.001$).

Intensivists had lower success rates compared with anaesthesiologists when using the AMS (HME without stylet) under DL ($p=0.03$). Non-anaesthesiologists were unsuccessful in all attempts at OTI using the AMS (HME without stylet) under VL. Conversely, success rates did not differ between specialists while using the AMS with stylet under DL ($p=0.14$) and VL ($p=0.07$) (table 1). There was no difference between intensivists and emergency physicians with regard to oesophageal intubation ($p=0.67$).

The median intubation times for each technique are shown in table 2. With DL, intensive care and emergency physicians required a longer time for successful OTI with AMS (HME without stylet) compared with anaesthesiologists, but required similar amount of time for successful OTI using the AMS with stylet compared with anaesthesiologists. With VL, intensive care and emergency physicians failed at all OTI attempts using AMS (HME without stylet), and required significantly more time for successful OTI using AMS with stylet compared with anaesthesiologists (table 2).

The degree of airway visualisation was reported as difficult more frequently by intensive care and emergency physicians under both DL and VL (table 3).

All anaesthesiologists were deemed experts in VL (ie, ≥ 10 OTIs under VL over the previous 12 months), whereas 55.6%

Table 2 Time (seconds) taken for successful orotracheal intubation (OTI) by medical specialty (anaesthesia, intensive care and emergency medicine) by OTI technique

Techniques used for OTI (T)	Successful OTI time in seconds				P value
	Overall	Anaesthesia (A)	Intensive care (IC)	Emergency (E)	
DL+stylet (no AMS) (1)	22 (17–28)	18 (16–18)	21.5 (20.2–25.7)	27.5 (19.2–36.2)	0.54
DL+AMS (HME filter without stylet) (2)	22 (18–28)	21 (18–22)	35.5 (32.5–38.75)	28 (27–34)	0.03; A>IC
DL+AMS+stylet (3)	31 (21–49)	21 (16–24)	31 (27.75–40)	34 (24.5–47.2)	0.055
VL+AMS (HME filter without stylet) (4)	38.5 (25–52.7)	38 (25–52.7)	NA	NA	NA
VL+AMS+stylet (5)	29 (20.5–39.5)	19 (19–23)	53 (42–62.5)	33 (24–33)	0.001; A<IC, A<E

Time values expressed as median (25%–75% percentile). Analysis between techniques (T1–T5) by specialty—analysis of variance: anaesthesiology ($p=0.06$); intensive care T5>T1 ($p=0.02$); emergency ($p=0.86$); overall T4>T1–T3 ($p<0.001$). AMS, aerosol-mitigating strategy (during OTI); DL, direct laryngoscopy; HME, heat and moisture exchanger; NA, not applicable (ie, unsuccessful OTI in all cases); VL, videolaryngoscopy.

Table 3 Airway visualisation for direct laryngoscopy and videolaryngoscopy by specialty

Medical specialty	Laryngoscopy view using Cormack and Lehane grading system				P value
	Direct laryngoscopy		Videolaryngoscopy		
	Grades I, II	Grades III, IV	Grades I, II	Grades III, IV	
Anaesthesia	100 (27)	0.0 (0)	100 (27)	0.00 (0)	NA
Intensive care	70 (19)	30 (8)	77.7 (14)	22.3 (4)	0.58
Emergency	81.4 (22)	18.6 (9)	72.2 (13)	27.8 (5)	0.46

Values expressed in % (n). Analysis between medical specialty by degree of airway visualisation for direct laryngoscopy (DL) and videolaryngoscopy (VL)— χ^2 test: difficult airway visualisation by DL in intensive care and emergency > anaesthesia; difficult airway visualisation by VL in intensive care and emergency > anaesthesia. NA, not applicable.

of intensivists and 22.2% of emergency physicians reported a similar level of experience. Previous expertise with VL was associated with higher success rates of first OTI attempt ($p < 0.05$) (table 4).

DISCUSSION

During OTI, 73% of patients with respiratory failure due to COVID-19 develop severe hypoxaemia and 2% suffer a cardiac arrest.¹⁵ The risk of infection for healthcare professionals increases when multiple or prolonged intubation attempts are necessary. Furthermore, an OTI failure may necessitate face mask bag ventilation, also a highly aerosolising manoeuvre especially when it is difficult.¹⁶ These considerations underscore the recommendations that OTI in patients with COVID-19 should be performed by the most proficient practitioner immediately available using the most efficient technique. In addition, AMS have been suggested to reduce the risks to healthcare teams.^{4 5 12}

Anaesthesiology trainees who have performed 50 successful OTIs under DL require 76 OTIs under VL to achieve a 90% success rate.¹⁷ This learning curve may explain in part why intensive care and emergency physicians, who may have less VL experience, did not perform as well in our simulation. Our results suggest that anaesthesiologists, if one is available in a timely fashion, should perform COVID-19 OTIs. They also suggest that for non-anaesthesiologists, depending on VL experience, use of DL with an effective AMS may be more appropriate, despite current COVID-19 recommendations. This is particularly true when VL is performed without a stylet to shape the ETT into a more hyperangulated curvature. Finally, our results validate a novel AMS used by our group.¹² When compared with HME filter (recommended in Canadian⁵ and British⁴ guidelines) without stylet, our novel AMS took less time to perform by anaesthesiologists and was universally successfully completed by intensive care and emergency physicians (table 2). Also worth noting, the use of HME without stylet, although recommended by guidelines,^{4 5} appeared to significantly hinder the non-anaesthesiologists' ability to secure the airway (table 1), thus

Table 4 Relationship between successful first attempt orotracheal intubation (OTI) and prior clinical expertise with videolaryngoscopy (VL)

Level of expertise with VL	Successful first OTI attempt, % (n)		P value*
	Yes, % (n)	No, % (n)	
Non-experts† (<10 OTIs under VL over past 12 months)	5 (18.5)	6 (21.5)	0.001
Experts† (≥10 OTIs under VL over past 12 months)	16 (60)	0 (0.0)	

Values expressed in % (n).

*Fisher's exact test.

†All physicians enrolled in this study received specific institutional simulation training on VL at the beginning of the pandemic as part of a hospital-wide campaign.

calling into question whether this AMS should be universally adopted in the first place, especially given the lack of concrete evidence that AMS would decrease aerosolisation, particularly if patients are well paralysed and not coughing.

Importantly, at the institution where the study took place, VL was not routinely used by intensive care and emergency physicians before the pandemic, and was mostly reserved for managing patients with features of difficult airway by anaesthesiologists. Hence, despite all participating physicians receiving the same institutional simulation training on VL at the beginning of the pandemic, prior clinical expertise with VL (defined as ≥10 OTIs under VL over the previous 12 months) had a significant impact on the success rates of first OTI attempt (table 4), suggesting that regional differences in physician training and expertise with VL must be taken into account.

The present investigation supports the concept of creating among non-anaesthesiologists a group of excellence for OTI in patients with COVID-19 aiming at successful intubation in the shortest possible time and with minimal number of attempts, because timely anaesthesiology availability is not guaranteed.

As to be expected, incorporating AMS should increase the time required for OTI. The increases (table 2) are small, and are required and well justified to prevent disease spread. With the exception of intensive care physicians performing AMS with stylet, our study was underpowered to show statistical significance in those differences. Likewise, our study was underpowered to show whether the differences in time between DL and VL were significant. Since these differences appear to be small, the choice between DL and VL should likely be based on assessment of the patient's relevant clinical features, including ease of OTI, and one's comfort level with the type of videolaryngoscopes available. Our simulation results also support the routine use of a stylet in the ETT during VL, especially by those with less experience in VL.

Intubating a manikin made of rigid plastic and a real person is not quite the same. Furthermore, the manikin is immobile but not all real-world patients are paralysed, although that is recommended for patients with COVID-19.⁴⁻⁷ The realism of a simulated environment may also affect operator performance. For example, concern over personal and personnel safety and a real person in extremis are difficult to reproduce. Caution must therefore be exercised when interpreting simulation results. On the other hand, experimental and objective real-world data are difficult and time consuming to obtain. The results of our study may help guide bigger simulation studies and help design clinical trials to devise the best and safest strategies for OTI in patients with highly contagious respiratory diseases.

Contributors Conception and design of the study: LMS, SQS, DWCLS. Revising the manuscript critically for important intellectual content: GBM, AMHH, SQS. Data acquisition: CMK, DWCLS, RSFN, MPS, SQS. Data analysis/interpretation: LMS, ACVA. Drafting the manuscript: GBM, AMHH, LMS. All authors revised and approved the final manuscript prior to submission. LMS is responsible for the overall content as guarantor.

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Competing interests None declared.

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