Aerosol and droplet dispersion during emergency front-of-neck access - A bench-top manikin simulation study

INTRODUCTION

The coronavirus disease 2019 (COVID-19), caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), can be transmitted via aerosols or droplets.[1] Emergency front of neck access (eFONA) procedures are considered aerosol generating procedures.[1] There are three main eFONA techniques described in a “can’t intubate can’t oxygenate” (CICO) scenario: Scalpel-bougie cricothyroidotomy, cannula cricothyroidotomy and surgical tracheostomy. Melker cricothyroidotomy commonly follows on from cannula cricothyroidotomy after the patient is stabilised. For SARS-CoV-2, the Australian and Indian guidelines both recommend the scalpel-bougie technique due to presumed increased aerosolisation during cannula cricothyroidotomy.[2,3] However, there is limited supporting evidence.

Our study aimed to investigate the extent of aerosol and droplet dispersion in various eFONA techniques. Using a manikin model and Glo Germ™ (Marletek Inc, Brockville, Canada) as a luminescent marker, we aimed to qualitatively characterise and compare the aerosol and droplet dispersion patterns of cannula, Melker and scalpel-bougie cricothyroidotomy. We hypothesised that cannula cricothyroidotomy and its associated oxygen insufflation device had the highest risk of aerosol and droplet transmission.

METHODS

Ethical approval was waived by our institution’s domain-specific review board for this observational manikin study conducted on a day in September 2020.

We used fluorescent ultraviolet (UV) powder Glo Germ™ (particle size 1-5 microns) in two forms, powder and suspension, to simulate aerosol and droplet transmission, respectively.[4,5] A single skilled expert operator donned in personal protective equipment (PPE) comprising hair protection cap, N95 mask, face shield, waterproof gown, gloves; performed each eFONA technique on an airway trainer (Deluxe difficult airway trainer; Laerdal Medical, Stavanger, Norway) in a darkened operating theatre, with a UV lamp suspended from above the setup. We used the manikin to simulate a real-life CICO circumstance of a patient who received neuromuscular paralysis and simultaneous bag mask ventilation. Positive pressure mechanical ventilation was administered via face mask, at fresh gas flow of 10 L/min, tidal volume of 500 ml, respiratory rate 15/min and positive end-expiratory pressure of 5 cm of water. Face mask was removed after each procedure and fresh gas flow stopped before removing the face mask to prevent accidental contamination of the field. Face mask was not used for Melker as cannula was already in situ. Anaesthetic gas scavenging was used. The manikin’s oesophagus was clamped to concentrate the particles in the respiratory tract.

For each aerosol simulation, half teaspoon of Glo Germ™ powder was deposited in the manikin’s lungs and shaken vigorously to ensure uniform spread. For each droplet simulation, one teaspoon of Glo Germ™ powder was mixed in 160 ml of 0.9% sodium chloride to form a suspension. 5 ml of the suspension was first atomised into droplets into the oropharynx and trachea via the MADgic Laryngo-Tracheal Mucosal Atomisation device (Teleflex, United States of America (USA)). The suspension was also continuously atomised down the respiratory tract via the nostril at 25 ml/min during the procedure to simulate ongoing secretions.

Cannula cricothyroidotomy was performed using a 14-gauge Insyte™ cannula (Becton Dickinson Ltd., Oxford, United Kingdom (UK)). The Rapid-O₂® insufflation device (Meditech Systems, UK) device was connected to an oxygen supply of 15 L/min from the anaesthesia machine auxiliary oxygen port, and jet oxygenation performed by occluding the side port for 4 s to deliver 1 L of oxygen into the manikin’s lungs. Subsequent breaths were given by occluding the side port for 2 s, and were repeated three times. Melker cricothyroidotomy followed on from cannula cricothyroidotomy, after wiping the manikin and environment clean. A Melker 5.0 mm cuffed tube (Cook Medical, Indiana, USA) was inserted via Seldinger technique, then connected to the breathing circuit and four ventilation breaths were administered. Scalpel-bougie cricothyroidotomy was performed using a blade 10 scalpel and a Frova intubating introducer (Cook Medical, Indiana, USA). A cuffed 6.0 mm endotracheal tube (ETT) was then railroaded over the introducer and connected to the
breathing circuit, where the assistant administered four ventilation breaths. UV fluorescent particles captured on the manikin and surroundings were regarded as contamination. The process was filmed with a digital single-lens reflex camera. The manikin’s interior and exterior and surrounding environment were wiped clean between each attempt. UV light was used to check for any residual fluorescent particles before commencement of the next attempt.

RESULTS

For cannula cricothyroidotomy, there was contamination of the manikin and drapes, but minimal contamination of the operator’s hands. An illuminated aerosolised jet was noted when the syringe was disconnected to attach the Rapid-Oxygen device. There was also droplet contamination on the operator’s face shield and assistant’s gown [Figure 1a-d]. For Melker cricothyroidotomy, there was contamination on the operator’s hands and equipment, especially the guidewire. Droplets were seen flicked off the guidewire and dilator unit during its removal [Figure 1 e-g]. For scalpel-bougie cricothyroidotomy, there was extensive contamination on the manikin and operator’s hands [Figure 1h]. The average time taken for cannula, Melker and scalpel-bougie cricothyroidotomy was 44.2 seconds, 84.6 seconds and 96.8 seconds, respectively. The equipment trolley remained clean during the cannula setup [Figure 2a]; whereas contamination was noted on both the Melker [Figure 2 b] and scalpel-bougie equipment and trolley [Figure 2c].

DISCUSSION

Our study demonstrated differing patterns of aerosol and droplet dispersion with cannula, Melker and scalpel-bougie cricothyroidotomies. Cannula cricothyroidotomy was associated with least contamination of the equipment, but showed distant spread onto the operating personnel, while the scalpel-bougie technique had the most contamination of the equipment and manikin. For Melker cricothyroidotomy, one would need to consider the contamination potential of both cannula cricothyroidotomy and Melker conversion procedures; therefore it has potential for both distant as well as local and equipment contamination.

Our study found that there is increased risk of distant contamination with cannula cricothyroidotomy. This is despite the shorter time taken to perform this procedure. Head and face protection is hence particularly important. This emphasises the importance of PPE, where careful donning and doffing of PPE will prevent infection to the personnel.

Scalpel-bougie cricothyroidotomy was found to have the most contamination around the cricothyroidotomy site and operator’s hands. Railroading of the ETT requires a forceful corkscrew motion, inevitably contaminating

Figure 1: Contamination during cricothyroidotomy simulations. (a) Contamination on manikin and drapes during cannula cricothyroidotomy. (b) Trajectory of Glo Germ™ particles after syringe is disconnected and prior to attachment of Rapid-Oxygen device during aerosol simulation. (c) Contamination on operator’s face shield during cannula cricothyroidotomy. (d) Contamination of assistant’s gown during cannula cricothyroidotomy. (e) Contamination of operator’s hands during Melker cricothyroidotomy. (f) Contamination of guidewire after cannula was removed during aerosol simulation. (g) Droplets flicked off the Melker guidewire during removal of the guidewire and dilator unit. (h) Contamination of operator’s hands and manikin during scalpel-bougie cricothyroidotomy.
the operator. Significant equipment contamination was observed with both Melker and scalpel-bougie cricothyroidotomy. These involve bulkier equipment and larger neck incisions, inadvertently contaminating the equipment as they enter the patient’s lower respiratory tract. The contamination was then transferred onto the equipment trolley. Caution must be exercised during removal of this equipment. To minimise contamination, the operator may consider wearing double gloves for the procedure, and to remove and dispose of the contaminated gloves immediately post procedure. A designated eFONA equipment trolley should be used to contain contaminated equipment. The number of personnel assisting the operator and handling contaminated equipment should be limited.

There are some limitations to our study. Aerosol droplets and Glo Germ™ powder do not have same properties. Also, real-life contamination may be more extensive if there are multiple attempts, or if the patient is not paralysed. The manikin used in the study may not accurately simulate real-life conditions, and results may not be readily generalisable to clinical situations. Furthermore, it was difficult to capture dynamic movement, and smaller less-visible particles. Lastly, we were unable to quantitatively analyse dispersion extent as we did not have objective measurement tools such as a spectrophotometer to quantify fluorescence intensity or particle concentration. This can be an area of further research.

CONCLUSION

The study provides qualitative illustration of aerosol and droplet dispersion patterns of the different eFONA techniques. Cannula cricothyroidotomy has a potential for distant spread; whereas Melker conversion and scalpel-bougie cricothyroidotomy have more extensive local contamination. With this knowledge, targeted precautions can be taken for each technique in COVID-19 patients, such as prudent use of PPE, and proper handling of contaminated equipment.

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Conflicts of interest

There are no conflicts of interest.

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