alone for preoxygenation followed by HFNO insufflation during the apnoeic period.[5,6]

The authors concluded that HFNO 'provided a shorter intubation time and less frequent incidence of desaturation during attempts at fibreoptic tracheal intubation compared with preoxygenation by face-mask ventilation'. Irrespective of the superiority of one method over another, neither of these has been compared with the standard of care of rapid sequence intubation, and both may represent inferior alternatives.

Declaration of interest

The author declares that they have no conflicts of interest.

References

1. Wu CN, Xia LZ, Li KH, et al. High-flow nasal-oxygenation-assisted fibreoptic tracheal intubation in critically ill patients with COVID-19 pneumonia: a prospective randomised controlled trial. *Br J Anaesth* 2020. https://doi.org/10.1016/j.bja.2020.02.020. Advance Access Published March 19
2. Lundstrøm LH, Duez CHV, Nørskov AK, et al. Effects of avoidance or use of neuromuscular blocking agents on outcomes in tracheal intubation: a Cochrane systematic review. *Br J Anaesth* 2018; **120**: 1381–93
3. Leung CCH, Joynt GM, Gomersall CD, et al. Comparison of high-flow nasal cannula versus oxygen face mask for environmental bacterial contamination in critically ill pneumonia patients: a randomized controlled crossover trial. *J Hosp Infect* 2019; **101**: 84–7
4. Shippam W, Preston R, Douglas J, Taylor J, Albert A, Chau A. High-flow nasal oxygen vs. standard flow-rate facemask pre-oxygenation in pregnant patients: a randomised physiological study. *Anaesthesia* 2019; **74**: 450–6
5. Lyons C, Callaghan M. Uses and mechanisms of apnoeic oxygenation: a narrative review. *Anaesthesia* 2019; **74**: 497–507
6. Renda T, Corrado A, Iskandar G, Pelaia G, Abdalla K, Navalesi P. High-flow nasal oxygen therapy in intensive care and anaesthesia. *Br J Anaesth* 2018; **120**: 18–27

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Rapid ramp-up of powered air-purifying respirator (PAPR) training for infection prevention and control during the COVID-19 pandemic

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Keywords: airway management; anaesthesia; COVID-19; infection prevention and control; PAPR; tracheal intubation

Editor—Singapore's first coronavirus disease 2019 (COVID-19) patient was diagnosed on January 23, 2020. This triggered an urgent ramp-up of just-in-time (JIT) training to expedite development of infection prevention and control capabilities in the Department of Anaesthesiology, Intensive Care, and Pain Medicine of Tan Tock Seng Hospital in anticipation of a rapidly escalating COVID-19 pandemic.

Frequent involvement in aerosol-generating procedures (AGPs) such as tracheal intubation, extubation, and open airway procedures including tracheostomy and bronchoscopy[1] exposes our staff to high risk of contamination. Proper use of a hooded powered air-purifying respirator (PAPR) offers better protection against respiratory pathogens during AGPs, with an assigned protection factor (APF) of up to 1000 compared with an APF of 10 for a N95 respirator.[2] Our hospital uses two types of PAPRs: the 3M™ Jupiter™ with 3M™ HT-101 Lightweight Hood (Fig 1) and the 3M™ Versaflo™ TR-300 with 3M™ Hood Assembly S-855. In the initial phase of our pandemic response plan, our department prioritised JIT resources for infection prevention and control measures against AGP, with a focus on PAPR training, as these are infrequently used, and their effectiveness requires a high level of staff involvement.

Development of a PAPR training programme

Pre-requisites

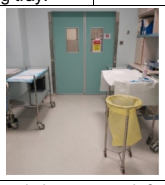
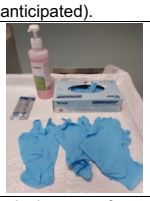
All staff had been N95 mask-fitted and had undergone two PAPR training sessions with competency checks, one each for Jupiter™ and Versaflo™ PAPRs. These covered the basic operation and donning and doffing of the PAPRs.

Timeline

Our department's infection prevention and control team was formed on January 28, 2020 and aimed to complete departmental PAPR training before Singapore progressed to a heightened risk. We allocated 2 weeks each for the training of Jupiter™ and Versaflo™ PAPR, and this allowed comprehensive one-on-one training for all 96 anaesthetists within February 2020.

Task	Thought Process
Prepare necessary equipment.	To prevent contamination and wastage of medical supplies, the anaesthetic drug cart and intubation trolley is not kept in the operating room (OR). Upon contact with a COVID-19 patient, it is not advisable to exit and re-enter the OR in order to obtain additional drugs or equipment. All necessary drugs and equipment thus need to be prepared in advance.
Prepare doffing area.	For the same reasons, the doffing area should be prepared in advance.

Action Plan

1. 	2. 	3. 	
Place anaesthetic and analgesic agents, vasopressors, paralytics, reversal agents, antibiotics, anti-emetic agents and other necessary drugs in a disposable drug tray.	Consider the number of additional fluid bags, syringes, needles, infusion lines that are needed for the case.	Prepare airway equipment including but not limited to oral airway, preferably a disposable video-laryngoscope, bougie and/or stylet, tracheal tube of various sizes, suction equipment, Spencer - Wells clamp and gauze to clamp tracheal tube, anti-viral HME filters and a rescue supraglottic airway (if difficult airway is anticipated).	
4. 		5. 	6. 
Prepare a suitable area that is large enough for safe doffing. Staff may have to doff separately to avoid cross-contamination. Two to three trolleys lined with impervious sheets, a biohazard waste receptable, gloves, alcohol wipes and alcohol hand rub should be readily available.		Doffing assistant should be in full PPE - cap, eye protection, N95 mask and gown. We recommend that the doffing assistant don inner and outer gloves.	Consider laying out a few pairs of gloves in preparation for the doffing process to avoid contamination of a clean box of gloves.

Task	Thought Process
Ensure PAPR unit is checked and functioning well.	A malfunctioning PAPR will expose the staff to unfiltered contaminated air. Emergency doffing of a malfunctioning PAPR unit also leads to a much higher chance of contamination.
Don PAPR and PPE safely.	The N95 mask worn must be clean. Staff should don two pairs of gloves if they are performing 'dirty' procedures e.g. intubation. The PAPR should be protected because it is not easy to decontaminate.

Action Plan

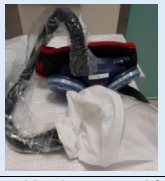
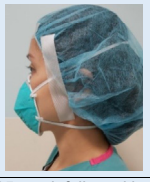
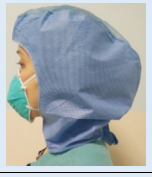
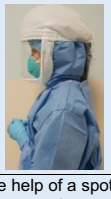
1. 	2. 	3. 	4. 
Turn on the blower unit. Check airflow with airflow indicator tube. Ensure white ball above meniscus. In our hospital, all units are regularly checked with the calibration tube (black ball).	Perform the occlusion test. Ensure red light appears and alarm sounds when outflow occluded. After occlusion is released, ensure green light appears and alarm ceases.	Ensure tubing is protected fully by a plastic sleeve that is secured on both ends with twist ties. Connect tubing to blower unit and hood.	Wear N95 mask followed by shower cap, which helps to prevent accidental dislodgement of N95 straps during doffing. Ensure shower cap covers both ears. Tape shower cap and spectacles (if any).
5. 	6. 	7. 	8. 
Consider donning a surgical hood to protect the ears and neck when using PAPR hoods that do not cover these areas. The hood is tied behind the neck and needs to be removed carefully to avoid contamination.	Don the PAPR unit and PAPR hood. Wear inner gloves, disposable gown and outer gloves. Ensure blower unit is protected by gown, for example, by using a wrap-around surgical gown.	Ensure that outer gloves overlap with sleeves of gown (red arrow) adequately so that the elastic wrist cuffs are always protected.	Engage the help of a spotter or mirror to ensure adequate coverage of face, neck, back and hands.

Fig 1. Jupiter™ PAPR donning, doffing, and decontamination training guide. PAPR, powered air-purifying respirator; PPE, personal preventive equipment.

Task	Thought Process
Induction, intubation and connection to the ventilator circuit.	Minimising generation of aerosols is crucial in reducing risk of staff infection.

Action Plan

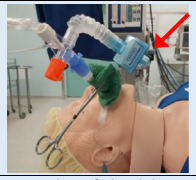
1. 	2. 	3. 	4. 
Minimise number of non-essential personnel during intubation. Use anti-viral HME filters. Optimise mask seal with an air-cushion mask. Adequate pre-oxygenation and rapid sequence induction should be performed to avoid bag-mask ventilation.	Ensure complete paralysis prior to attempting intubation. Optimise first intubation attempt – patient positioning, experienced operator, appropriate choice of laryngoscope and intubation adjuncts.	Inflate tracheal tube cuff as soon as intubation is performed. Top up paralytic if a short-acting agent was used for intubation. Connect tracheal tube to breathing circuit as soon as possible. If there are delays, consider clamping the tracheal tube with a pair of Spencer-Wells clamp.	Auscultation is not easy. Direct visualisation of tracheal tube passing through the vocal cords on the video-laryngoscope, observation of chest rise and $ETCO_2$ monitoring are recommended. If auscultating, do not put stethoscope directly to ears. Ears must be protected by the surgical hood and/or shower cap.
5. 	6. 	7. 	8. 
Consider using an in-line suction device which allows closed-circuit suctioning of tracheal tube secretions.	If disconnection of circuit is necessary, leave the HME filter attached to the tracheal tube and ensure that the patient is well - paralysed. The HME filter should be attached as proximally to the patient as possible.	Ensure proximity of a biohazard waste receptable to dispose of contaminated items.	Place items for decontamination in a disposable kidney dish.

Fig 1. *(continued)*.

Task	Thought Process
Extubation and recovery.	Extubation is a critical process as coughing and removal of ETT may lead to aerosolization and dissemination of virus. Steps should be taken to prevent this.
Doff PAPR and PPE safely.	The main principle is that any contact should be 'clean-to-clean' and 'dirty-to-dirty'.

Action Plan

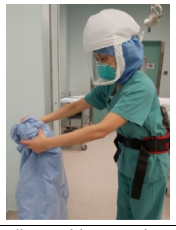
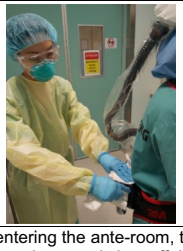
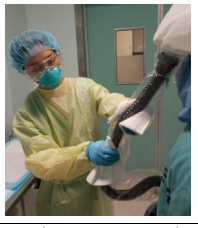
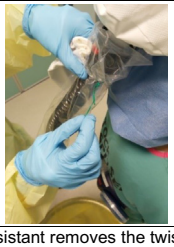
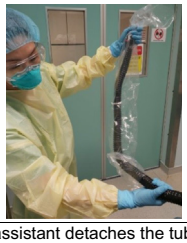
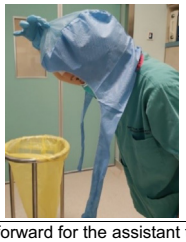
Minimise number of non-essential personnel during extubation. Ensure that the biohazard waste receptable is in close proximity to discard the tracheal tube immediately. Consider deep extubation or use of remifentanil infusion to reduce coughing, if it is deemed clinically appropriate.	Delegate tasks efficiently e.g. anaesthetic nurse to hold suction catheter and deflate tracheal tube cuff, senior anaesthetist to extubate and gently disconnect tracheal tube from circuit while junior anaesthetist applies face mask to patient's face immediately upon extubation and re-connects circuit as soon as possible.	1.  Perform thorough and gentle oropharyngeal and tracheal suctioning prior to extubation.	2.  Place a surgical mask on patient once clinically appropriate. Patient should be recovered in an isolated area e.g. isolation OR.
3.  Once ready to commence doffing, place items to be decontaminated on a 'dirty' trolley. Remove outer gloves in a 'clean-to-clean' and 'dirty-to-dirty' fashion. Put on a pair of new gloves.	4.  Using one hand, wipe face shield in an S-flow direction with an alcohol wipe. If applicable, use the other hand to untie the front of the disposable gown. Discard outer gloves, leaving clean inner gloves.	5.  Doffing assistant unties the back of the disposable gown and rolls it forward.	6.  Remove the disposable gown by pinching the clean inner surface using the clean inner gloves.
7.  Roll the disposable gown inwards and downwards, taking care not to flip or shake the gown. Discard the disposable gown and inner gloves. Perform alcohol hand rub and put on a pair of new gloves prior to entering the ante-room.	8.  Upon entering the ante-room, the doffing assistant switches off the blower unit before wiping the outer components with alcohol wipes.	9.  Doffing assistant uses new alcohol wipes to clean the plastic tubing sleeve starting from the end attached to the blower unit.	10.  The assistant removes the twist ties and discards them in a biohazard waste receptable. The assistant then discards his/her outer gloves.
11.  The assistant detaches the tubing from the PAPR hood and removes the plastic sleeve with one 'clean hand' touching the tubing only (right hand in this picture) and one 'dirty hand' touching the plastic sleeve only (left hand in this picture).	12.  With his/her 'clean hand', the assistant supports the blower unit while the staff unbuckles the belt. The assistant then places the PAPR on the 'dirty' trolley.	13.  Lean forward and with one hand pulling the top of the PAPR hood, and the other hand stabilising the bottom, remove the hood in an outwards motion away from face. Perform alcohol hand rub and put on a pair of new gloves.	14.  Lean forward for the assistant to untie the surgical hood, allowing the straps of the surgical hood to fall forward away from body. Pinch the top of the surgical hood and remove it, avoiding contact with face. Discard surgical hood and gloves.

Fig 1. *(continued)*.

Task	Thought Process
Decontamination of PAPR.	As the PAPR unit and breathing tube will need to be re-used, it is important to decontaminate them thoroughly to prevent infection transmission to the next user. Always start by decontaminating the cleanest items. Wiping of equipment should always be in one direction, ensuring all surfaces are covered with alcohol.

Action Plan

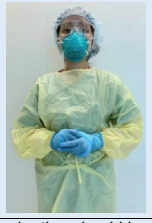
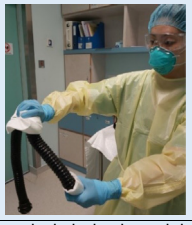
1. 	2. 	3. 	4. 
Decontamination should be performed in appropriate PPE - cap, eye protection, either N95 mask (if already donned) or surgical mask, gown and gloves.	With an alcohol wipe in each hand, detach the tubing from the blower unit. Clean the tubing with alcohol wipes using a rotational motion to catch the grooves on the tubing.	Using a new alcohol wipe, clean the hard components of the blower unit, ensuring all surfaces are covered with alcohol.	Using a new alcohol wipe, clean the fabric straps and buckles.
5. 	6. 	7. 	If conditions allow, shower thoroughly and change into a new set of scrubs.
Place the decontaminated items on the 'clean' trolley to dry.	Using new alcohol wipes, clean the non-disposable equipment that were used and place them in biohazard bags.	Pass these items to the anaesthetic nurse. Several of these items may need to undergo further disinfection or sterilisation.	

Fig 1. *(continued)*.

Focus

The Infection Prevention and Control team developed a concise JIT training programme with the highly specific focus of safe donning, doffing, and decontamination of PAPR, managing PAPR failure, and performing procedures while wearing PAPR.

Training design

Immersive learning and pre-training interventions[3] were used to optimise capability development within the limited time we had. We produced a preparatory instructional video to enhance pre-learning and expedite the practical session. Pictograms and cognitive aids were displayed in the operating rooms (ORs) and Emergency Airway Management Response (EAMR) kit. Educational materials were uploaded on the Intranet and shared via an online platform. Trainees had the option of video recording their training performance for subsequent reflection.

Training scenarios

We prioritised infection prevention and control training for AGPs in two clinical settings: EAMR and the conduct of general anaesthesia (GA) in a COVID-19 patient in the OR. The training placed emphasis on the expected role of the anaesthetist: senior doctors performed tracheal intubation while wearing the PAPR, whereas junior doctors focused on OR preparation and assisting the senior doctor.

Trainee scheduling

We prioritised doctors who may encounter clinical scenarios with minimal logistical support. This included registrars who provide EAMR after hours. We collaborated with the roster maker to assign PAPR-competent anaesthetists to the ORs designated for contagious pathogens.

Principles behind respiratory protection

As a prescriptive model may not always fit unpredictable clinical circumstances, we assisted doctors in developing thought processes that enable them to make safe infection prevention and control decisions independently. Although PAPR may be used for AGPs, the anaesthetist should rely on their best judgement based on patient and medical team safety, bearing in mind that the acuity of the situation, for example critical patient conditions requiring urgent intubation, may preclude safe donning, doffing, and decontamination of a PAPR.

Logistics

We coordinated with the OR director for manpower deployment as training had to be prioritised, and doctors had to be released from routine clinical work. We were able to locate two ORs to conduct training as business-as-usual workload gradually reduced. We liaised with the nursing officer to obtain PAPR units for training, while maintaining sufficient operational units for clinical use.

Training—individual level

For a realistic learning experience, *in situ* simulation was used. This allowed doctors to familiarise themselves with the actual OR set-up and identify possible barriers with the use of PAPR during patient care. The agenda of each session included:

- Clinical scenario of a COVID-19 patient requiring urgent surgery under GA or requiring intubation in the general ward as part of an EAMR.

- A discussion on the thought process of choosing appropriate PPE for different clinical scenarios.
- OR or ward preparation with focus on infection prevention and control measures.
- Checking and donning of PAPR.
- Conduct of GA in OR or urgent intubation in the general ward.
- Capabilities to counter drawbacks of PAPR use:
  - o Safe doffing and decontamination of PAPR.
  - o PAPR failure drill.

Thought processes and step-by-step instructions are detailed in Fig 1, which includes practical pointers to achieve maximal protection. Figure 1 is tailored to the use of Jupiter™ PAPR in the OR, but the same principles can be applied to the use of any PAPR in a variety of clinical settings.

Training—team level

To validate and improve our processes, a multidisciplinary OR drill was organised for an elective tracheostomy, which is a high-risk AGP requiring robust infection prevention and control measures for staff protection. Participants' proficiency in PAPR use was supervised and evaluated by our infection prevention and control team. An inter-professional debrief was conducted to refine our processes further. For example, we observed that our standard isolation gown with back ties may inadvertently expose one's back and risk contamination of the PAPR; hence the wrap-around surgical gown is now recommended when a PAPR is used.

Training—hospital level

Workflow for use of PAPR in an EAMR and for emergency OR cases was tested in the broader context of a hospital-level drill, where a manikin-simulated COVID-19 patient was intubated in the general ward and subsequently transferred for scans and procedures. This drill led to further improvements to the EAMR logistical support by providing a trained OR nurse to bring the Jupiter™ PAPR to the anaesthetist at the EAMR location, assist in safe donning and doffing, and set up of a doffing area.

With rigorous infection prevention and control measures and PAPR training, we managed to keep patient-to-doctor transmission at 0% from January to March 2020, while providing seamless care for the majority of COVID-19 patients in Singapore.

Declarations of interests

The authors declare that they have no conflicts of interest.

References

1. Tran K, Cimon K, Severn M. Aerosol generating procedures and risk of transmission of acute respiratory infections to healthcare workers: a systematic review. *PLoS One* 2012; **7**, e35797
2. Centres for Disease Control and Prevention. *A guide to air-purifying respirators*. DHHS (NIOSH) Publication No. 2018-176; August 2018. https://doi.org/10.26616/NIOSH-PUB2018176. Available from: . [Accessed 14 April 2020]
3. Mesmer-Magnus J, Viswesvaran C. The role of pre-training interventions in learning: a meta-analysis and integrative review. *Hum Resour Manag Rev* 2010; **20**: 261–82

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Reducing droplet spread during airway manipulation: lessons from the COVID-19 pandemic in Singapore

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Keywords: airway management; COVID-19; extubation; infection control; intubation; operating room; prevention

Editor—Coronavirus disease 2019 (COVID-19) was declared a pandemic by the World Health Organization[1] on March 11, 2020 because of its rapid worldwide spread. In the operating theatre (OT), anaesthetists are taking precautions for every patient to minimise perioperative viral transmission as infected patients can be asymptomatic.[2] Airway manipulation poses a high risk of viral transmission to humans within close contact because of the proximity of the respiratory secretions that can aerosolise from coughing and gagging.[3] Supplementary Fig 1 from Chan and colleagues[4] shows the dispersion of respiratory particles: the dispersion distance of exhaled air can range from 42 to 99 mm, and from coughing bouts after intubation up to 460 mm.

The Singapore General Hospital instituted guidelines for airborne and contact precautions, including (i) environmental, reducing staff during airway manipulation, regular disinfection and sterilisation, sufficient air exchange time; and (ii) personal protective equipment (PPE). We identified a potential