Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

significant limitations in their data hamper our ability to interpret the evidence base, but their data do highlight that the real concern is not measuring how limited airway management is by PPE, but rather the need for better understanding of PPE diversity; correct use of PPE; and development and training in new techniques, protocols, and devices to overcome such difficulties. Otherwise, as with the Chinese proverb, 'When the wise points the moon, the fool looks at the finger'.

Declarations of interest

MS has received paid consultancy from Teleflex Medical, Verathon Medical, and DEAS Italia. MS is a patent co-owner (no royalties; DEAS Italia), and received lecture grants and travel reimbursements (MSD Italia and MSD USA). KE has received educational funding and research support from Ambu, Fisher & Paykel Healthcare Ltd, and GE Healthcare. IA has received educational funding from Ambu, Verathon, Fisher & Paykel Healthcare Ltd, and BioMarin. JS declares no competing interests.

References

1. Sanfilippo F, Tigano S, Palumbo GJ, Astuto M, Murabito P. Systematic review of simulated airway management whilst wearing personal protective equipment. *Br J Anaesth* 2020; **125**: e301–5
2. Schumacher J, Arlidge J, Garnham F, Ahmad I. A randomised crossover simulation study comparing the impact of chemical, biological, radiological or nuclear substance personal protection equipment on the performance of advanced life support interventions. *Anaesthesia* 2017; **72**: 592–7
3. Schumacher J, Arlidge J, Dudley D, Sicinski M, Ahmad I. The impact of respiratory protective equipment on difficult airway management: a randomised, crossover, simulation study. *Anaesth Adv* 2020. https://doi.org/10.1111/anae.15102. Access published on April 26
4. Begley JL, Lavery KE, Nickson CP, Brewster DJ. The aerosol box for intubation in coronavirus disease 2019 patients: an in-situ simulation crossover study. *Anaesthesia* 2020. https://doi.org/10.1111/anae.15115
5. Fregene TE, Nadarajah P, Buckley JF, Bigham S, Nangalia V. Use of in situ simulation to evaluate the operational readiness of a high-consequence infectious disease intensive care unit. *Anaesthesia* 2020; **75**: 733–8
6. Yang SS, Zhang M, Chong JJR. Comparison of three tracheal intubation methods for reducing droplet spread for use in COVID-19 patients. *Br J Anaesth* 2020; **125**: e190–1
7. Schumacher J, Gray SA, Weidelt L, Brinker A, Prior K, Stratling WM. Comparison of powered and conventional air-purifying respirators during simulated resuscitation of casualties contaminated with hazardous substances. *Emerg Med J* 2009; **26**: 501–5
8. Sorbello M, Afshari A, De Hert S. Device or target? A paradigm shift in airway management: implications for guidelines, clinical practice and teaching. *Eur J Anaesth* 2018; **35**: 811–4
9. Aberle SJ, Sandefur BJ, Sunga KL, et al. Intubation efficiency and perceived ease of use of video laryngoscopy vs direct laryngoscopy while wearing HazMat PPE: a preliminary high-fidelity mannequin study. *Prehosp Disaster Med* 2015; **30**: 259–63
10. Shin DH, Choi PC, Na JU, Cho JH, Han SK. Utility of the Pentax-AWS in performing tracheal intubation while wearing chemical, biological, radiation and nuclear personal protective equipment: a randomised crossover trial using a manikin. *Emerg Med J* 2013; **30**: 527–31
11. Sorbello M, El-Boghdadly K, Di Giacinto I, et al. The Italian coronavirus disease 2019 outbreak: recommendations from clinical practice. *Anaesthesia* 2020; **75**: 724–32
12. Cook TM, El-Boghdadly K, McGuire B, McNarry AF, Patel A, Higgs A. Consensus guidelines for managing the airway in patients with COVID-19: guidelines from the difficult airway society, the association of anaesthetists the intensive care society, the faculty of intensive care medicine and the royal college of anaesthetists. *Anaesthesia* 2020; **75**: 785–99
13. Peng PWH, Ho P, Hota SS. Outbreak of a new coronavirus: what anaesthetists should know. *Br J Anaesth* 2020; **124**: 497–501
14. Brewster DJ, Chrimes N, Do TB, et al. Consensus statement: safe Airway Society principles of airway management and tracheal intubation specific to the COVID-19 adult patient group. *Med J Aust* 2020; **212**: 472–81
15. Sorbello M, Morello G, Pintaudi S, Cataldo R. COVID-19: intubation kit, intubation team or intubation spots? *Anesth Analg* 2020. https://doi.org/10.1213/ANE.0000000000004970
16. Houghton C, Meskell P, Delaney H, et al. Barriers and facilitators to healthcare workers' adherence with infection prevention and control (IPC) guidelines for respiratory infectious diseases: a rapid qualitative evidence synthesis. *Cochrane Database Syst Rev* 2020; **4**, CD013582

doi: 10.1016/j.bja.2020.06.038
Advance Access Publication Date: 30 June 2020

Use of HEPA filters to reduce the risk of nosocomial spread of SARS-CoV-2 via operating theatre ventilation systems

Sophia Yeo*, Ian Hosein and Leo McGregor-Davies

Medway Maritime Hospital, Kent, UK

*Corresponding author. E-mail: s.yeo@nhs.net

Keywords: aerosol; COVID-19; HEPA filter; infection control; nosocomial spread; operating room; SARS-CoV-2; theatre ventilation

Editor—Transmission of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) via respiratory droplets and surface contacts is clear. The increasing evidence of aerosol disease transmission raises concern of an additional potential route of nosocomial spread. It is within this context that our small obstetric theatre complex presented a novel infection control challenge that we believe other departments may also face.

Positive pressure theatre ventilation is commonplace in operating theatres worldwide. Positive pressure pushes air from our obstetric theatre through large ventilation grills into the adjacent recovery area where the extraction vents reside. This results in potentially contaminated airflow passing directly over the recovery beds (Fig. 1). Current UK guidelines state that positive pressure theatre ventilation should not be considered a risk for aerosol spread to adjacent areas because of the dilution of particles resulting from rapid air changes.[1] This is in conflict with other guidelines which advise that the operative management of coronavirus disease 2019 (COVID-19) patients should take place in a negative pressure or airborne infection isolation room to ensure viral transmission is contained.[2–4]

The proximity of our obstetric recovery beds to aerosol-generating procedures occurring in the obstetric theatre is just over 3 m distant and therefore well within the environmental contamination range described.[5,6] Furthermore, evidence of aerosol concentration downstream of infected subjects highlights the potential for disease spread to staff and patients in our recovery area.[5,7] The potential to expose our staff and recovering non-COVID-19 women and their babies to the bulk flow of the aerosol generated in our COVID-19 theatre seemed unjustifiable even if this were diluted. There is currently little evidence on adapting theatre ventilation systems to reduce the risks of nosocomial spread of SARS-CoV-2. We therefore reviewed the techniques used to produce respiratory isolation rooms described in the literature from previous respiratory disease outbreaks.[8] We outline these options below in the hope of providing potential solutions to colleagues faced with similar challenges.

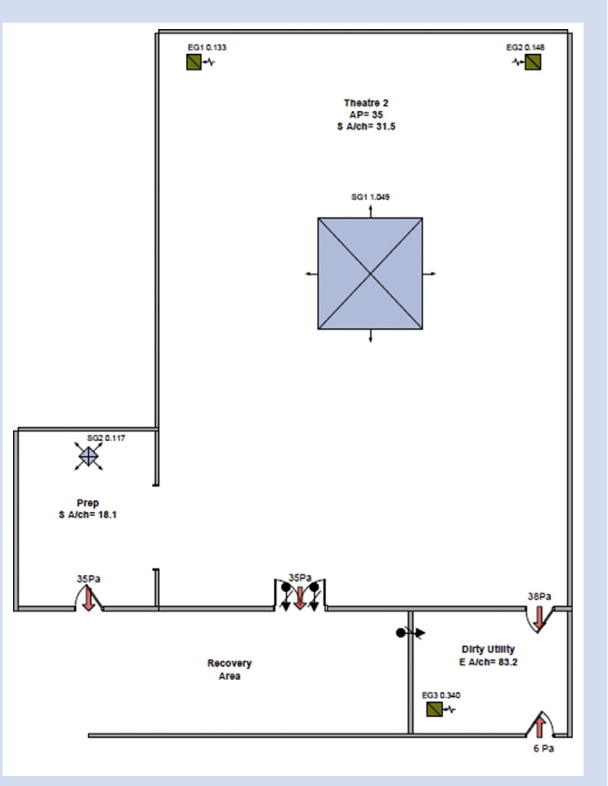

Fig 1. Schematic of ventilation setup in our obstetric coronavirus disease 2019 (COVID-19) theatre showing positive pressure ventilation and bulk airflow direction from theatre to recovery.

Though contrary to national guidelines,[1] we initially trialled turning off the theatre ventilation for the duration of any COVID-19 case, thereby reducing airflow and with it the risk of disease transmission to adjacent areas. However, this resulted in unbearable temperatures in the operating room, especially for staff wearing personal protective equipment (PPE). The increased risk of wound infections was difficult to justify, as was the increased viral aerosol load to which staff would be exposed. Further, the absence of aerosol removal by the ventilation system necessitated the use of prolonged airborne precautions, significantly slowing patient flow.

A seemingly simple way of creating a respiratory isolation area is to modify positive pressure theatre ventilation systems to maintain negative pressure by rebalancing the air input and extraction.[2] Unfortunately, our obstetric theatre does not contain any extraction vents and the airflow in the input vents cannot be reversed, rendering this adaption impossible in our case. Allocating a physically separate theatre complex for COVID-19 patients to reduce the risk of contamination of adjacent areas[3,4] was also impossible in our small obstetric theatre setup.

We considered sealing the ventilation grills between theatre and recovery and installing an exhaust pipe to vent theatre air to the outside to create a make-shift negative pressure room as described in the context of the 2003 severe acute respiratory syndrome (SARS-CoV-1) outbreak.[8] However, this solution required significant structural work, rendering it impracticable.

In the absence of temporary negative pressure respiratory isolation rooms, airborne infectious disease outbreaks have resulted in the use of novel techniques to limit nosocomial disease spread. Amongst these, high-efficacy particulate air (HEPA) filters have been shown to be effective.[8] HEPA filters are composed of mats of randomly arranged fibres that intercept passing particles by a combination of diffusion, interception, and inertial impaction. This confers their filtration capacity which is effective to 99.97% of 0.1 micron particles.[9] Aerosol droplets are 1–5 microns in size. Though research on HEPA filtration of SARS-CoV-2 is yet to be published, their efficacy in capture and containment of diseases of similar particle size is well documented.[9] Because of the low cost and ease of installation, we concluded that fitting a HEPA filter over the

ventilation grills to filter the air passing to recovery was the best solution for our case. We designed a housing for the filters to ensure a good seal.

After installation, theatre ventilation function testing was repeated. In view of the increased resistance to air flow created by the filter, we assessed for a potential air leak, which was found to be significant. The smoke seal on the theatre doors was refitted. Further testing showed that the theatre air changes remained above the recommended minimum 25 per hour with negligible leak and contamination of adjacent areas.

It is important to highlight that in a modified airborne infection isolation room such as this, the mechanical elements degenerate over time, rendering them inefficient and placing staff and patients at risk. They therefore require regular testing and maintenance to ensure they are operating effectively, the frequency of which should be guided by the manufacturer. Usual precautions required in respiratory isolation, such as keeping doors closed and using appropriate protective equipment, must also be adhered to.

As our obstetric theatre setup is not unusual, we considered that we may not be alone in facing this infection control challenge. With the COVID-19 crisis potentially continuing for some time, we wished to share our experience in the hope that this will prove useful to colleagues in other hospitals and trusts.

Authors' contributions

Engineering and technical aspects: LMD
Infection control and prevention consulting: IH
Clinical aspects and research and drafting manuscript: SY
Manuscript proof reading and editing: all authors

Declarations of interest

The authors declare that they have no conflicts of interest.

References

1. Public Health England. *Reducing the risk of transmission of COVID19 in the hospital setting Public Health England* 2020. Available from: https://www.gov.uk/government/publications/wuhan-novel-coronavirus-infection-prevention-and-control/reducing-the-risk-of-transmission-of-covid-19-in-the-hospital-setting. [Accessed 24 April 2020]
2. Tang G, Chan AKM. *Perioperative management of suspected/confirmed cases of COVID-19*. Anaesthesia Tutorial of the Week 2020. Tutorial 421 Available from: https://www.wfsahq.org/components/com_virtual_library/media/1c4ec5c64b9aaacf7c47f76a61fb6edc-atow-422-01.pdf. [Accessed 23 April 2020]
3. Wong J, Goh QY, Tan Z, et al. Preparing for a COVID-19 pandemic: a review of operating room outbreak response measures in a large tertiary hospital in Singapore. *Can J Anaesth* 2020; **67**: 732–45
4. World Health Organisation. *Clinical management of severe acute respiratory infection (SARI) when COVID-19 disease is suspected*. Available from: https://www.who.int/publications-detail/clinical-management-of-severe-acute-respiratory-infection-when-novel-coronavirus-(ncov)-infection-is-suspected. [Accessed 25 April 2020]
5. Guo ZD, Wang ZY, Zhang SF, et al. Aerosol and surface distribution of severe acute respiratory syndrome coronavirus 2 in hospital wards, Wuhan, China. *Emerg Infect Dis* 2020; **26**: 7
6. Ong SWX, Tan YK, Chia PY, et al. Air, surface environmental, and personal protective equipment contamination by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) from a symptomatic patient. *JAMA* 2020; **323**: 1610–2
7. Kurnitski J, Franchimon F, Hogeling J, et al. *How to operate and use building services in order to prevent the spread of the coronavirus disease (COVID-19) virus (SARS-CoV-2) in workplaces. REHVA COVID-19 guidance document*. REHVA: Federation of European Heating, Ventilation and Air Conditioning Associations; 2020. Available from: https://www.rehva.eu/fileadmin/user_upload/REHVA_COVID-19_guidance_document_ver2_20200403_1.pdf. [Accessed 20 April 2020]
8. Rebmann T. Management of patients infected with airborne-spread diseases: an algorithm for infection control professionals. *Am J Infect Contr* 2005; **33**: 571–9
9. Schentag JJ, Akers C, Campagna P, Chirayath P. *SARS: clearing the air*. Washington (DC): National Academies Press; 2004

doi: 10.1016/j.bja.2020.07.013
Advance Access Publication Date: 23 July 2020

Use of a high-flow extractor to reduce aerosol exposure in tracheal intubation

Clyde Matava[1,2,*], Vincent Collard[3], Jeffrey Siegel[4,5], Simon Denning[1,2], Tianyuan Li[4], Bowen Du[4], John Fiadjoe[6], Pierre Fiset[3], Thomas Engelhardt[3], and CLEARANCE Group[†]

[1]Department of Anesthesia and Pain Medicine, Hospital for Sick Children, Toronto, ON, Canada, [2]Department of Anesthesiology and Pain Medicine, Faculty of Medicine, University of Toronto, Toronto, ON, Canada, [3]Department of Anesthesia, McGill University Health Center, Montreal Children's Hospital, Montreal, QC, Canada, [4]Department of Civil and Mineral Engineering, University of Toronto, Toronto, ON, Canada, [5]Dalla Lana School of Public Health, University of Toronto, Toronto, ON, Canada and [6]Department of Clinical Anesthesiology & Critical Care, Perelman School of Medicine at the University of Pennsylvania, Children's Hospital of Philadelphia, Philadelphia, PA, USA