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.

net zero plan is necessary for every nation's healthcare system, particularly the wealthier nations that contribute disproportionately more to global environmental emissions.

COVID-19 has taught us that in the face of imminent disaster, we can abruptly mobilise vast sums of money, alter behaviours of the majority of the populace, and prepare healthcare systems for the worst. Compared with this pandemic, a decade is a very long time to transition to a sustainable economy and avert the worst anticipated impacts from climate change.[14] Anaesthetists and critical care physicians can continue to serve as leaders in the path to a healthier, environmentally sound pandemic recovery. To paraphrase Rabbi Hillel, 'If not us, who? If not now, when?'

Declarations of interest

The authors declare that they have no conflicts of interest.

References

1. White SM, Shelton CL. Effects of the COVID-19 pandemic on environmental sustainability in anaesthesia. *Br J Anaesth* 2020. https://doi.org/10.1016/j.bja.2020.12.003
2. McGain F, Muret J, Lawson C, Sherman JD. Environmental sustainability within anaesthesia and critical care. *Br J Anaesth* 2020; **125**: 680–92
3. Whitmee S, Haines A, Beyrer C, et al. Safeguarding human health in the Anthropocene epoch: report of the Rockefeller Foundation–Lancet Commission on planetary health. *Lancet* 2015; **386**: 1973–2028
4. Liu Z, Ciais P, Deng Z, et al. Near-real-time monitoring of global CO_2 emissions reveals the effects of the COVID-19 pandemic. *Nat Commun* 2020; **11**: 5172
5. Intergovernmental Panel on Climate Change. *Global Warming of 1.5° C. An IPCC special report on the impacts of global warming of 1.5° C above pre-industrial levels and related global greenhouse gas emission pathways* 2018. Available from: https://www.ipcc.ch/sr15/. [Accessed 1 October 2020]
6. United Nations Environment Programme. *Emissions Gap Report 2019*. 2019. Available from https://www.unenvironment.org/resources/emissions-gapreport-2019 [Accessed October 2020]
7. Webster P. Virtual health care in the era of COVID-19. *Lancet* 2020; **395**: 1180–1
8. Kenney P, Chan B, Kortright K, et al. Hydrogen peroxide vapor sterilization of N95 respirators for reuse. *MedRxiv* 2020. https://doi.org/10.1101/2020.03.24.20041087. Adv Access Published March 27, 2020
9. McGain F, Chamberlin M, Milburn J. Environmentally sustainable health care: now is the time for action. *Med J Aust* 2020; **213**: 478
10. MacNeill A, Hopf H, Aman K, et al. A call for medical device industry transformation: toward a circular economy. *Health Aff* 2020; **39**: 2088–97
11. Sherman JD, Hopf HW. Balancing infection control and environmental protection as a matter of patient safety: the case of laryngoscope handles. *Anesth Analg* 2018; **127**: 576–9
12. Sherman JD, Thiel C, MacNeill A, et al. The green print: advancement of environmental sustainability in healthcare. *Res Conserv Recycl* 2020; **161**: 104882
13. NHS England and NHS Improvement. *Delivering a 'net zero' national health service* 2020. Available from: https://www.england.nhs.uk/greenernhs/wp-content/uploads/sites/51/2020/10/delivering-a-net-zero-national-health-service.pdf. [Accessed 1 October 2020]
14. Sherman JD. COVID and climate change. *ASA Monitor* 2020; **84**: 28–9

doi: 10.1016/j.bja.2020.11.031
Advance Access Publication Date: 3 December 2020

Impact of an aerosol box on time to tracheal intubation: systematic review and meta-analysis

Zheng Jie Lim[1,*], Mallikarjuna Ponnapa Reddy[2,3], Dharshi Karalapillai[4], Kiran Shekar[5,6,7,8] and Ashwin Subramaniam[3,9]

[1]Department of Intensive Care Medicine, Ballarat Health Services, Ballarat, VIC, Australia, [2]Department of Intensive Care Medicine, Calvary Hospital, Canberra, ACT, Australia, [3]Department of Intensive Care Medicine, Peninsula Health, Frankston, VIC, Australia, [4]Department of Anaesthesia and Department of Intensive Care Medicine, Austin Health, Heidelberg, VIC, Australia, [5]Department of Intensive Care Medicine, The Prince Charles Hospital, Brisbane, QLD, Australia, [6]School of Medicine, University of Queensland, Brisbane, QLD, Australia, [7]Institute of Health and Biomedical Innovation, Queensland University of Technology, Brisbane, QLD, Australia, [8]School of Medicine, Bond University, Gold Coast, QLD, Australia and [9]Faculty of Medicine, Nursing and Health Sciences, Monash University, Clayton, VIC, Australia

*Corresponding author. E-mail: zhengjie.lim@icloud.com

Keywords: aerosol box; COVID-19; infection control; meta-analysis; SARS-CoV-2; systematic review; tracheal intubation

Editor—The coronavirus disease 2019 (COVID-19) pandemic caused by severe acute respiratory syndrome coronavirus 2 continues to spread, infecting millions worldwide. Critically ill COVID-19 patients with profound respiratory failure often require tracheal intubation. To minimise peri-intubation healthcare worker infection risk from COVID-19, an additional protection barrier known as an aerosol box or intubation box was introduced. Although hospitals worldwide have used various prototypes of aerosol boxes, their effect on intubation remains unclear, with studies suggesting these barriers may hinder and potentially delay airway management.[1] Initial reports raised concerns, such as restricted range of motion and increased intubation difficulty.[2] The aim of this systematic review and meta-analysis was to evaluate the impact of an aerosol box on time to tracheal intubation (TTI). Other factors influencing TTI, such as skill level (experienced proceduralists [consultants] *vs* less experienced proceduralists [residents]) and type of laryngoscope used, were also analysed.

This review was reported using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses framework and was registered on the International Prospective Register of Systematic Reviews (CRD42020220378). Studies evaluating the impact of aerosol box use on TTI were included. Two authors independently searched the COVID-19 living systematic review from January 1, 2020 to November 10, 2020, using the search terms 'barrier', 'box', 'intubate', or 'intubation'. Statistical analyses were performed using Review Manager 5.4 (Cochrane Collaboration). Comparisons between aerosol box and no aerosol box were analysed using mean difference (MD). An estimation formula was used to convert median values to mean values with standard deviation to facilitate statistical analyses.[3] The Cochrane risk-of-bias tool for randomised trials was used.

A total of 54 studies were identified, with 40 studies selected for full-text review (Supplementary Fig 1). Twelve studies reporting on 351 proceduralists were included (Supplementary Table 1). Supplementary table 2 outlines the risk of bias assessment for the selected studies. Supplementary Table 3 summarises the characteristics of selected studies.

All studies provided data on TTI with and without an aerosol box (Supplementary Table 3). Eight studies reported statistically significant ($P<0.05$) increases in TTI with an aerosol box. Fig. 1 demonstrates the impact of aerosol boxes during intubation. TTI was longer when an aerosol box was used (MD=4.0 s; 95% confidence interval [CI]: 2.4–5.6; $P<0.001$). Heterogeneity was moderate ($I^2=38\%$). Amongst 10 studies, where TTI was measured using manikins, TTI was longer with an aerosol box (MD=3.9 s; 95% CI: 2.2–5.5; $P<0.001$; $I^2=45\%$). In two studies, where TTI was measured using patients, the observed TTI was more than double that of when manikins were used, however, not statistically significant (MD=9.4 s; 95% CI: −0.2 to 18.9; $P=0.05$; $I^2=0\%$).

Amongst 136 residents in six studies, the MD in TTI reported remained similar to the overall TTI reported in the primary outcome (Supplementary Fig 2a; MD=4.0 s; 95% CI: 2.1–5.9; $P<0.001$; $I^2=21\%$). However, amongst 159 consultants, TTI with the aerosol box was comparatively lower (Supplementary Fig 2b; MD=2.6 s; 95% CI: 0.8–4.5; $P=0.005$; $I^2=20\%$) than that of residents.

Ten studies reported on TTI using videolaryngoscopy. In these studies, TTI with an aerosol box was significantly longer compared with intubation without an aerosol box (Supplementary Fig 2c; MD=3.7 s; 95% CI: 1.7–5.7; $P=0.0004$; $I^2=54\%$). Intubation with direct laryngoscopy yielded longer TTI compared with videolaryngoscopy (Supplementary Fig 2d; MD=4.5 s; 95% CI: 2.4–6.6; $P<0.001$; $I^2=45\%$). Where consultants performed the intubation with a videolaryngoscope, an increase in TTI was not statistically significant (Supplementary Fig 2e; MD=1.9 s; 95% CI: −0.04 to 3.8; $P=0.06$; $I^2=26\%$). In a *post hoc* analysis, first-pass success was significantly lower amongst intubations with an aerosol box (482/533; 90.4%; 95% CI: 87.6–92.8%) than without an aerosol box (499/521; 95.8%; 95% CI: 93.7–97.3%). Personal protective equipment (PPE) breaches were reported in three studies, where breaches were significantly more common when an aerosol box was used (19/58; 32.8%; 95% CI: 21.0–46.3%) than when no aerosol box was used (0/46; 0.0%; 95% CI: 0.0–7.7%).

We observed a significant increase in TTI when an aerosol box was used. Multiple factors, such as increased procedural difficulty, lack of experience, and cognitive overload for the proceduralist, may prolong TTI.[4,5] Although a mean delay of 4 s may seem negligible in the overall intubation time sequence, it is important to consider that simulated studies do not fully capture the influence human factors can play in real-life situations. This prolonged TTI should be considered in the context of critically ill patients with COVID-19, where risk of hypoxaemia can be higher, underpinning the importance of minimising apnoea time amongst these patients.[6,7] The finding of relatively shorter TTI by consultants supports the recommendation that the most experienced physician should be involved with intubating suspected or confirmed COVID-19 patients.[8]

A meaningful interpretation of these findings necessitates a careful risk–benefit analysis from both patient and proceduralist perspectives. On the one hand, the use of an aerosol box may prolong TTI to a variable degree based on proceduralist experience, exposing patients to a risk of hypoxaemia.[4] On the other hand, damage to conventional PPE when using the box potentially increases aerosol exposure, placing the proceduralist and others assisting in airway management at risk of infection.[9] Hence, with the current available evidence, it is important that proceduralists need to consider with caution the ongoing use of aerosol boxes when its use is delaying TTI without improving safety for healthcare professionals.

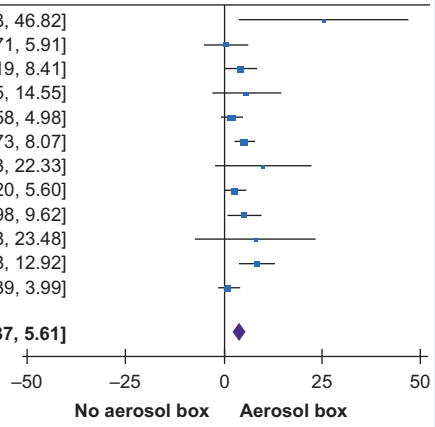
The limitations of this systematic review include the use of manikins to simulate intubation in most studies, variability in the definition for TTI between studies, and lack of evaluation of clinical or patient-centred outcomes.

In conclusion, TTI when an aerosol box was used was significantly longer compared with intubation without an aerosol box. TTI was relatively shorter when intubation was performed by more experienced proceduralists using videolaryngoscopy. These findings should be interpreted in the context of increased infection risks to the proceduralist and other healthcare workers assisting with airway management.

a

Study or subgroup	Aerosol box Mean	SD	Total	No aerosol box Mean	SD	Total	Weight (%)	Mean difference IV, random, 95% CI
Begley 2020	67.1	36.6	12	41.6	9	12	0.6	25.50 [4.18, 46.82]
Chun-Fai 2020	17.7	13.9	41	17.1	10.4	41	6.8	0.60 [–4.71, 5.91]
Clariot 2020	53	12.2	47	48.7	7.6	47	9.7	4.30 [0.19, 8.41]
Fong 2020	30.9	23	34	25.1	12.2	34	3.0	5.80 [–2.95, 14.55]
Idei 2020	20.7	6.1	30	18.5	4.8	30	14.6	2.20 [–0.58, 4.98]
Laack 2020	20.9	7.3	50	15.5	6.3	50	15.1	5.40 [2.73, 8.07]
Madabhushi 2020	52.1	13.3	8	42	11.6	8	1.6	10.10 [–2.13, 22.33]
Saito 2020	17	5.2	20	14.1	3.3	20	15.0	2.90 [0.20, 5.60]
Serdinsek 2020	30.6	10.6	36	25.3	7.9	36	9.1	5.30 [0.98, 9.62]
Trujillo 2020	26.7	16.1	7	18.5	12.9	7	1.1	8.20 [–7.08, 23.48]
Turner 2020	20.6	13.9	48	12.2	7.9	48	8.5	8.40 [3.88, 12.92]
Wakabayashi 2020	15	4.5	18	13.7	3.7	18	15.0	1.30 [–1.39, 3.99]
Total (95% CI)			**351**			**351**	**100.0**	**3.99 [2.37, 5.61]**

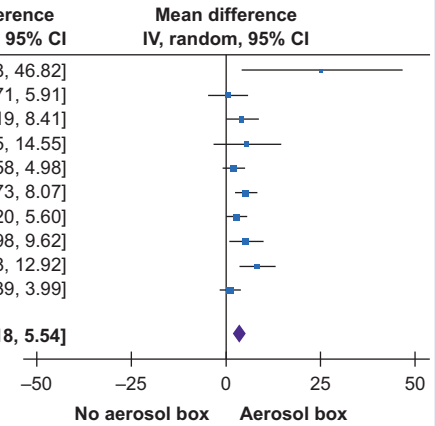
Heterogeneity: τ^2=2.67; χ^2=17.75, df=11 (P=0.09); I^2=38%
Test for overall effect: Z=4.83 (P<0.00001)



b

Study or subgroup	Aerosol box Mean	SD	Total	No aerosol box Mean	SD	Total	Weight (%)	Mean difference IV, random, 95% CI
Begley 2020	67.1	36.6	12	41.6	9	12	0.6	25.50 [4.18, 46.82]
Chun-Fai 2020	17.7	13.9	41	17.1	10.4	41	7.2	0.60 [–4.71, 5.91]
Clariot 2020	53	12.2	47	48.7	7.6	47	10.0	4.30 [0.19, 8.41]
Fong 2020	30.9	23	34	25.1	12.2	34	3.2	5.80 [–2.95, 14.55]
Idei 2020	20.7	6.1	30	18.5	4.8	30	14.9	2.20 [–0.58, 4.98]
Laack 2020	20.9	7.3	50	15.5	6.3	50	15.3	5.40 [2.73, 8.07]
Saito 2020	17	5.2	20	14.1	3.3	20	15.2	2.90 [0.20, 5.60]
Serdinsek 2020	30.6	10.6	36	25.3	7.9	36	9.4	5.30 [0.98, 9.62]
Turner 2020	20.6	13.9	48	12.2	7.9	48	8.9	8.40 [3.88, 12.92]
Wakabayashi 2020	15	4.5	18	13.7	3.7	18	15.2	1.30 [–1.39, 3.99]
Total (95% CI)			**336**			**336**	**100.0**	**3.86 [2.18, 5.54]**

Heterogeneity: τ^2=2.96; χ^2=16.33, df=9 (P=0.06); I^2=45%
Test for overall effect: Z=4.49 (P<0.00001)



c

Study or subgroup	Aerosol box Mean	SD	Total	No aerosol box Mean	SD	Total	Weight (%)	Mean difference IV, random, 95% CI
Madabhushi 2020	52.1	13.3	8	42	11.6	8	61.0	10.10 [–2.13, 22.33]
Trujillo 2020	26.7	16.1	7	18.5	12.9	7	39.0	8.20 [–7.08, 23.48]
Total (95% CI)			**15**			**15**	**100.0**	**9.36 [–0.19, 18.91]**

Heterogeneity: τ^2=0.00; χ^2=0.04, df=1 (P=0.85); I^2=0%
Test for overall effect: Z=1.92 (P=0.05)

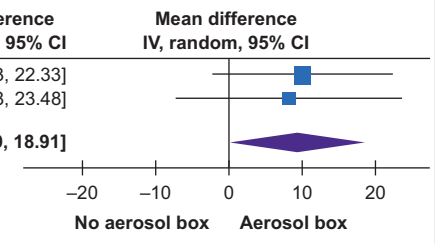


Fig 1. Primary outcome: time to intubation: (a) all selected studies, (b) studies using simulations and manikins, and (c) amongst patients. CI, confidence interval; SD, standard deviation; IV, Inverse Variance.

Declarations of interest

The authors declare that they have no conflicts of interest.

Acknowledgements

The authors thank Nejc Umek, Praneeth Madabhushi, and Alexander Trujillo for providing additional information that made this systematic review and meta-analysis possible.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.bja.2020.11.036.

References

1. Sorbello M, Rosenblatt W, Hofmeyr R, Greif R, Urdaneta F. Aerosol boxes and barrier enclosures for airway management in COVID-19 patients: a scoping review and narrative synthesis. *Br J Anaesth* 2020; **125**: 880–94

2. Gould CL, Alexander PDG, Allen CN, McGrath BA, Shelton CL. Protecting staff and patients during airway management in the COVID-19 pandemic: are intubation boxes safe? *Br J Anaesth* 2020; **125**: e292–3
3. Hong Kong Baptist University. *Estimating the sample mean and standard deviation from the sample size, median, range and/or interquartile range* 2020. Available from: http://www.math.hkbu.edu.hk/~tongt/papers/median2mean.html. [Accessed 20 November 2020]
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; **75**: 1014–21
5. Fong S, Li E, Violato E, Reid A, Gu Y. Impact of aerosol box on intubation during COVID-19: a simulation study of normal and difficult airways. *Can J Anaesth* 2020: 1–9
6. Yao W, Wang T, Jiang B, et al. Emergency tracheal intubation in 202 patients with COVID-19 in Wuhan, China: lessons learnt and international expert recommendations. *Br J Anaesth* 2020; **125**: e28–37
7. Arentz M, Yim E, Klaff L, et al. Characteristics and outcomes of 21 critically ill patients with COVID-19 in Washington State. *JAMA* 2020; **323**: 1612–4
8. Kearsley R. Intubation boxes for managing the airway in patients with COVID-19. *Anaesthesia* 2020; **75**: 969
9. Simpson JP, Wong DN, Verco L, Carter R, Dzidowski M, Chan PY. Measurement of airborne particle exposure during simulated tracheal intubation using various proposed aerosol containment devices during the COVID-19 pandemic. *Anaesthesia* 2020; **75**: 1587–95

doi: 10.1016/j.bja.2020.11.036
Advance Access Publication Date: 4 December 2020

Repeated vaporised hydrogen peroxide disinfection of 3M 1860 N95 mask respirators does not degrade quantitative fit performance

Phillip Moschella[1,*,†], Wesley Liao[1,*,†], Alain Litwin[1], Jonn Foulk[2], Jeff Anthony[3], Matt Player[4], Jerry Chang[5] and Christine Cole[2]

[1]Prisma Health: Upstate Affiliate, University of South Carolina School of Medicine Greenville, SC, USA, [2]Department of Materials Science and Engineering, Clemson University, Clemson, SC, USA, [3]Office of Occupational and Environmental Safety, Clemson University, Clemson, SC, USA, [4]Office of Infection Prevention and Control, Prisma Health: Upstate Affiliate, Greenville, SC, USA and [5]Samaritan Biologics, J. Crayton Pruitt Department of Biomedical Engineering, University of Florida, Gainesville, FL, USA

*Corresponding author. E-mails: Phillip.Moschellal@prismahealth.org, Wesley.Liao@prismahealth.org

†Both authors contributed equally to this work.

Keywords: COVID-19; fit testing; mask respirator; N95 mask; personal protective equipment; reuse

Editor—We describe our mask recycling and repeated National Institute for Occupational Safety and Health (NIOSH) quantitative fit testing as performed by a multidisciplinary collaboration of clinicians and materials science experts to address the current shortages of appropriate personal protective equipment (PPE) caused by the current coronavirus disease 2019 pandemic.

Disposable filtering face-piece respirators (FFRs), including N95 masks, are mainstays of PPE designed to prevent the spread of aerosolised infections. Worldwide demand because of the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) pandemic has outstretched worldwide N95 FFR supplies.[1–3] To mitigate these shortages, extended use or limited reuse of N95 FFRs in healthcare settings is under investigation; the US Centers for Disease Control and Prevention (CDC) currently recommends isolating used FFRs in a paper bag and allowing 72 h for any residual virus to deactivate.[4] Other decontamination techniques (ultraviolet light, vaporised hydrogen peroxide, and moist heat) have been suggested, but not currently endorsed by the CDC.[4]

Our health system addressed shortages of N95 FFRs by instituting a vaporised hydrogen-peroxide-based system to disinfect the most abundant commercially available N95 FFR currently in use at our institution: the 3M® model 1860 dome-type N95 FFR. We chose to reprocess these FFRs for reuse to expand our stockpiles for use by healthcare workers and remove the need to isolate masks for 72 h. Previously published results on decontamination of N95 masks (including the same 3M 1860 N95 FFR) using vaporised hydrogen peroxide have focused on the results of this sterilisation technique and the performance of the decontaminated mask material only.[5–8] There are no studies using the NIOSH quantitative fit testing of decontaminated masks to assess both the fit and function of a full mask after repeated decontamination using 35% vaporised hydrogen peroxide (35% VHP).