BJA

British Journal of Anaesthesia, 125 (6): 880–894 (2020)

doi: 10.1016/j.bja.2020.08.038
Advance Access Publication Date: 3 September 2020
Review Article

Aerosol boxes and barrier enclosures for airway management in COVID-19 patients: a scoping review and narrative synthesis

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Summary

Exposure of healthcare providers to severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is a significant safety concern during the coronavirus disease 2019 (COVID-19) pandemic, requiring contact/droplet/airborne precautions. Because of global shortages, limited availability of personal protective equipment (PPE) has motivated the development of barrier-enclosure systems, such as aerosol boxes, plastic drapes, and similar protective systems. We examined the available evidence and scientific publications about barrier-enclosure systems for airway management in suspected/confirmed COVID-19 patients. MEDLINE/Embase/Google Scholar databases (from December 1, 2019 to May 27, 2020) were searched for all articles on barrier enclosures for airway management in COVID-19, including references and websites. All sources were reviewed by a panel of experts using a Delphi method with a modified nominal group technique. Fifty-two articles were reviewed for their results and level of evidence regarding barrier device feasibility, advantages, protection against droplets and aerosols, effectiveness, safety, ergonomics, and cleaning/disposal. The majority of analysed papers were expert opinions, small case series, technical descriptions, small-sample simulation studies, and pre-print proofs. The use of barrier-enclosure devices adds to the complexity of airway procedures with potential adverse consequences, especially during airway emergencies. Concerns include limitations on the ability to perform airway interventions and the aid that can be delivered by an assistant, patient injuries, compromise of PPE integrity, lack of evidence for added protection of healthcare providers (including secondary aerosolisation upon barrier removal), and lack of cleaning standards. Enclosure barriers for airway management are no substitute for adequate PPE, and their use should be avoided until adequate validation studies can be reported.

Keywords: aerosol box; aerosol-generating procedures; COVID-19; droplets; intubation box; tracheal intubation

Received: 12 June 2020; **Accepted:** 18 August 2020

Editor's key points

- Airway management in patients with COVID-19 carries the risk of aerosol and droplet transmission of the virus.
- Shortages of personal protective equipment have prompted the development of many novel barriers to reduce the risk to practitioners.
- Evidence for the effectiveness of these barriers is currently lacking, and some studies suggest that they may hinder airway management, bringing additional risk.
- Before 'airway management isolation boxes' (and other barriers) can be recommended for widespread clinical use, further study in the simulation and clinical environments is needed.

According to Greek mythology, when Prometheus stole fire from the gods, Zeus took his revenge by introducing Prometheus's brother, Epimetheus, to Pandora. This curious lady opened a box she had been given for safekeeping, thereby unleashing disease, death, and uncountable evils into the world.

Since then, 'Pandora's box' has become an idiom representing 'any source of great and unexpected troubles' or 'a present which seems valuable, but which in reality is a curse'.[1] Coronavirus disease 2019 (COVID-19) may not have been one of the maladies contained in Pandora's box, but the pandemic provides an opportunity to discuss similar mysterious new coffers.

Regional shortages of personal protective equipment (PPE) have triggered concerns regarding the transmission of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) by respiratory droplets and aerosols during airway management. A large number of aerosol boxes, plastic covers, tents and sheets, and similar barrier-enclosure systems have been proposed to augment or adjunct PPE. None of these barrier devices have undergone rigid evaluation and validation. This review aims to highlight the features of the variously proposed solutions, and discuss limitations, potential pitfalls, and dangers related to their use as tools to prevent healthcare provider (HCP) contamination and infection during airway management.

Search methods

A literature review was performed in MEDLINE, Embase, and Google Scholar databases, including publications from December 1, 2019 to May 27, 2020. Articles pertaining to barrier enclosures for airway management in the context of COVID-19 in any language were retrieved. The search strategy used included the following search terms: '(((COVID OR COVID-19 OR coronavirus) AND (airway OR airway management OR intubation) AND (aerosol box OR intubation box OR airway box OR barrier enclosure OR tent OR barrier OR sheet OR protection OR shield OR drape OR aerosol-generating procedure OR droplet OR safety))) AND ('2019/12/01' [Date - Publication]:

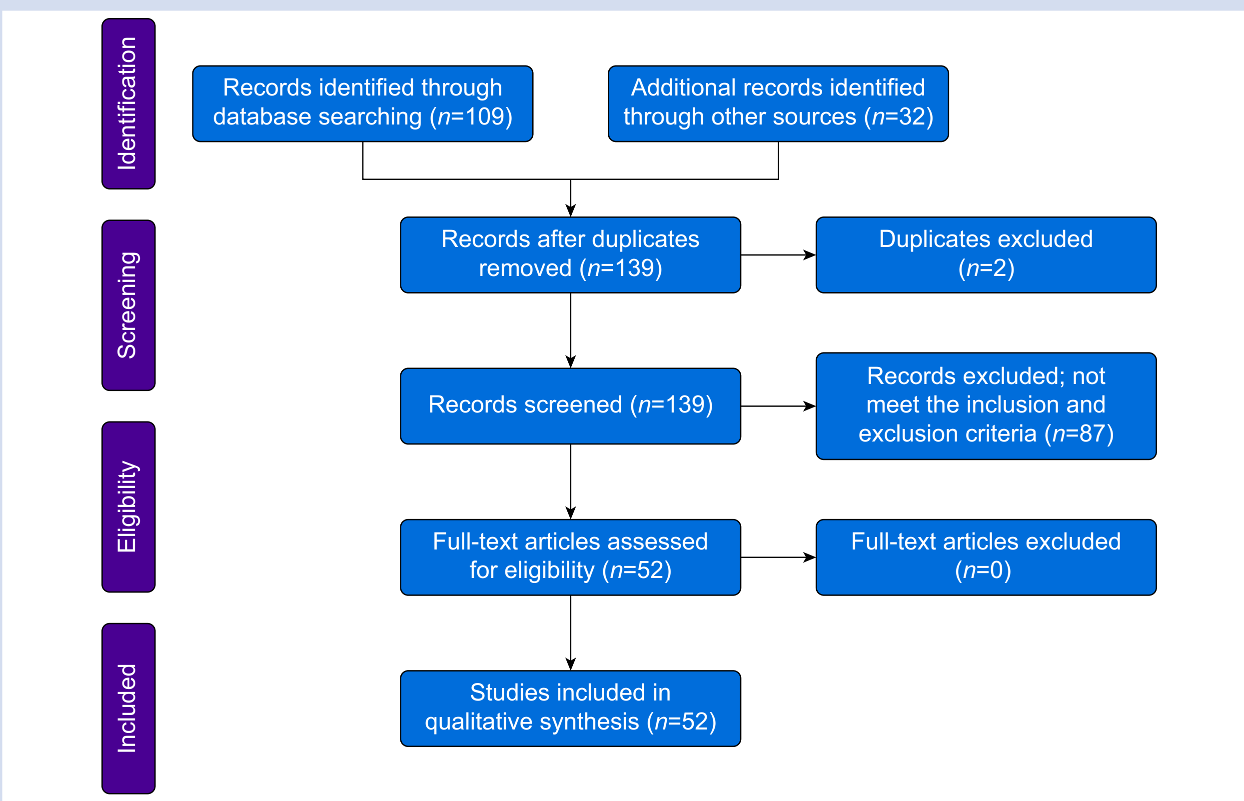

Fig 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram of the study.

Table 1 Characteristics of the reviewed reports. List and study characteristics of all references included in the review (see Methods for detail). AB, aerosol box; COVID-19, coronavirus disease 2019; CPD, clear plastic drape; CPR, cardiopulmonary resuscitation; CPS, clear plastic sheet; ENT, ear, nose, and throat; FDA, Food and Drug Administration; LMA, *laryngeal mask airway;* N/A, not available; OT, operating theatre; PeDI-C, Pediatric Difficult Intubation Collaborative; PPE, personal protective equipment; SAD, supraglottic airway device; VLS, videolaryngoscope.

Reference	Article type	Study design	Type of barrier	Sample size	Study setting	Summary of interventions	Main findings
Canelli and colleagues[4]	Correspondence	Simulated cough and investigated contamination of the laryngoscopist	Acrylic AB	Two (case + control)	Simulated cough on mannequin and investigated contamination of the laryngoscopist with or without AB	Application of AB	AB minimises large droplet diffusion.
Cubillos and colleagues[5]	Correspondence	Description of barrier-enclosure system	Rigid plastic frame + plastic bag + vacuum	N/A (1 simulation—12 operators?)	Not specified tests (qualitative assessment of clearance of fluorescein tracer, and contamination of the operator, bag, table, and support structures)	Barrier-enclosure system for intubation	During a simulated airway management training session of our COVID-19 intubation team, direct vision, communication, and manoeuvrability were accomplished for 12 operators.
Fonseca and colleagues[6]	Correspondence	Technical description	Anti-Aerosol Igloo (polyethylene terephthalate + CPS)	N/A	Simulation; case series (not described)	Description of the enclosure barrier	Seamless, single-piece element shaped like an igloo; easy to clean; lightweight; given the shape, minimal aerosol escape
Rahmoune and colleagues[7]	Correspondence	Clinical report	Recycled neonatal incubator hood	N/A	Unspecified tests on patients in OT/ICU	Application of recycled neonatal incubator hood for airway management	Intubation feasible, robust, economic; disadvantage: weight, some movements relatively limited
Lai and Chang[8]	Correspondence	Clinical report	Carton AB + plastic wrap	N/A	N/A	Application of carton/plastic AB for airway management	Economic; limited visibility; patient's discomfort
Au Yong and Chen[9]	Correspondence	Experimental report	Plastic tent/screen	N/A	Human volunteer simulations	Application of plastic tent/ screen for intubation and extubation	Low cost, easy availability, and disposability; room for VLS and bougie
Lim and colleagues[10]	Correspondence in response to research letter	Commentary	Plastic tent/screen	N/A	N/A	Application of plastic tent/ screen for intubation and extubation	Concerns for claustrophobia, secondary aerosolisation, impingement of airway devices
Yang and colleagues[11]	Correspondence	Simulation study	AB	N/A (single test?)	Comparison of tracheal intubation with direct laryngoscopy, VLS, and VLS + acrylic AB; measurement of trajectory and amount of droplet spread (atomiser model) in airway mannequin (detection system not detailed)	Effect of AB on trajectory and amount of generated droplets	Laryngoscopy: large amount of dye on the laryngoscopist's face shield, gown, arms, glove, neck, and hair; VLS: significantly lower amount of dye on the laryngoscopist in similar locations, visually less than half the quantity than direct laryngoscopy; VLS + AB: dye only on the gloves and forearms within the box; no dye on any part of the laryngoscopist located outside the box, including gown, face shield, neck, and hair; AB is additional protection against droplets, although redundant if proper PPE are used

Continued

Table 1 Continued

Reference	Article type	Study design	Type of barrier	Sample size	Study setting	Summary of interventions	Main findings
Matava and colleagues[12]	Correspondence	Simulation study	CPD	Single series of two experiments	Assessing if CPD contains aerosolisation during extubation with simulated cough by use of fluorescent resin powder with particle sizes between 1 and 5 μm with UV light detection in a darkened OT	Simulated extubation and coughing: measurement without (Exp. 1A) and with (Exp. 1B) a single CPD applied over the head and tracheal tube; second experiments (Exp. 2) using a modified three-layer CPD configuration	Use of a single CPD (Exp. 1B) restricted the aerosolisation and droplet spraying of the particles; the three-drape technique (Exp. 2) significantly reduced contamination of the immediate area surrounding the patient; limitation: dye droplets much larger than aerosolised droplets
Malik and colleagues[13]	Correspondence	Simulation study (?)	AB + CPS	N/A; report of 'trials' (in mannequin? not described)	Modification of AB, including CPS proposed for airway management, including extubation, tracheostomy, tube exchange, gastric tube placement, patient transfer	Use of AB + CPS for airway management	Improved ergonomics, visibility, and room for instrumentation; ramped position possible; side ports; discouraged for emergency, vigilance to avoid PPE disruption
Cordier and colleagues[14]	Correspondence	Clinical report	External fixator wrapped with a single-use clear surgical C-arm plastic cover	N/A	N/A	Application of barrier enclosure for tracheostomy and cannula exchange	Tracheostomy feasible
Zeidan and colleagues[15]	Correspondence	Case report	Plastic AB	1	Case report of single intubation	Plastic AB placed after induction, coupled with VLS + bougie	Use of bougie associated with increased viral spread; need for protection during intubation
Lang and colleagues[16]	Correspondence	Particles (>0.3 μm) count with and without negative-pressure system	Negative-pressure isolation hood (plastic cover + supports + smoke evacuator)	One single measurement	Experiment description	Application of negative-pressure generation within barrier-enclosure system	Reduction of 98% of particles: 183 *vs* 5 min without and with negative pressure, respectively
Jain[17]	Correspondence	Commentary	Adjustable frame and CPS + suction system	N/A	N/A	Construction of modified enclosure barrier	Missing FDA approval for all models; idea of new adjustable barrier-enclosure system (not described)
Kearsley[18]	Correspondence	Commentary	Plastic AB	N/A	N/A	Plastic AB for airway management	Criticism for missing limitation of aerosols, patient's fitting, intubation success rate, risk of PPE disruption, and complexity
Gould and colleagues[19]	Correspondence in response to research letter	Simulation study	AB	N/A	Simulation (?)	Application of AB	Test of AB in simulation setting increased the difficulty of tracheal intubation, especially during transition between airway devices and when using intubation adjuncts, such as the gum elastic bougie.
Sorbello and colleagues[20]	Correspondence in response to research letter	Commentary	CPS	N/A		CPS over supraglottic airways during CPR	Criticism for difficult manipulation, unfeasible position tests, SAD-aided intubation, delay in CPR, and risk of fire
		Simulation study		N/A	Mannequin (?)		

Continued

Table 1 Continued

Reference	Article type	Study design	Type of barrier	Sample size	Study setting	Summary of interventions	Main findings
Endersby and colleagues[21]	Correspondence in response to research letters		Surgical Mayo stand + C-arm plastic drape			Detection of Glo Germ fluorescent dye atomised by laryngotracheal mucosal atomisation device to simulate the production of fine droplets and aerosol	Without barrier, Glo Germ identified on the laryngoscopist's hands, arms, gown, neck, face, eye protection, mask, and extended spread around the OT
Laosuwan and colleagues[22]	Correspondence	Simulation study	AB (3 configurations); CPS	Five simulations for each configuration (AB1, AB2, AB3, CPS, and no barrier) in simulated extubation		Self-designed droplet-generating device with fluorescent dye used to compare three AB configurations (number of stained 5×5 squares outside the boxes: around the mannequin, on the chest of the mannequin, and on the anaesthetist's gown and face shield	Overall droplet dispersion: acrylic AB models (3.3−19.0%), CPS (2.8%), and non-coverage technique (26.3%); all AB showed no contamination on anaesthesia personnel; CPS caused contamination both on the chest and abdomen of anaesthetist (self-contamination)
Brown and colleagues[23]	Letter to the editor	Clinical report	CPD on bag barrier system	N/A	Mannequin and patients	Application of CPD on bag barrier system for airway management	Economic and intubation feasible, including assistant's help; proposed removal of the clear drape during mid-laryngoscopy in case of difficulty
Leyva Moraga and colleagues[24]	Letter to the editor	Clinical report	AB	Five patients	N/A	Application of AB for intubation/extubation	AB has proved to be a valuable resource functioning as an adaptive tool to aid in resource-limiting setting. The AB did not represent an obstacle to established protocol, acting as feasible solution in low- and middle-income healthcare settings.
Yang and colleagues[25]	Letter to the editor	Technical report	CPS with incisions and tape reinforce	N/A	Mannequin?	Use of modified CPS for intubation and extubation (left in place)	Modification aimed to improve laryngoscopic manoeuvring; multi-layer option
Babazade and colleagues[26]	Letter to the editor	Technical report	CPS with cross-cut	N/A	Mannequin?	Use of modified CPS for airway management	Economic; intubation feasible
Rehm and colleagues[27]	Letter to the editor	Clinical report	Full-body CPS	N/A (60 patients?)	Mannequin and patients	Use of total-body CPS for airway management	Economic; intubation feasible; also for transport
Scapigliati and colleagues[28]	Letter to the editor	Technical report	CPS	N/A	CPS over SAD during CPR in mannequin model	Hypothesis of aerosol limitation when using SAD during CPR; measurement of differential inspiration/expiration with spirometer during simulated mechanical ventilation	Hypothesis of efficacy
Patino Montoya and Chitilian[29]	Letter to the editor	Technical report	CPS with midline slit	N/A	CPS sealed to tracheal tube to prevent aerosolisation and droplets during extubation	Use of CPS for extubation	The CPS blocks the dispersion of aerosolised particles during extubation.
Rosenblatt and Sherman[30]	Letter to the editor	Commentary	AB	N/A	N/A	N/A	Restrictions in movement and limitations in emergency; heavy for carrying/moving; issues with cleaning
Fang and colleagues[31]	Letter to the editor	Technical report	Frame and CPS	N/A	Patients?	Construction of enclosure barrier	Economic, flexible, and lightweight
Swart and Strydom[32]	Letter to the editor	Simulation study					

Continued

Table 1 Continued

Reference	Article type	Study design	Type of barrier	Sample size	Study setting	Summary of interventions	Main findings
			Plastic AB + CPS + suction tube	One experiment in four steps	Optical evaluation of smoke spreading	Home-made smoke source to explore AB retaining capacity	AB effectively limits aerosol spread qualitatively, but even adding suction and CPS covering AB does not prevent the escape of aerosol, especially when the internal volume is accessed through arm holes.
Brown and colleagues[33]	Letter to the editor	Simulation study	CPS over Mayo table frame	Two experiments, comparing with AB	Atomised droplet model using fluorescent dye and qualitative assessment	CPS over Mayo frame compared with traditional AB	Less spread using CPS over Mayo frame than with traditional AB
Hung and colleagues[34]	Research letter	Simulation study	CPS tent + suction system applied	N/A	CPS tent + suction applied for simulated extubation on mannequin	Barrier-enclosure system for extubation	Solution to limit the small droplet diffusion out of conventional AB; used successfully in simulation and clinical experience
Suresh[35]	Letter to the editor	Technical report	Acrylic AP/CPS tent	N/A	N/A	Barrier-enclosure systems for airway management: AB, CPS tent, and C-ARM cover for anaesthesiologist	Suggested use of 'home-made' PPE for preserving available resources during the pandemic
Puthenveettil and Vijayaraghavan[36]	Letter to the editor	Technical report	Acrylic AB (asymmetric ports)	N/A	N/A	AB for airway management (including nasotracheal intubation and LMA placement)	AB is ergonomic because of asymmetric ports; not advised for difficult intubation. Authors recommend this device be used for all patients so that the learning curve can be reached before intubation has to perform actual critical COVID patients.
Asokan and colleagues[37]	Letter to the editor	Technical report	Acrylic AB (C-shaped curved side panels) with or without CPS	N/A	Description and experience in 50+ patients (no information provided)	AB for airway management, including obese	The C-shaped curved side panels are ergonomic for assistant use in obese; proved safe and effective
Singh and colleagues[38]	Letter to the editor	Technical report	CPS + frame with linear cuts	N/A	N/A	CPS + frame for airway management	Adaptable and lightweight; suggested cleaning before removal with alcohol-based disinfectant spray be done in the chamber with the patient breathing spontaneously through face mask and eyes closed
Raimann and colleagues[39]	Letter to the editor	Simulation study	Modified packaging tray used for heart–lung machine sets (cut/glued/polished)	Two experiments (with/without barrier)	Simulated cough in mannequin with a mucosal atomisation device filled with a fluorescent dye	Inspective evaluation of fluorescent dye	Effective and protective; limits spread of large droplets
Martin and colleagues[40]	Original article		Modified packaging tray used for heart–lung machine sets (cut/glued/polished)	N/A	N/A	Modified medical packaging (COVid aErosol pRotEction Dome—'COVERED')	Economic; recycled material; help possible; need for training, limitations for other manoeuvres, advanced airway techniques, obese patients; intended as extra barrier to be added, and not to replace PPE

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Table 1 Continued

Reference	Article type	Study design	Type of barrier	Sample size	Study setting	Summary of interventions	Main findings
Francom and colleagues[41]	Original article	Multicentre protocol description	Complete CPS tent (bed/body/suspension over head and chin) + frames + smoke evacuator	N/A	Simulations and paediatric patients series	Description of surgical procedures (suspected airway foreign body, microlaryngoscopy, and flexible/rigid bronchoscopy) in paediatric patients with tent in place	The tents are sound to decrease aerosolisation and droplet contamination; little to no added risk to the patient, as the drapes may be rapidly removed; greatly perceived benefit to the safety of the anaesthesiologist, surgeon, and OT staff involved; tent does not replace the need for individual PPE; it can be used when PPE is scarce and preoperative testing is unavailable.
Foster and colleagues[42]	Original article	Case report	Combination of CPD, magnetic mat, surgical retractor, and smoke evacuator	One patient	Technical description + clinical report	Use of combination of CPD, magnetic mat, surgical retractor, and smoke evacuator for performance of tracheostomy	Effective and allows safe performance of tracheostomy
Pollaers and colleagues[43]	Original article	Case series	'Suspension box' (polymethyl methacrylate [Perspex] box with three open sides + CPS)	Eight paediatric patients	Case series in operatory room	Description of a modified technique for paediatric microlaryngoscopy and bronchoscopy	Suspension box, PPE, and team arrangement are theoretically associated with reduced risk
Chow and colleagues[44]	Original article	Case series	CPS + horizontal anaesthetic screens (tent)	Five patients	Droplets count on 7×7 cm grids on plastic sheet and face shields	Adoption of plastic tent to contain droplet spreading during tracheostomy	Droplet count contamination was mainly over the central upper half of plastic sheet correspondingly to lower neck. Total droplet count was highest along the centre and decreased towards the periphery on both sides. Plastic tent could obviate the need for a face shield given adequate eye protection and respirator.
Begley and colleagues[45]	Original article	Comparison of no AB with two AB in simulation crossover study	AB (two models)	36 (12 PPE donned anaesthesiologists/three intubations each): no AB/AB1/AB2	Intubation of simulated Cormack–Lehane 2 in mannequin with VLS + bougie	Application of two different AB during intubation	Primary outcome: intubation time longer with both AB (17% <60 s *vs* 100% <60 s without AB); secondary outcomes: first-pass intubation success: lower (75% and 83%) with AB *vs* no AB (100%); breaks in preoxygenation mask seal: no differences; breaches or damage to PPE: eight in AB; none without AB; qualitative comments on their experience: discomfort (50%) and increased cognitive load (33%) with AB
Convissar and colleagues[46]	Original article	Technical description	CPS + frame + suction system	N/A	N/A	CPS over PVC frame connected to Stryker suction system to	Addition of negative-pressure system may clear aerosols and reduce contamination of

Continued

Table 1 Continued

Reference	Article type	Study design	Type of barrier	Sample size	Study setting	Summary of interventions	Main findings
						create negative-pressure environment	room. Actual efficacy is not assessed in this report.
Hill and colleagues[47]	Original article	Technical description	CPS over customised frame	Preliminary use in 25 patients	No patient information given; 25 cases in emergency department	'Corona Curtain' barrier	Use described as simple, pragmatic, and cost effective
Alves Filho and colleagues[48]	Original article	Technical description	CPS + frame	N/A	N/A	Polyethylene sheet on metallic frame used for tracheostomy (sterile)	Fully autoclavable; free movement inside; incomplete barrier; concerns for correct removal
Gore and colleagues[49]	Original article	Simulation study	Acrylic panels + CPS	Four mannequin simulations	Intubation using four methods (including control) using a mannequin model with smoke generator	Acrylic panels supplemented by CPS in simulation study with mannequin	Reduced aerosol dispersion with acrylic panels combined with CPS than with panels or no barrier
Kinjo and colleagues[50]	Research letter	Clinical report	Metal brackets + acrylic panel	One patient	Intubation/extubation with barrier enclosure of COVID suspected patient	Application of novel barrier-enclosure system	More economic and easy access than AB; care for metal parts contact
Dalli and colleagues[51]	Research letter	Simulation study	AB	One	Simulated OT setting with coughing human volunteer, detection of airflows (assumption that airflows carry droplets/aerosols); schlieren imaging of airflows around the AB during both normal and deep exhalation and during coughing to assess aerosol spreading	High-speed imaging to assess airflows inside/outside the AB	AB does not contain airflows; visualised airflows also from side ports; concerns for added complexity and secondary aerosolisation during doffing/cleaning
Matava and colleagues[52]	Guidelines	Guidelines for paediatric airway management in COVID-19 patients	CPS	N/A (paediatric)	N/A	Discussion of barrier systems on anaesthetic equipment and on patient's airway devices	The PeDI-C recommended a transparent barrier over the airway device and patient's head to trap any aerosolised virus.
Chahar and colleagues[53]	Short recommendations (curbside consultation)	Airway management considerations in COVID-19 patients	Aero-Guard barrier device (patent pending, tab and pins collapsible design)	N/A	Technical features not provided	Barrier-enclosure system for intubation	Use of barrier devices, such as screens and intubation boxes should be considered to prevent cross infection during intubation. CPS can be used if a screen and intubation box are not available.
Sampson and Beckett[54]	Case report	Intubation with barrier-enclosure report	Plastic wrap + PVC support	One	N/A	Barrier-enclosure system for intubation	Intubation feasible
Bertroche and colleagues[55]	Quality improvement study	Clinical report	Laryngoscope suspension arm at the head of the bed and tented drape with C-arm plastic cover + smoke evacuator	One	Use of a novel negative-pressure aerosol reduction cover for tracheostomy	Application of barrier enclosure for tracheostomy	Allows for generally good mobility of the surgeon's hands and assistant's help; however, limitation in forearm movement; some degree of glare if cover became overlapped
SickKids The Hospital for Sick Children/ University of Toronto[56]	Website report	Descriptive	CPS + frame (protective tent for ENT surgical paediatric procedures)	N/A	N/A	Installation of the enclosure barrier	Description of installation and preparation

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Table 1 Continued

Reference	Article type	Study design	Type of barrier	Sample size	Study setting	Summary of interventions	Main findings
Lai[57]	Website report	Descriptive	AB	N/A	N/A	Construction of AB	AB minimises large droplet diffusion
BBC News Services[58]	Website report	Descriptive	AB	N/A	N/A	Description of AB	AB minimises large droplet diffusion
Tso[59]	Website report	Descriptive	Vacuum system	N/A	N/A	Description of extractor	Extractor minimises droplet diffusion
CONMED[60]	YouTube video	Descriptive	Smoke extractor	N/A	N/A	Simulation of tent + smoke extractor in paediatric patient	The enclosure system isolates aerosols and the smoke extractor quickly removes them.
Chan[61]	Website report	Descriptive	AB	N/A	N/A	Pros and cons	Advantages and disadvantages

'3000' [Date - Publication])' (Supplementary Appendix 2). A hand search of references cited in the selected papers was performed by an expert panel. An additional Google search was undertaken to identify grey literature evidence and online guidelines of scientific societies; pre-print articles; and relevant documents published by governmental or healthcare agencies, professional associations, and medical educators and innovators.

Irretrievable full-text reports; data referring to outbreaks caused by non-COVID-19-causing pathogens; and articles available in languages other than English, French, Spanish, Italian, and German were excluded. As a scoping review, this study was conducted in accordance with published standards.[2,3]

Findings

The database search returned 109 papers, with an additional 32 publications (including six websites) found on manual search. Two papers were eliminated as duplicates. Applying inclusion and exclusion criteria, 87 papers were removed. A total of 52 articles and six websites were included in this review (Fig 1 and Supplementary Appendix 1). All documents were reviewed by the expert panel and assessed for article type, study design, type of barrier (intervention), sample size, study setting, a summary of interventions (outcomes), main findings, and relevance (Table 1). A narrative synthesis was drafted and referenced. The final result was obtained through a discussion with a modified Delphi method using a modified nominal group technique (mNGT). Given the limitations imposed by the pandemic lockdown and geographical distances, all mNGT discussion rounds (literature search, definitions of questions, literature selection, literature comparison and evaluation, and elaboration of conclusions and statements) were performed virtually using e-mail, WhatsApp (https://www.whatsapp.com), and Zoom (https://www.zoom.us) platforms during a 6 week time span.

Narrative summary of evidence identified

Characteristics of studies

We found a considerable number of relevant reports and studies. Because of the high heterogeneity, small sample sizes, and limited patient data, we elected to write a scoping review resulting in a narrative summary.

This review included 52 written reports and six websites (Table 1). All were published between December 1, 2019 and May 27, 2020. There were 19 correspondences,[4–22] 16 letters to the editor,[23–33,35–39] 10 original articles,[40–49] three research letters,[34,50,51] one guideline,[52] one short recommendation,[53] one case report,[54] and one quality improvement study.[55] Of these reports, there were only six case reports or small case series.[6,15,42–44,54] The most common barrier-enclosure types were plastic wraps or tents (25 reports),[5,9,12,15,17,23–29,31,33,34,38,39,41,42,44,46,47,52,54,56] acrylic aerosol boxes (19 reports),[4–6,8,11,15,16,18,19,22,24,35,36,43,45,51,53,57,58] and combinations of aerosol boxes and plastic wraps (eight reports).[6,8,13,15,32,37,43,49] Eleven reports included other types of barrier enclosures (modified incubator hood,[7] carton box,[8] acrylic panels,[50] surgical retractors, frames and anaesthetic poles,[21,42,44,48] external fixators,[14] suspension laryngoscopy support,[41,55] and modified packaging tray[40]). In 10 cases, a smoke evacuator/aspirator was reported.[5,16,17,32,41,42,46,55,59,60]

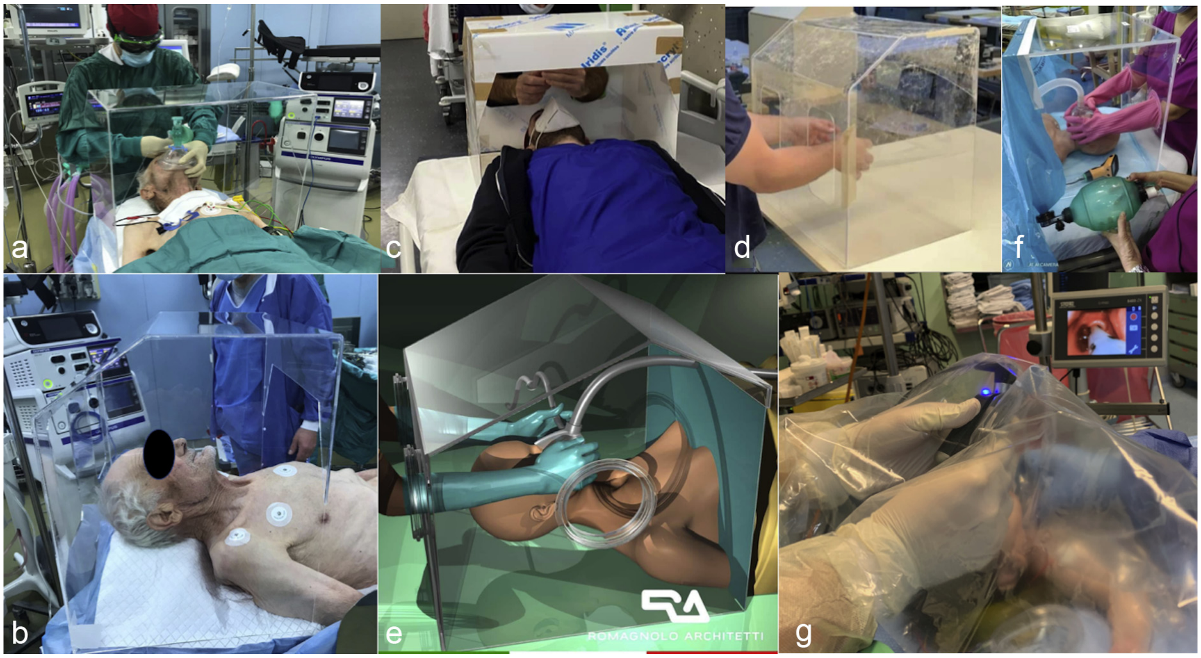

Fig 2. Airway boxes and drapes. (a–d) Credit: idea by: Pasquale De Negri MD, Giugliano, Napoli, Italy; courtesy Clelia Esposito MD, Napoli, Italy. Patient granted permission for use of picture. (e) Credit: Dr Idea: Antonio Lamberto, coronavirus disease (COVID) hospital di Barcellona Pozzo di Gotto, Messina, Italy (antoniolamberto@tiscali.it); project: Studio di Architettura Romagnolo, Messina, Italy (romagnoloarchitetti@gmail.com); manufacturing: Vision (Barcellona Pozzo di Gotto, Italy). The airway boxes were donated for free to COVID hospitals. (f) Simulated paediatric induction using airway box paediatric version. (g) Paediatric intubation using videolaryngoscope and plastic cover. (f–g) Courtesy Lorena Pasini MD, Bologna, Italy. (a–b) Patient expressed consent for use of picture. (d) Human volunteer expressed his consent for use of picture.

Sample sizes were often not given.[5,6,8–11,13,14,17–21,23,25–27,29–31,33,40,41,46,48,52,53,57,58] Cases of barrier-enclosure use with one mannequin or one human were noted in eight reports,[12,15,16,42,50,54,62,63] five cases in three reports,[22,24,44] and series of 25 or more cases in three reports.[37,45,47] The reported settings were simulations with mannequins in 20 cases,[4–6,11–13,16,19,21–23,25–28,39,41,45,49,60] simulations with study volunteers in two cases,[9,51] use in adult patients in 11 cases,[7,15,23,27,31,37,42,44,47,50,55] and four in paediatric patients.[41,43,52,56] In 24 reports, there was either no setting described or there was a barrier-enclosure description without demonstration.[6–8,10,13,14,17,18,20,24–26,29–32,34,38,40,46,52–54,58]

Types of interventions and outcomes

After the original concept was reported by a Taiwanese physician,[57] Canelli and colleagues[4] described a transparent plexiglass barrier enclosure intended to minimise the spread of aerosolised particles during intubation. Their seemingly elegant simulation of a cough (with and without an ‘aerosol box’ in place) demonstrated various particle diffusion patterns and the potential for contamination of personnel charged with airway management. Worldwide, many HCPs have rushed to adopt similar barrier enclosures, and papers describing boxes have been published.[5,6,53,54,58] Reusable protective shields[31,40,50] and disposable plastic covers for airway management procedures[9,10,23,24,41,47,52] that include intubation,[11,25–27] placement of supraglottic airway devices,[28] extubation,[12,29,34] tracheostomy,[42,44,55] bronchoscopy,[43] tracheal tube exchange, paediatric airway management,[41,52,56] and other aerosol-generating procedures (AGPs)[13,14,42,44,55] have been proposed. More recently, handmade and three-dimension printed boxes (Fig 2), adapted neonatal incubator hoods,[7] and even carton–plastic enclosures have been introduced.[8] Many of these devices provide limited or no access for an assistant, and no or limited accommodations for advanced airway management techniques (e.g. flexible scope-aided tracheal intubation).

Feldman and colleagues[63] concurred with the findings of Canelli and colleagues[4] in adult and paediatric simulated scenarios. This group confirmed that many airway procedures are AGPs. Extubation may generate more aerosol particles than intubation,[62] and HCPs charged with airway management have higher exposure and increased transmission risk, and should don airborne-level PPE when performing AGPs.[20,64,65]

Based on these findings, it has been suggested that in cases where adequate PPE is not available, barrier enclosures might mitigate HCP exposure. However, because of the large variability of the approaches, the often-small sample sizes, sparse patient data, and no evidence of decrease viral transmission with their use, many questions remain to be addressed. Therefore, in this narrative, the expert panel proposes that the following issues should be investigated in a controlled fashion before widespread adoption or recommendation of barrier interventions.

Is SARS-CoV-2 spread by airborne transmission (via suspended droplets or aerosols)?

Whilst still under investigation, data from the SARS and Middle Eastern respiratory syndrome (MERS) outbreaks[20] and more recent reports[66–70] strongly suggest airborne transmission results in HCP exposure, especially during airway management procedures.[71,72] Disease spread and clinical illness incidence appear to be directly proportional to viral load and exposure time,[65] which are higher and longer during airway management[71] because of the proximity of the HCP to the airway.

Do 'aerosol boxes' and other barrier-enclosure systems effectively prevent aerosol spread?

Aerosols are defined as a suspension of small particles (0·001–100 μm) that may carry the live virus for up to 3 h.[66] As demonstrated by Canelli and colleagues[4] and Raimann and colleagues,[39] barriers, such as aerosol boxes and plastic covers, may limit *large droplet* spread. However, there has been no evidence presented that they adequately protect HCPs against *aerosolised* viral particles. A study with schlieren imaging (a passive imaging method for direct visualisation of refractive index changes used to assess small particle spread) of a coughing volunteer showed that considerable amounts of air moved out of the aerosol box from the distal open end and through the operative holes.[48,51] Simulations with e-cigarettes and propylene glycol vapours (that contain large aerosol particles ranging from 40 to 200 μm in diameter) suggest that neither the boxes nor the plastic barriers provide sufficient protection from the spread of aerosols, and may even channel or contain them into a higher concentration close to HCPs managing the airway (Supplementary Appendix 3, Video 1). Trapped aerosols may later be unknowingly released upon removal of the barrier ('secondary aerosolisation'). Alternative solutions might include the addition of plastic tents to the boxes,[10,12,29,31,49,60] negative-pressure systems,[7,20,32,34,40,43,46,62–65] or rapid vacuum aspiration, which in itself might be more effective than the use of barriers (see Marriott Extractor, Supplementary Appendix 3, Video 2).[59,60]

Supplementary video related to this article can be found at https://doi.org/10.1016/j.bja.2020.08.038

Are the rigid boxes ergonomically practical?

Although many of the aerosol box simulations have been performed in an operating theatre environment, these devices may be used in other patient settings, with different patient surfaces, sizes, and types (e.g. ICU, radiology suite, and ambulance). A box placed above the patient's head might not fit (e.g. an obese patient); may be uncomfortable; or provoke claustrophobia, anxiety, restlessness, and combativeness. Furthermore, they are not usable in situations of severe respiratory distress, where patients are often sitting upright or semi-recumbent to maintain respiratory function. Demonstrations of barrier models that are wider, possibly more stable, that allow for ramped positioning and increased manoeuvrability have been suggested,[13,37] but there remains no evidence that they improve airway management performance. If an intubation introducer[18] or a bulky or hyperangulated videolaryngoscope is used, then there may not be sufficient intra-box space to allow for unencumbered manipulation.[19] A simulation study comparing intubation success with or without two generations of aerosol boxes demonstrated that the boxes were associated with higher intubation failure rates and prolonged intubation times.[45] In contrast, other simulations have shown that the use of powered respirator PPE does not affect the time to intubation and first-pass success of videolaryngoscope-aided tracheal intubation.[73] We must also consider how monitor cables, i.v. tubing, breathing circuits, suction tubing, and bedding might interfere with barrier use and be disrupted by barrier placement and removal. Use of advanced features of supraglottic airway devices (i.e. gastric tube placement, position-check tests, and optically guided tracheal intubation) might be limited.[20] A concern for accidental tracheal extubation through entanglement during barrier removal must be considered. Appreciating the time pressure, cognitive load, and stress associated with airway management in patients with anatomically or physiologically difficult airways,[74] and the limitations imposed by PPE,[18] the addition of another physical barrier seems counter-intuitive.

It has been argued that physical barriers might be more useful for the extubation phase of airway management, but controlled investigations are likewise needed.[20,34] At the time of anaesthetic emergence, still more questions arise: How will a waking patient react to a confining barrier? What happens in cases of patient coughing after extubation or the need for airway suctioning? If emergency reintubation is needed, can the operator manoeuvre properly? Will the confines of the barrier enclosure hinder the use of an airway exchange catheter? What are the proper procedures for managing airway compromise on awakening?

Could barrier enclosures be a risk during airway emergencies?

Cases of failed tracheal intubation or extubation requiring reintubation, rescue manoeuvres (including the use of alternative devices, such as face mask or supraglottic airway ventilation), or emergency surgical airway access may be necessary. One simulation has demonstrated that in case of difficult airway resuscitation, the ability of an assistant to aid the intubator was encumbered.[21] If a barrier must be rapidly removed during an airway emergency, then this may cause delay or be hazardous to the patient, airway operator, or assistant.[61] It is not difficult to demonstrate through simulation how this approach could make an airway crisis more difficult to handle, including the added task of barrier-enclosure removal to provide adequate access to the patient (see Supplementary Appendix 3, Video 3). Furthermore, should cardiopulmonary resuscitation and defibrillation be needed, the box or tent may represent a flammable oxygen reservoir, increasing the risk of fire.[41,75]

Supplementary video related to this article can be found at https://doi.org/10.1016/j.bja.2020.08.038

Can multi-use barriers themselves be an infection hazard?

Severe acute respiratory syndrome coronavirus 2 can survive on plastic surfaces for 3–5 days,[76] and although sensitive to available disinfectants,[77] there is little information on reliable methods of cleaning reusable barrier devices.[41] A variety of reusable barrier-enclosure designs with features, such as evacuation systems, have been reported.[5,16,55] Each variation introduces new recesses for which effective cleaning will need to be demonstrated. As alluded to above, the issue of aerosol viral particle load within the confines of a barrier and its release on removal ('secondary aerosolisation') will need to be addressed.[22,70] In parallel with the observation of increased contamination risk during PPE doffing,[78] we might inadvertently create a 'secondary aerosolisation' risk upon barrier-enclosure removal.[30]

What effect may barriers have on the use of adequate PPE?

Concerns exist that there may be a false sense of security amongst HCPs using these barrier devices, leading to less attentive use of suitable PPE, or that organisations may compromise on providing PPE, using the provision of aerosol boxes or other barrier enclosures as a substitute. We want to raise concerns against such practices, as recent guidelines have advised.[79] Furthermore, aerosol boxes can disrupt or damage the intubator's PPE,[18] as demonstrated in a recent simulation study.[45] Throughout the world, a delicate balance exists between the need for maximal protection and PPE shortages.[80] A recent Cochrane review suggests that ambiguous, constantly changing, or contradictory PPE guidelines might result in PPE underuse and resistance to adhere to infection prevention guidelines.[81] The unquestioned use of barrier-enclosure systems might dangerously contribute to this phenomenon. As in all other areas of medicine, application of unproven devices and tools that otherwise appear to be technical or common-sense solutions can be fraught with harm to patients and HCPs. It appears more rational to adopt correct individual and social protective behaviours,[82] develop PPE prioritisation strategies,[62,69,78,80,82] establish boundaries for non-clinical working areas,[83] and recommend suitable protection levels of PPE for AGPs.[69,84,85]

Limitations and knowledge gaps

It must be acknowledged that most data regarding the COVID-19 outbreak should be considered of low-level evidence given that many of the analysed papers were expert opinions, technical reports, small simulation studies, small case series, pre-print proofs, or narrative reviews based on previous SARS and MERS outbreaks. Hence, the expert panel could not perform a systematic review. The expert panel highlighted some crucial gaps in knowledge that need to be addressed in future research:

(i) The ability of barrier-enclosure systems to contain or limit aerosols
(ii) Effects of barrier-enclosure systems on basic, advanced, and difficult airway management
(iii) Implications of barrier-enclosure systems on the integrity of PPE, adoption of adequate PPE levels and adherence to guidelines
(iv) Implications of barrier-enclosure systems on the safety of HCPs and patients
(v) Definition of clear and univocal protocols for cleaning, disinfection, or disposal of barrier-enclosure systems

Conclusions

There is a growing interest in and enthusiastic dissemination[58,86] of barriers, such as *aerosol boxes*, additional covers, and other creative solutions.[87] However, until these modalities show clear advantages and safety after undergoing adequate levels of scrutiny and testing in laboratory examination, simulation,[88,89] and a practical demonstration in low-risk patient care scenarios, the authors strongly advise to resist their use in hazardous patient care situations. In the absence of this evidence, the opinion of this expert panel is that 'aerosol boxes' increase task loading and complexity; add additional barriers to effective airway management; may become reservoirs for contact transmission; may damage or compromise PPE; and, fundamentally, do not stop aerosols.

We are in desperate times: many hard-hit areas resemble battlefield hospitals. In this setting, we need tried-and-true battlefield solutions. Evidence tells us that only properly selected, tested, and fitted PPE will protect healthcare practitioners. In time and with appropriate scientific investigation, it may be possible to demonstrate whether these barriers *are* of benefit in the fight against the virus, or, like their ancestor in Pandora's curious hands, are 'a gift which seems valuable, but is, in reality, a curse'.

Authors' contributions

Review idea: MS, FU
Literature search: RH
Methodology: RG
Search strategy: RG
Writing of paper: MS, FU
Review/critical appraisal: RH
Critical review: RG
Final review: WR

Acknowledgements

The authors wish to thank all healthcare providers involved in critical care of COVID-19 patients.

Declarations of interest

MS has received paid consultancy from Teleflex Medical, Verathon Medical, and DEAS Italia; is a patent co-owner (no royalties) of DEAS Italia; and has received lecture grants and travel reimbursements from MSD Italia. RH directs a fellowship programme, which is funded in part by an unrestricted educational grant from KARL STORZ. RG is European Resuscitation Council Director of Training and Education, and International Liaison Committee on Resuscitation Task Force Chair on Education, Implementation and Teams. FU is part of an Advisory Board for Vyaire Medical and consultant for Medtronic. WR declares travel reimbursement from Ambu.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.bja.2020.08.038.

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Handling editor: Jonathan Hardman