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.

American Journal of Emergency Medicine 41 (2021) 209–218

Contents lists available at ScienceDirect

American Journal of Emergency Medicine

journal homepage: www.elsevier.com/locate/ajem

Review article

Barrier enclosure use during aerosol-generating medical procedures: A scoping review

Courtney Price [a], Maxim Ben-Yakov [b,c], Joseph Choi [b,c], Ani Orchanian-Cheff [d], Davy Tawadrous [b,c,*]

[a] Faculty of Medicine, University of Ottawa, Ottawa, ON, Canada
[b] Division of Emergency Medicine, Faculty of Medicine, University of Toronto, Toronto, ON, Canada
[c] Toronto General Hospital - Emergency Department, University Health Network, Toronto, ON, Canada
[d] Library and Information Services, University Health Network, Toronto, ON, Canada

ARTICLE INFO

Article history:
Received 21 September 2020
Received in revised form 30 October 2020
Accepted 31 October 2020

Keywords:
Barrier enclosure
Protected intubation
Aerosol box
AGMP
COVID-19

ABSTRACT

Introduction: Barrier enclosure devices were introduced to protect against infectious disease transmission during aerosol generating medical procedures (AGMP). Recent discussion in the medical community has led to new designs and adoption despite limited evidence. A scoping review was conducted to characterize devices being used and their performance.

Methods: We conducted a scoping review of formal databases (MEDLINE, Embase, Cochrane Database of Systematic Reviews, CENTRAL, Scopus), grey literature, and hand-searched relevant journals. Forward and reverse citation searching was completed on included articles. Article/full-text screening and data extraction was performed by two independent reviewers. Studies were categorized by publication type, device category, intended medical use, and outcomes (efficacy – ability to contain particles; efficiency – time to complete AGMP; and usability – user experience).

Results: Searches identified 6489 studies and 123 met criteria for inclusion (k = 0.81 title/abstract, k = 0.77 full-text). Most articles were published in 2020 (98%, $n = 120$) as letters/commentaries (58%, $n = 71$). Box systems represented 42% ($n = 52$) of systems described, while plastic sheet systems accounted for 54% ($n = 66$). The majority were used for airway management (67%, $n = 83$). Only half of articles described outcome measures (54%, $n = 67$); 82% ($n = 55$) reporting efficacy, 39% ($n = 26$) on usability, and 15% ($n = 10$) on efficiency. Efficacy of devices in containing aerosols was limited and frequently dependent on use of suction devices.

Conclusions: While use of various barrier enclosure devices has become widespread during this pandemic, objective data of efficacy, efficiency, and usability is limited. Further controlled studies are required before adoption into routine clinical practice.

1. Introduction

During the COVID-19 pandemic, the threat of diminishing supplies of personal protective equipment sparked an interest in alternative means to protect healthcare providers. One such means included barrier enclosure devices, which are generally described as a plastic sheet over a structural frame or a transparent plastic four-sided box that are used as a potential method of protecting healthcare providers from SARS-CoV-2 during aerosol generating medical procedures (AGMP) (e.g. intubation or extubation). This device is typically placed in between a patient and airway operator during an AGMP as a means of physically limiting the transmission of aerosols and/or droplets to healthcare providers.

Currently there is limited evidence to support the use of barrier enclosure devices and important questions remain regarding their efficacy in reducing contamination, efficiency of use, and usability within various healthcare settings. In May 2020, the United States Food and Drug Administration issued a temporary emergency medical device license for the use of protective barrier enclosures [1]. While healthcare institutions continue to test, modify, and adopt these barriers into practice, we sought to collate and characterize the published literature on devices that are being used in various settings, as well as elucidate any performance outcomes (i.e., efficacy, efficiency, usability) associated with

* Corresponding author at: Division of Emergency Medicine, Toronto General Hospital, 200 Elizabeth Street, R. Fraser Elliott Building, Ground Floor Room 480, Toronto, ON, M5G 2C4, Canada.
E-mail addresses: cpric016@uottawa.ca (C. Price), maxim.benyakov@utoronto.ca (M. Ben-Yakov), joseph.choi@utoronto.ca (J. Choi), ani.orchanian-cheff@uhn.ca (A. Orchanian-Cheff), davy.tawadrous@uhn.ca (D. Tawadrous).

https://doi.org/10.1016/j.ajem.2020.10.071
0735-6757/

each system. A scoping review was selected given the heterogeneity of the literature on this topic.

2. Methods

2.1. Identifying relevant studies

A protocol of our methodology was published a priori and followed PRISMA-ScR guidelines [2,3]. A search to identify barrier enclosure devices was executed by an academic information specialist in bibliographic databases including Ovid MEDLINE, Ovid Embase, Cochrane Database of Systematic Reviews, Cochrane Central Register of Controlled Trials and Scopus (2000-01-01 to 2020-06-24) for the main concepts of AGMPs and barrier enclosure devices (Appendix A) across all languages. The year 2000 was chosen to capture barrier devices potentially used during previous pandemics (e.g., SARS-CoV-1). We excluded non-human studies, conference and book materials. Additionally, a grey literature search of Google Scholar, clinical trials registries (ClinicalTrials.gov, WHO Clinical Trials), pre-print repositories (OSF, MedRvix), disseminated reports (Canadian Agency for Drug Technologies in Canada, World Health Organization, National Health Service, Public Health Agency of Canada, Centers for Disease Control and Prevention) was performed. Relevant journals in emergency medicine (American Journal of Emergency Medicine, Annals of Emergency Medicine, Canadian Journal of Emergency Medicine, British Medical Journal – Emergency Medicine), anesthesiology (Anesthesia, Anesthesia & Analgesia, British Journal of Anesthesia, Canadian Journal of Anesthesia, Journal of Clinical Anesthesia), and otolaryngology (Head & Neck and Ear, Nose & Throat Journal) were manually searched on 2020-07-03 reviewing articles published in March to July 2020 issues and those available as early release. Forward and reverse citation searching was completed on all included articles (2020-07-19). All citations were managed in Covidence (covidence.org) screening software.

2.2. Study selection

Two reviewers (CP, DT) independently evaluated the eligibility of studies on the basis of title and/or abstract using pre-established inclusion and exclusion criteria (Table 1). A sample of 100 articles were screened to ensure consistency among reviewers and fidelity of established criteria. Reviewers independently evaluated the eligibility of all articles; disagreements were resolved by re-evaluation, discussion, and when necessary, in consultation with a third reviewer. Full-text articles were retrieved if reviewers considered a citation potentially relevant. Reviewer agreement for study eligibility was assessed using the unweighted Cohen's kappa coefficient.

Table 1
Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
1) Descriptions, design, and/or protocol for barrier enclosure use in AGMPs[a]	1) Conference abstracts, posters or proceedings, registered trials, online website material
2) All article types (e.g. original research, reviews)	2) Critique or opinion on prior published work, with no introduction of a new device
3) Any publication status (e.g., pre-print, online)	3) Non-infectious risk exposure (e.g. chemotherapy, radiation)
4) Time frame: 2000–2020-06-24	
5) Studies in: humans, experimental, simulation	
6) Any language	

[a] Defined as any enclosure which surrounds the patient and aims to prevent droplet spread and aerosol dispersion into the environment during an intervention.

2.3. Charting the data

Data abstraction was completed independently by one reviewer (CP) using a standardized form (Appendix B) and verified by a second reviewer (DT, JC, MBY). We abstracted publication details (author, title, publication date, country of origin, publication status, publication type), setting, device design details, intended medical use, methods and outcomes. A list and definition of variables collected can be found in Appendix B.

2.4. Collating, summarizing, and reporting the results

Devices were categorized as either a box, plastic sheet (with frame), plastic sheet (without frame), or other system. Outcomes, both qualitative and quantitative, were categorized as either efficacy (i.e., related to the device's ability to protect the intubator and contain particles), efficiency (i.e., time taken to perform an AGMP) or usability metrics (i.e., feedback on experience of the use of the system).

3. Results

A total of 6336 articles were identified through formal database search strategies, and 153 articles through grey literature and citation screening (Fig. 1). After duplicate removal, 4509 unique articles were screened, and 169 full-text articles were assessed for eligibility. We identified 123 articles for inclusion. Our kappa coefficient was good for title/abstract screening (kappa = 0.81) and full-text review (kappa = 0.77).

Most articles were published between March 2020 – July 2020 (n = 120), with three articles published prior to 2020 [4-6]. Over half of articles were published as letters/commentaries (58%, n = 71), 29% as original research studies (n = 36), and 13% (n = 16) as brief/short reports. Publications originated from 27 unique countries with the top 3 countries including the United States (34%, n = 42), India (10%, n = 12), and Canada (10%, n = 12).

3.1. Device design

Commonly reported barrier enclosure devices include box (42%, n = 52) and plastic sheet (54%, n = 66) systems. Over half (59%, n = 39/66) of plastic sheet systems utilized a supportive frame and 41% (n = 27/66) had no supportive structure (Fig. 2).

Box designs were often similar to the original design in Canelli et al. [7], which is a transparent 4-sided structure with two open faces: an inferior face bound by the stretcher and a caudal face pointed towards the foot of the bed. Common modifications included change in the number or size of ports (i.e., for operators and/or tools) [8-12], increased device size for improved operator ergonomics and/or patient body habitus [13-15], built-in gloves and/or port coverings [11,12,16,17], addition of a plastic drape or covering on the caudal face [18-20], a sloped top panel for improved visibility [15,18,21] and the use of a negative suction system [22-24].

Conversely, plastic sheet systems with frames were constructed using polyvinyl chloride tubing [25,26], operating room equipment (e.g., anesthetic screens) [24,27], and Mayo stands [28,29]. Six articles introduced a plastic canopy system, which is semicircular in shape enclosing the patient's upper or full body [4,30-34]. Alternatively, plastic sheet systems without a frame were often akin to surgical draping, where a clear sheet drapes over the patient's head, neck and/or entire body and the physician works beneath the drape or cuts an opening into the plastic sheet [5,35-37].

There were a number of other unique designs. Three articles introduced large, non-mobile plastic chamber units for COVID-19 testing [38,39] and outpatient ENT procedures [40] in which the patient entered the closed system and the procedure was performed through

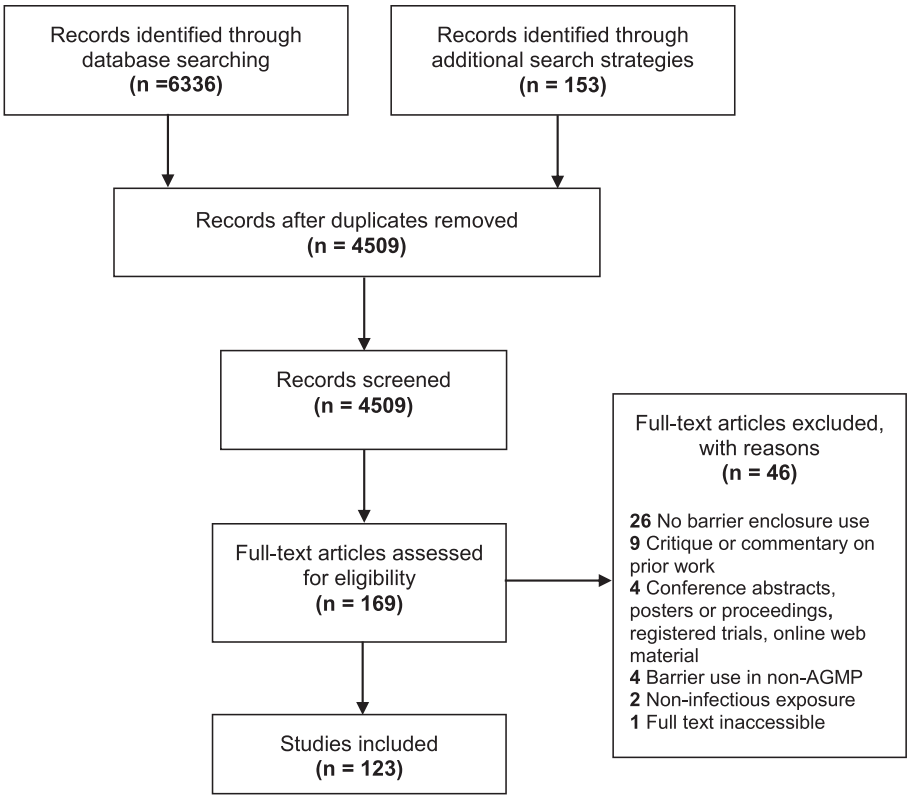

Fig. 1. Barrier system study selection.

two ports. Seven articles described shield structures (e.g. 1 or 2-faced plastic stand or board). [21,41-46]

3.2. Intended medical use/medical context

The most commonly reported use was for airway management (67%, $n = 83$) (Table 2). Within these, 84% reported use for intubation or extubation ($n = 70/83$), 7% ($n = 6/83$) for tracheostomies [23,47-51], and 6% ($n = 5/83$) for non-invasive respiratory support (e.g. high-flow nasal cannula) [26,30,34,52,53]. Two studies (2%, $n = 2/83$) used a device in pediatric laryngoscopy and bronchoscopy [54,55]. Nine studies (7%) discussed these devices for general AGMPs [22,25,32,46,56-60] and 9 (7%) for endoscopic procedures. [10,11,43,45,61-64]

A small proportion of studies (11%, $n = 14$) used an enclosure during surgical procedures, mainly for otolaryngology procedures (57%, $n = 8/14$) (e.g. mastoidectomy, *endo*-nasal/endo-oral procedures) [40,65-71] as well as in other types of surgery (43%, $n = 6/14$) (e.g. craniotomy, oral maxillofacial, colorectal surgery) [5,6,72-75]. Other uses included dental procedures [41,76], dermatological procedures [29], and regional anesthesia [9,77] (4%, $n = 5/123$).

3.3. Evaluation

Over half of articles included an evaluation component (54%, $n = 67$), the majority of which only included qualitative outcomes (54%, $n = 36/67$). Among these, 70% ($n = 47$) of studies reported on the use of enclosures in simulation settings, 19% ($n = 13$) reported

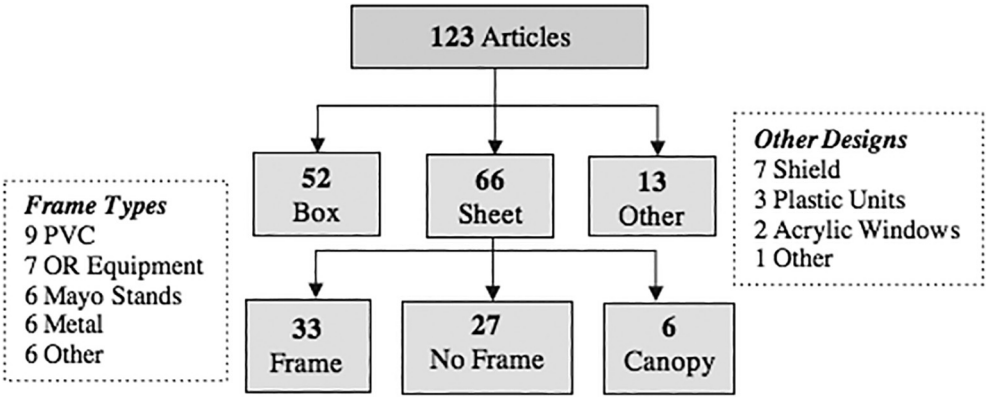

Fig. 2. Barrier device designs. Note: 8 articles discussed the use of multiple device types[13, 20, 21, 24, 39, 87, 98, 99]. [1]PVC = polyvinyl chloride. [2]OR = operating room. [3]Plastic Units = large non-mobile chambers fully enclosing the patient.

Table 2
Summary of barrier devices by category, intended use, and purpose of publication

Device category	Intended medical use		Total	Objective	
				Descriptive	Evaluation
Description: 4-sided transparent plastic box. Typically includes 2 ports for the provider and/or assistant.	Airway Management	Intubation/Extubation (38)[a] Tracheostomy (1) Bronchoscopy & Laryngoscopy (1)	40	33 (83%)	23 (58%)
	Endoscopic[a]	Endoscopy (5)	5	5 (100%)	3 (60%)
	Surgical	Craniotomy (1)	1	1 (100%)	1 (100%)
	AGMPs (General)	AGMPs (General) (3)	3	3 (100%)	2 (67%)
	Other	Dental (1) Dermatology (1) Regional Anesthesia (2)	4	3 (75%)	1 (25%)
	Total		**52**	44 (85%)	30 (58%)
Plastic Sheet (Frame, No Frame, Canopy) *Description*: Clear plastic sheet draped over a rigid frame or sheet placed directly on the patient during a procedure.	Airway Management	Intubation / Extubation (36) Respiratory Support (5) Tracheostomy (5) Bronchoscopy & Laryngoscopy (1)	47	43 (91%)	23 (49%)
	Endoscopic	Endoscopic (2)	2	2 (100%)	–
	Surgical	ENT Procedures (7) Other Surgery (5)	12	10 (83%)	8 (67%)
	AGMPs (General)	AGMPs (General) (5)	5	5 (100%)	5 (100%)
	Total		**66**	60 (91%)	36 (55%)
Other *Description:* devices include – 3 large plastic units, 2 acrylic windows, 7 shield-like structures and 1 inverted face tent (other).	Airway Management	Intubation / Extubation (3)	3	3 (100%)	3 (100%)
	Endoscopic	Endoscopic (2)	2	2 (100%)	2 (100%)
	AGMPs (General)	AGMPs (General) (1)	1	1 (100%)	–
	Other	Outpatient ENT (1) Sampling (5) Dental (1)	7	7 (100%)	1 (14%)
	Total		**13**	13 (100%)	6 (46%)
TOTAL			**123***	110 (89%)	67 (54%)

* Note: 8 articles discuss the use of multiple device types. 6 were discussing a box & plastic sheet system, 1 box & other, and 1 other & plastic sheet. These articles have been counted in their respective groups in category counts and only once in the summary total count.

[a] Study discusses dual-purpose use of the box for endoscopic procedures and airway management. *Definitions:* Descriptive = Description or device modification; Evaluation = Study includes an evaluation of device (qualitative or quantitative).

their use in real patients, and 10% ($n = 7$) reported on use in both environments. Efficacy was the most frequently reported outcome among articles (82%, $n = 55/67$) followed by usability (39%, $n = 26/67$) and efficiency (15%, $n = 10/67$).

3.3.1. Efficacy

The most common method to assess the device's ability to contain particles or prevent contamination was through the visual assessment of droplets or smoke (71%, $n = 39/55$), primarily with box systems (51%, $n = 20/39$). Four studies used the ability to smell [78,79] or taste a bitter solution [60,80] as a proxy for aerosols escaping into the environment. Using these qualitative methods, studies concluded that the use of a barrier device was effective at either preventing or reducing the number of particles escaping the system.

Only 40% ($n = 22/55$) studies reported quantitative results. Three of these studies used pre-established grids to quantify exposure outside of the enclosure with fluorescent dye or gross droplets and reported success in reducing contamination [13,49,81]. Two studies reported no SARS-CoV-2 infection rates of physicians after using the system [59,82], while another four studies detected the presence of molecules contained within the enclosure and/or a decrease in particles outside the enclosure as a proxy for its effectiveness [5,6,34,74].

The majority of barriers (77%, $n = 17/22$) with objective findings used suction to generate negative pressure and reported particle counts or aerosol clearance rates (59%, $n = 13/22$) (Table 3). In contrast to the visual contamination studies showing effectiveness, evidence from quantitative data was often less favourable and contingent on the use of suction devices. For example, Simpson et al. [24] evaluated the efficacy of four different designs – a box, sealed box (caudal end closed), and two plastic sheet barrier systems and found that only when suction was applied, particle counts decreased. Similar results were seen in in Lyaker et al. with increased particle detection outside the chamber without the use of suction [83].

3.3.2. Usability

Usability was assessed primarily by self-reported qualitative feedback from physicians using these devices (81%, $n = 21/26$). Generally, authors reported success carrying out procedures using the device with no major issues, [33,44,54,61,75,77,84] however four studies using the box system reported additional workflow complexities [85] and challenges while performing intubation. [12,86,87]

Six articles included a quantitative assessment of usability for intubation (23%, $n = 6/26$, 4, 12, 88–91], mainly in the box (83%, $n = 5/6$) [12,88-91] and one in a plastic sheet system (canopy) (17%, $n = 1/6$) [4]. Seger et al. reported a limited increase in time required for device maneuverability: removal and disposal within 10 s, and completion of a position change within the enclosure in less than 2 s. [91] However, Clariot et al. [88], Begley et al. [12], and Hamal et al. [89] reported worsening laryngoscopic views when using a box system. Similarly, Serdinšek et al. [90] and Plazikowski et al. [4] both reported more difficulty with airway management when using box and plastic canopy systems.

3.3.3. Efficiency

The most frequent efficiency metric reported was time to intubation or related metrics to securing an airway (e.g., first-pass success) (70%, $n = 7/10$, 4, 12, 88–92] primarily in the box system (86%, $n = 6/7$) [12,88-92]. Those assessing intubation times (40%, $n = 4/10$) noted

Table 3
Efficacy – Quantitative results, review of particle counter studies

Study	Device & methods	Comparators/Interventions	Main results
Box			
Lyaker, US[83]	**Airway Management.** Particle generator placed inside/outside enclosure.	1-wall suction vs. 2-wall suction vs. No Suction	Particle detection outside the chamber increased above the ambient level without suction. Suction reduced the counts.
Brar, UK[23]	**Tracheostomy.** Vaporizer generated particles with counters outside the enclosure.	Device vs. no device / Suction vs. no Suction	Decrease in particles detected at the position of the surgeon with the device and a reduction in the number of particles over time.
Hellman, US[58]	**AGMPs.** Particle generator and a particle counter inside enclosure.	Hospital suction / commercially available suction / none	Aerosol clearance was significantly hastened with suction vs. passive clearance and the commercial suction device was better than in-hospital system.
Perella, UK[22]	**AGMPs.** Simulated cough with normal breath measured through a particle generator.	Suction position /device openings/suction flow rate / device vs. no device	Device prevented particle escape. Optimal condition was when the suction was vertically next to the patient's head.
Le, US[95]	**Airway Management.** Atomizer used to simulate aerosol production with counter inside/outside enclosure.	None listed	Containment of greater than 90% of sub-micrometer particles across all particle sizes.
Plastic Sheet			
Lang, US[57]	**AGMPs.** Humidifier generated particles with particle counters placed inside/outside enclosure.	Device vs. no device / Suction vs. no suction	Particle count detected outside hood significantly decreased with the system. Suction system reduced particle count inside the enclosure.
Shaw, US[52]	**Respiratory Support.** Humidifier generated particles with particle counters placed inside/outside enclosure. Nasal cannula used inside hood.	Smoke evacuator 60%/80%/100%/Off	Particle count outside and inside the hood decreased with the use of smoke evacuator.
Bryant, US[96]	**Airway Management.** Particle generator placed inside enclosure. Counter measured inside & outside enclosure.	Complete closure, arms inserted, enclosure with flaps open and closed. All vs. suction.	Greatest reduction in particles was with the enclosure closed using suction and highest concentrations when the flap was open. There was no change in particles concentrations with the front flap was open.
Bassin, US[32]	**Canopy. AGMPs**. Particle generator inside hood with counters placed inside/outside enclosure.	HFNC, Nebulizer, CPAP with / without particle generator	No detectable increase in room air particle counts.
Chari, US[66]	**Surgical.** Mastoidectomy performed on a cadaver. Spectrometer measured particles 30 cm from site.	2 barrier drape designs with/without suction	No drape, no barrier drape + suction, barrier drape without suction had high particle counts. Original drape with suction, modified barrier drape, and modified barrier drape with suction showed no increase.
Milne, Canada[97]	**Airway Management.** Flow rate testing completed with two suction sources.	Surgical suction sources vs. in-hospital wall suction	Theoretical times for airborne contaminant at 99% and 99.9% would be faster with the in-hospital suction system due to higher flow rates.
Adir, Israel[30]	**Respiratory Support.** Face velocity and smoke direction of air measured perpendicular to hood. Photometry used for particle leakage.	None listed	The average air flow velocity was 4.4 $m \cdot s - 1$ with the smoke flowing into the back side of the canopy. Filtration efficiency was reported at 0.0006%.
Multiple Device Types			
Simpson, Australia[24]	**Box & Plastic Sheet. Airway Management.** Nebulized saline through a simulated cough with particle counter outside enclosure.	Box / vertical drape / horizontal drape / sealed box with suction / sealed box without suction	The sealed intubation box with suction resulted in a decrease in almost all particle sizes across all time periods. The box had an increase in particle exposure. No difference using the plastic drapes.

increased time to intubation using the box system. [12,88-90] In Clariot et al., median tracheal intubation was longer (53 s vs. 48 s, $p < 0.01$) compared to no system. [88] Similarly, in Begley et al., comparison of two box systems to no barrier system increased time to intubation by 48 s and 28 s seconds, respectively [12]. First-pass success when using barrier systems was variable. While Plazikowski et al. [4] and Begley et al. [12] reported lower first-pass success when using plastic canopy and box systems, others noted no intubation failures or challenges with box systems. [88,90-92]

3.3.4. Box vs. sheet system comparisons

Five articles compared the box and plastic sheet systems [13,20,21,24,87]. In Brown et al. [87], Ibrahim et al. [20]., and Gore et al. [21], particles escaped through the open caudal end of box systems with increased contamination of the operator and/or environment relative to the plastic systems during airway management. Laosuwan et al. also assessed droplet contamination on a standardized grid in an extubation simulation and similarly reported increased contamination with box systems relative to plastic sheet systems [13]. Simpson et al. found that there was no significant difference in particle exposure outside the enclosure when comparing plastic sheet systems to no system during intubation, whereas the use of the box system concentrated particles without limiting dispersion [24]. Only one study compared usability between a box and plastic sheet system and reported that physicians favoured the plastic sheet system due to ease of mobility and the ability to accommodate an airway assistant [87].

4. Discussion

Barrier enclosures are described as innovative systems which protect healthcare workers from infectious disease transmission. We identified 123 articles from 27 countries, the majority of which were published following the original aerosol box design released in April 2020 [7]. Across these studies, three general device types were identified: box, plastic sheet with frame, and plastic sheet without frame systems for use in airway management (intubation, extubation, tracheostomies or respiratory support) or general aerosolizing medical procedures.

To date, there is a lack of strong evidence to support the use of barrier systems in clinical settings. Our review demonstrated a reliance on short letters/commentaries to validate various devices' medical use and safety and limited rigorous trials. Currently, evidence to support the reduction of aerosol and droplet contamination is based primarily on visual assessments of aerosol and droplet spread. While these results are generally positive, emerging quantitative studies have reported less favourable results that frequently depend on concurrent use of a suction device [24,83]. Often discussed as a low-cost, pragmatic means of protecting physicians, use of the box systems in some instances demonstrated a delay in time to intubation [12,88]

and worsening laryngoscopic views [12,88,89], which has important clinical implications in physiologically difficult intubations. In fact, while simplistic, plastic sheet systems appear to outperform box systems in efficacy and usability characteristics, with less environmental contamination [13,24] and better ergonomics [87].

These variable characteristics are important to consider in light of the evolving SARS-CoV-2 pandemic. In May 2020, the United States FDA granted emergency approval for barrier enclosure device manufacturing, distribution and use during AGMPs without guidance on the design or intended medical uses for these devices [1]. Subsequently, a plethora of various devices were heavily promoted through social media, press and in many medical journals translating to a large uptake of these systems [93] despite limited scientific evidence on efficacy, efficiency and usability. Recognizing this risk, the FDA has since revoked its emergency license for barrier enclosures devices in August 2020 [1], and now recommends the use of enclosures with suction devices in keeping with emerging objective evidence. [12,24]

The pandemic has highlighted the delicate balance of thorough evaluation with the need for immediate solutions. Commercial medical devices undergo rigorous testing in order to prove efficacy and safety for the patient and physician and requires strict reporting of adverse events through a centralized system to make decisions regarding continued use [94]. This is an opportunity for regulatory bodies to reexamine how emergency approvals are granted, and to set up infrastructure to encourage local innovation while providing a platform to register and monitor its effects, similar to how trials are registered.

In light of the established characteristics and performance outcomes, researchers and innovators looking to further develop and optimize barrier enclosures should focus on quantitative assessments of efficacy, efficiency, and usability in real clinical environments. Other opportunities for further exploration include focusing on patient-centered outcomes, such as frequency of desaturations and peri-intubation cardiac arrest, as well as the economics associated with implementation, widespread adoption, and maintenance (e.g., sterilization) of these devices.

5. Limitations

Our review focused on the published literature related to the use of barrier enclosure devices and did not include designs that were published on websites, social media or design sites. While devices published in non-academic mediums may have been missed in our scoping review, we believe this further highlights the need for a central platform to catalog and regulate the use of barrier enclosures. We also performed the last formal search on 2020-06-24 and were unable to obtain the full text of one study. As a rapidly growing field of research, other studies published since that time were not included in this review. However, forward and reverse citation screening on included articles was completed.

Many of these enclosure systems were devised in the early stages of the pandemic when things were rapidly evolving with many unknowns. As a consequence of that, the studies largely included qualitative and simulation-derived data on process measures. It will be important to perform quantitative studies analyzing real-world outcome (e.g. infectivity rates) in order to make any conclusions on the efficacy of these devices.

6. Conclusions

The use of barrier systems in clinical care was introduced to protect physicians during AGMPs. However, the efficacy of barrier enclosures in protecting physicians is limited. Overall, clinical use of these devices in the absence of thorough medical device testing is concerning and contrary to regulatory legislation intended to safeguard patient and physician safety.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declaration of Competing Interest

None.

Appendix A: Sample Database Search Strategy

Ovid MEDLINE(R) ALL <1946 to June 24, 2020>.

Search history sorted by search number ascending

#	Searches	Results	Type
1	Autopsy/	41,987	Advanced
2	Bronchoscopy/	25,070	Advanced
3	exp "Nebulizers and Vaporizers"/	11,291	Advanced
4	exp Aerosols/	31,294	Advanced
5	exp Airway Management/	114,940	Advanced
6	exp Cardiopulmonary Resuscitation/	17,926	Advanced
7	exp Oxygen Inhalation Therapy/	25,828	Advanced
8	exp Respiratory Function Tests/	233,679	Advanced
9	exp Respiratory Therapy/	114,316	Advanced
10	exp Ventilators, Mechanical/	9044	Advanced
11	Laryngoscopy/	12,643	Advanced
12	Suction/	12,404	Advanced
13	Thoracostomy/	1453	Advanced
14	Aerosol*.mp.	55,689	Advanced
15	AGMP?.mp.	24	Advanced
16	(Airway* adj2 control*).mp.	1736	Advanced
17	(Airway* adj2 manage*).mp.	9341	Advanced
18	(Airway* adj2 manipulat*).mp.	231	Advanced
19	(Airway adj2 surger*).mp.	754	Advanced
20	(artificial adj2 respirat*).mp.	49,345	Advanced
21	Aspirat*.mp.	114,006	Advanced
22	Atomizer*.mp.	749	Advanced
23	(Autopsy adj3 lung?).mp.	819	Advanced
24	Bioaerosol*.mp.	1500	Advanced
25	BiPAP.mp.	670	Advanced
26	Bronchoscop*.mp.	39,004	Advanced
27	(cardiac adj2 life support*).mp.	1980	Advanced
28	code blue.mp.	240	Advanced
29	CPAP.mp.	8377	Advanced
30	Cpr.mp.	12,426	Advanced
31	(Dental adj3 procedure*).mp.	4780	Advanced
32	Extubat*.mp.	13,695	Advanced
33	HFOV.mp.	737	Advanced
34	(high flow adj2 oxygen*).mp.	710	Advanced
35	(High frequency adj3 oscillat*).mp.	3833	Advanced
36	(High speed adj2 device*).mp.	167	Advanced
37	(High-speed adj2 drill*).mp.	388	Advanced
38	(Inhalation adj2 device*).mp.	605	Advanced
39	(Inhalation adj2 therap*).mp.	16,350	Advanced
40	Inhalator*.mp.	692	Advanced
41	(Insert* adj2 chest tube*).mp.	869	Advanced
42	Intubat*.mp.	84,407	Advanced
43	Ippb.mp.	296	Advanced
44	Ippv.mp.	731	Advanced
45	Laryngoscop*.mp.	22,075	Advanced
46	(Lung adj2 function test*).mp.	3992	Advanced
47	(Nasal cannula adj2 therap*).mp.	316	Advanced
48	Nasopharyngoscop*.mp.	488	Advanced
49	Ncpap.mp.	1086	Advanced
50	Nebuli?er*.mp.	11,985	Advanced
51	(Oral adj2 surger*).mp.	12,381	Advanced
52	(Pharyngeal adj2 surger*).mp.	379	Advanced
53	(physiotherapy* adj3 chest).mp.	871	Advanced
54	(Positive adj2 Airway Pressure*).mp.	13,879	Advanced
55	(Positive end adj2 expiratory pressure*).mp.	5925	Advanced
56	(positive adj2 pressure breath*).mp.	1385	Advanced
57	(positive adj2 pressure respirat*).mp.	17,429	Advanced
58	(Pulmonary adj2 function test*).mp.	12,273	Advanced
59	respirator*.mp.	570,255	Advanced

(*continued*)

Search history sorted by search number ascending			
#	Searches	Results	Type
60	(Respiratory adj2 therap*).mp.	9846	Advanced
61	(Resuscitat* adj2 cardiopulmonary).mp.	24,366	Advanced
62	(Sputum adj3 induc*).mp.	3258	Advanced
63	Suction*.mp.	26,595	Advanced
64	(Thoracic adj2 surger*).mp.	29,352	Advanced
65	Thoracoscop*.mp.	18,348	Advanced
66	Thoracostom*.mp.	2939	Advanced
67	(Thorax adj2 drain*).mp.	60	Advanced
68	Tracheostom*.mp.	16,396	Advanced
69	Tracheotomy.mp.	11,400	Advanced
70	(Transphenoidal adj2 surger*).mp.	155	Advanced
71	Vapori?er*.mp.	10,231	Advanced
72	ventilat*.mp.	186,237	Advanced
73	Videolaryngoscop*.mp.	1173	Advanced
74	or/1–73	1,237,644	Advanced
75	(Acrylic adj3 barrier*).mp.	6	Advanced
76	(Acrylic adj3 box*).mp.	43	Advanced
77	(Acrylic adj2 cover*).mp.	61	Advanced
78	(Acrylic adj3 drap*).mp.	1	Advanced
79	(Acrylic adj3 enclosure*).mp.	2	Advanced
80	(Acrylic adj3 hood?).mp.	0	Advanced
81	(Acrylic adj3 screen?).mp.	4	Advanced
82	(Acrylic adj3 sheet?).mp.	54	Advanced
83	(Acrylic adj3 shield*).mp.	27	Advanced
84	(Acrylic adj3 system*).mp.	129	Advanced
85	(Acrylic adj3 tarp?).mp.	0	Advanced
86	(Acrylic adj2 unit?).mp.	32	Advanced
87	(Aerosol adj3 cover*).mp.	34	Advanced
88	(Aerosol adj2 evacuation system?).mp.	2	Advanced
89	(Aerosol* adj2 enclosure*).mp.	1	Advanced
90	(Aerosol* adj2 evacuation system?).mp.	2	Advanced
91	(Aerosol* adj3 barrier*).mp.	26	Advanced
92	(Aerosol* adj3 box*).mp.	22	Advanced
93	(Aerosol* adj3 enclosure*).mp.	1	Advanced
94	(Aerosol* adj3 screen?).mp.	4	Advanced
95	(Aerosol* adj3 shield*).mp.	6	Advanced
96	(Aerosol* adj3 tent*).mp.	10	Advanced
97	(Aerosol adj2 unit?).mp.	27	Advanced
98	(Barrier adj2 device?).mp.	217	Advanced
99	(Barrier adj2 measure?).mp.	394	Advanced
100	(Barrier adj3 box*).mp.	12	Advanced
101	(Barrier adj2 cover*).mp.	118	Advanced
102	(Barrier adj3 enclosure*).mp.	12	Advanced
103	(Barrier adj3 hood?).mp.	2	Advanced
104	(Barrier adj3 screen?).mp.	40	Advanced
105	(Barrier adj3 sheet*).mp.	37	Advanced
106	(Barrier adj3 shield*).mp.	75	Advanced
107	(Barrier adj3 system?).mp.	1163	Advanced
108	(Clear adj2 barrier*).mp.	93	Advanced
109	(Clear adj2 box*).mp.	35	Advanced
110	(Clear adj2 cover*).mp.	78	Advanced
111	(Clear adj2 enclosure*).mp.	6	Advanced
112	(Containment adj2 chamber?).mp.	14	Advanced
113	(Containment adj2 device?).mp.	69	Advanced
114	(Containment adj2 unit?).mp.	25	Advanced
115	(Corona* adj2 curtain*).mp.	1	Advanced
116	(Disposable adj3 barrier*).mp.	30	Advanced
117	(Disposable adj3 box*).mp.	11	Advanced
118	(Disposable adj2 cover*).mp.	63	Advanced
119	(Disposable adj3 drap*).mp.	70	Advanced
120	(Disposable adj3 enclosure*).mp.	1	Advanced
121	(Disposable adj3 film?).mp.	44	Advanced
122	(Disposable adj3 hood?).mp.	6	Advanced
123	(Disposable adj3 screen?).mp.	257	Advanced
124	(Disposable adj3 sheet?).mp.	24	Advanced
125	(Disposable adj3 shield*).mp.	39	Advanced
126	(Disposable adj3 tarp?).mp.	0	Advanced
127	(Disposable adj3 tent*).mp.	2	Advanced
128	(Disposable adj2 unit?).mp.	86	Advanced
129	(Drape* adj2 cover*).mp.	29	Advanced
130	(Droplet adj2 enclosure*).mp.	2	Advanced
131	(Droplet adj2 evacuation system?).mp.	0	Advanced
132	(Glass adj3 barrier*).mp.	64	Advanced
133	(Glass adj3 box*).mp.	66	Advanced
134	(Glass adj2 cover*).mp.	2041	Advanced

(*continued*)

Search history sorted by search number ascending			
#	Searches	Results	Type
135	(Glass adj3 enclosure*).mp.	8	Advanced
136	(Glass adj3 screen?).mp.	83	Advanced
137	(Glass adj3 shield*).mp.	44	Advanced
138	(Glass adj2 unit?).mp.	49	Advanced
139	(Intubation adj3 barrier*).mp.	8	Advanced
140	(Intubation adj3 box*).mp.	12	Advanced
141	(Intubation adj3 cover*).mp.	11	Advanced
142	(Intubation adj3 enclosure*).mp.	4	Advanced
143	(Intubation adj3 screen?).mp.	4	Advanced
144	(Intubation adj3 shield*).mp.	1	Advanced
145	(Intubation adj3 tent*).mp.	3	Advanced
146	(Intubation adj2 unit?).mp.	79	Advanced
147	(Isolat* adj2 chamber*).mp.	340	Advanced
148	(Isolat* adj2 container*).mp.	12	Advanced
149	(Isolat* adj2 cover*).mp.	371	Advanced
150	(Isolat* adj2 drape*).mp.	11	Advanced
151	(Isolat* adj2 enclosure*).mp.	15	Advanced
152	(Isolat* adj2 hood*).mp.	32	Advanced
153	(Isolat* adj2 tent*).mp.	256	Advanced
154	(Isolat* adj2 unit?).mp.	1325	Advanced
155	(Negative pressure adj3 cover*).mp.	16	Advanced
156	(Negative pressure adj3 enclosure*).mp.	0	Advanced
157	(Patient adj2 covering).mp.	188	Advanced
158	(Physical adj3 barrier*).mp.	5128	Advanced
159	(Physical adj3 box*).mp.	61	Advanced
160	(Physical adj3 enclosure*).mp.	9	Advanced
161	(Physical adj3 screen?).mp.	755	Advanced
162	(Physical adj3 shield*).mp.	60	Advanced
163	(Physical adj2 unit?).mp.	400	Advanced
164	(Plastic adj3 barrier*).mp.	108	Advanced
165	(Plastic adj3 box*).mp.	249	Advanced
166	(Plastic adj3 cover*).mp.	1068	Advanced
167	(Plastic adj3 drap*).mp.	108	Advanced
168	(Plastic adj3 enclosure*).mp.	24	Advanced
169	(Plastic adj2 film?).mp.	1031	Advanced
170	(Plastic adj3 hood?).mp.	20	Advanced
171	(Plastic adj3 screen?).mp.	30	Advanced
172	(Plastic adj3 sheet?).mp.	426	Advanced
173	(Plastic adj3 shield*).mp.	72	Advanced
174	(Plastic adj3 system?).mp.	633	Advanced
175	(Plastic adj3 tarp?).mp.	16	Advanced
176	(Plastic adj3 tent*).mp.	25	Advanced
177	(Plastic adj2 unit?).mp.	344	Advanced
178	(Plexiglass adj3 barrier*).mp.	0	Advanced
179	(Plexiglass adj3 box*).mp.	19	Advanced
180	(Plexiglass adj3 cover*).mp.	12	Advanced
181	(Plexiglass adj3 drap*).mp.	0	Advanced
182	(Plexiglass adj3 enclosure*).mp.	3	Advanced
183	(Plexiglass adj3 hood?).mp.	2	Advanced
184	(Plexiglass adj3 screen?).mp.	4	Advanced
185	(Plexiglass adj3 sheet?).mp.	6	Advanced
186	(Plexiglass adj3 shield*).mp.	7	Advanced
187	(Plexiglass adj3 system?).mp.	4	Advanced
188	(Plexiglass adj3 tarp?).mp.	0	Advanced
189	(Plexiglass adj2 unit?).mp.	0	Advanced
190	(Polycarbonate adj3 barrier*).mp.	3	Advanced
191	(Polycarbonate adj3 box*).mp.	4	Advanced
192	(Polycarbonate adj3 cover*).mp.	27	Advanced
193	(Polycarbonate adj3 drap*).mp.	0	Advanced
194	(Polycarbonate adj3 enclosure*).mp.	1	Advanced
195	(Polycarbonate adj3 hood?).mp.	0	Advanced
196	(Polycarbonate adj3 screen?).mp.	4	Advanced
197	(Polycarbonate adj3 sheet?).mp.	39	Advanced
198	(Polycarbonate adj3 shield*).mp.	7	Advanced
199	(Polycarbonate adj3 system?).mp.	30	Advanced
200	(Polycarbonate adj3 tarp?).mp.	0	Advanced
201	(Polycarbonate adj2 unit?).mp.	2	Advanced
202	(Polymer adj3 barrier*).mp.	151	Advanced
203	(Polymer adj3 box*).mp.	11	Advanced
204	(Polymer adj3 cover*).mp.	347	Advanced
205	(Polymer adj3 drap*).mp.	1	Advanced
206	(Polymer adj3 enclosure*).mp.	0	Advanced
207	(Polymer adj3 hood?).mp.	0	Advanced
208	(Polymer adj3 screen?).mp.	42	Advanced

(*continued on next page*)

(*continued*)

Search history sorted by search number ascending			
#	Searches	Results	Type
209	(Polymer adj3 sheet?).mp.	321	Advanced
210	(Polymer adj3 shield*).mp.	66	Advanced
211	(Polymer adj3 system?).mp.	3501	Advanced
212	(Polymer adj3 tarp?).mp.	0	Advanced
213	(Polymer adj2 unit?).mp.	213	Advanced
214	(Portable adj2 barrier*).mp.	7	Advanced
215	(Portable adj2 box*).mp.	35	Advanced
216	(Portable adj2 cover*).mp.	7	Advanced
217	(Portable adj2 enclosure*).mp.	6	Advanced
218	(Portable adj2 hood*).mp.	5	Advanced
219	(Protect* adj2 intubation?).mp.	56	Advanced
220	(Protect* adj2 unit?).mp.	387	Advanced
221	(Protect* adj3 barrier*).mp.	4549	Advanced
222	(Protect* adj3 box*).mp.	109	Advanced
223	(Protect* adj3 cover*).mp.	1367	Advanced
224	(Protect* adj3 drap*).mp.	46	Advanced
225	(Protect* adj3 enclosure*).mp.	25	Advanced
226	(Protect* adj3 hood?).mp.	59	Advanced
227	(Protect* adj3 screen?).mp.	200	Advanced
228	(Protect* adj3 sheet?).mp.	76	Advanced
229	(Protect* adj3 shield*).mp.	889	Advanced
230	(Protect* adj3 tarp?).mp.	2	Advanced
231	(Protect* adj3 tent*).mp.	47	Advanced
232	(Tent adj2 cover*).mp.	4	Advanced
233	(Transparent adj2 barrier*).mp.	74	Advanced
234	(Transparent adj2 box*).mp.	58	Advanced
235	(Transparent adj2 cover*).mp.	110	Advanced
236	(Transparent adj2 enclosure*).mp.	5	Advanced
237	or/75–236	31,062	Advanced
238	74 and 237	1699	Advanced
239	limit 238 to yr = "2000 -Current"	1330	Advanced
240	animals/ not (animals/ and humans/)	4,677,410	Advanced
241	239 not 240	1192	Advanced
242	remove duplicates from 241	1183	Advanced

Appendix B: Data abstraction form with variable definitions

Data field	Definition
Publication details	
Study Title	Full article title.
Publication Date	Date of first publication. If online, indicated the date the article was first available.
Primary Author	First author listed.
Publication Status	Status at the time of data abstraction. *Options:* Published: Peer Reviewed; Pre-Print Server; Pre-Proof; Other
Publication / Article Type	*Options:* Letter to The Editor, Original Research, Commentary, Brief Report, Opinion/Editorial, Other
Country	Country where the study took place, or where the study was published from (corresponding author's location).
Setting	*Options:* ED/Critical Care, Surgical/Draping, GI/ENT Procedures, Non-Emergent Airway Management (e.g. general OR procedures), Other
Study Category	*Options:* - *Device Description or Modification* – presenting a new device, including the modification of an existing device. - *Evaluation* – article includes measurement of any outcomes (quantitative or qualitative). - *Other*
Device Details	
Device Description	Design details of all the device (e.g. # of drapes, different size / shapes, coverage provided) and any unique features included.
Device Category	*Options:* - *Plastic Box* – similar in design to the 4-sided aerosol box design - *Plastic Sheet – Rigid Frame* - *Plastic Sheet – No Rigid Frame* - *Other*
Intended Medical Use	Actual use or intended medical use of the device. If describing a device for "general use", but no procedure specified, list "AGMPs". *Options:* intubation, extubation, tracheostomy, endoscopy, bronchoscopy, NIPPV, ENT surgeries (e.g. endonasal / *endo*-oral), dental procedures, other (free-text)
Evaluation & Results	
Study Design Type	Study design type, if applicable and available.
Patient Population	Description of the patient population in the study.
Methods	Study participants, sample size and method of measurements.
Study Outcomes	Listed outcomes for efficacy, efficiency, usability, and other.
Results	Main results of each study outcome(s).
Limitations	Main study limitations as listed by the author(s)

References

[1] U.S. Food & Drug Administration. Protective Barrier Enclosures Without Negative Pressure Used During the COVID-19 Pandemic May Increase Risk to Patients and Health Care Providers - Letter to Health Care Providers. https://www.fda.gov/medical-devices/letters-health-care-providers/protective-barrier-enclosures-without-negative-pressure-used-during-covid-19-pandemic-may-increase;; 2020. accessed August 31 2020.

[2] Price C, Tawadrous D, Ben-Yakov M, Orchanian-Cheff A, Choi J. Barrier enclosure use during aerosol-generating medical procedures: a scoping review protocol. OSF.

[3] Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation. Ann Intern Med. 2018;169(7):467–73.

[4] Plazikowski E, Greif R, Marschall J, Pedersen TH, Kleine-Brueggeney M, Albrecht R, et al. Emergency airway Management in a Simulation of highly contagious isolated patients: both isolation strategy and device type matter. Infect Control Hosp Epidemiol. 2018;39(2):145–51. https://doi.org/10.1017/ice.2017.287.

[5] Putzer D, Lechner R, Coraca-Huber D, Mayr A, Nogler M, Thaler M. The extent of environmental and body contamination through aerosols by hydro-surgical debridement in the lumbar spine. Arch Orthop Trauma Surg. 2017;137(6):743–7. https://doi.org/10.1007/s00402-017-2668-0.

[6] Nogler M, Lass-Florl C, Wimmer C, Bach C, Kaufmann C, Ogon M. Aerosols produced by high-speed cutters in cervical spine surgery: extent of environmental contamination. Eur Spine J. 2001;10(4):274–7. https://doi.org/10.1007/s005860100310.

[7] Canelli R, Connor CW, Gonzalez M, Nozari A, Ortega R. Barrier enclosure during endotracheal intubation. N Engl J Med. 2020;382(20):1957–8https://doi.org/10.1056/NEJMc2007589.

[8] Vijayaraghavan S, Puthenveettil N. Aerosol box for protection during airway manipulation in covid-19 patients. Indian J Anaesthesia. 2020;64(14 Supplement 2):S148–9.

[9] Jaichandran VV, Raman R. Aerosol prevention box for regional anaesthesia for eye surgery in COVID times. Eye. 2020. https://doi.org/10.1038/s41433-020-1027-5.

[10] Mcleod RWJ, Warren N, Roberts SA. Development and evaluation of a novel protective device for upper gastrointestinal endoscopy in the COVID-19 pandemic: the EBOX. Frontline Gastroenterol. 2020:1–5.

[11] Traina M, Amata M, Granata A, Ligresti D, Gaetano B. The C-Cube: an endoscopic solution in the time of COVID-19. Endoscopy. 2020. https://doi.org/10.1055/a-1190-3462.

[12] 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.

[13] Laosuwan P, Earsakul A, Pannangpetch P, Sereeyotin J. Acrylic Box Versus Plastic Sheet Covering on Droplet Dispersal During Extubation in COVID-19 Patients. Anesth Analg. 2020;131(2):e106–8.

[14] Malik JS, Jenner C, Ward PA. Maximising application of the aerosol box in protecting healthcare workers during the COVID-19 pandemic. Anaesthesia. 2020;75(7):974–5. https://doi.org/10.1111/anae.15109.

[15] Girgis AM, Aziz MN, Gopesh TC, Friend J, Grant AM, Sandubrae JA, et al. Novel Coronavirus Disease 2019 (COVID-19) Aerosolization Box: Design Modifications for Patient Safety. J Cardiothoracic Vascular Anesthesia. 2020. https://doi.org/10.1053/j.jvca.2020.05.001.

[16] Marquez-Gde VJ, Lopez Bascope A, Valanci-Aroesty S. Low-cost double protective barrier for intubating patients amid COVID-19 crisis. Anesthesiology. 2020;05:05. https://doi.org/10.1097/ALN.0000000000003439.

[17] Rahmoune FC, Ben Yahia MM, Hajjej R, Pic S, Chatti K. Protective device during Airway Management in Patients with coronavirus disease 2019 (COVID-19). Anesthesiology. 2020;06:06. https://doi.org/10.1097/ALN.0000000000003369.

[18] Asokan K, Babu B, Jayadevan A. Barrier enclosure for airway management in COVID-19 pandemic. Indian J Anaesthesia. 2020;64(14 Supplement 2):S153–4. https://doi.org/10.4103/ija.IJA_413_20.

[19] Cartwright J, Boyer TJ, Hamilton MC, Ahmed RA, Mitchell SA. Rapid prototype feasibility testing with simulation: improvements and updates to the Taiwanese "aerosol box". J Clin Anesth. 2020;66:109950. https://doi.org/10.1016/j.jclinane.2020.109950.
[20] Ibrahim M, Khan E, Babazade R, Simon M, Vadhera R. Comparison of the effectiveness of different barrier enclosure techniques in protection of healthcare workers during tracheal intubation and Extubation. A&A Practice. 2020;14(8):e01252. https://doi.org/10.1213/XAA.0000000000001252.
[21] Gore RK, Saldana C, Wright DW, Klein AM. Intubation Containment System for Improved Protection from Aerosolized Particles during Airway Management. IEEE J Transl Eng Health Med. 2020;8. https://doi.org/10.1109/JTEHM.2020.2993531 no pagination.
[22] Perella P, Tabarra M, Hataysal E, Pournasr A, Renfrew I. Minimising exposure to droplet and aerosolised pathogens: a computational fluid dynamics study. medRxiv. 2020. https://doi.org/10.1101/2020.05.30.20117671 2020.05.30.20117671.
[23] Brar S, Daya J, Schuster-Bruce J, Krishna S, Daya H. St George's COVID shield for use by ENT surgeons performing tracheostomies. medRxiv. 2020. https://doi.org/10.1101/2020.05.04.20087072v1 (preprint).
[24] 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 (Lond). 2020. https://doi.org/10.1111/anae.15188.
[25] Cubillos J, Querney J, Rankin A, Moore J, Armstrong K. A multipurpose portable negative air flow isolation chamber for aerosol-generating procedures during the COVID-19 pandemic. Br J Anaesthesia. 2020;27. https://doi.org/10.1016/j.bja.2020.04.059.
[26] Martel ML, Reardon RF. Aerosol Barrier Hood for Use in the Management of Critically Ill Adults With COVID-19. Ann Emergency Med. 2020. https://doi.org/10.1016/j.annemergmed.2020.04.030.
[27] Iwasaki N, Sekino M, Egawa T, Yamashita K, Hara T. Use of a plastic barrier curtain to minimize droplet transmission during tracheal extubation in patients with COVID-19. Acute Med. 2020;7(1):e529. https://doi.org/10.1002/ams2.529.
[28] Mehta HJ, Patterson M, Gravenstein N. Barrier enclosure using a Mayo stand and plastic sheet during cardiopulmonary resuscitation in patients and its effect on reducing visible aerosol dispersion on healthcare workers. J Crit Care. 2020. https://doi.org/10.1016/j.jcrc.2020.05.007.
[29] Babu B, Shivakumar S, Dr Asokan K. "Thinking outside the box in COVID-19 era"-Application of Modified Aerosol Box in Dermatology. Dermatologic Therapy. 2020: e13769. https://doi.org/10.1111/dth.13769.
[30] Adir Y, Segol O, Kompaniets D, Ziso H, Yaffe Y, Bergman I, et al. COVID-19: minimising risk to healthcare workers during aerosol-producing respiratory therapy using an innovative constant flow canopy. Eur Respir J. 2020;55(5):05. https://doi.org/10.1183/13993003.01017-2020.
[31] Hosseini Boroujeni SM, Khajehaminian MR, Hekayati M. Developing a Simply Fabricated Barrier for Aerosol Generating Procedures. J. Disaster Emergency Res.. 2020:0-.
[32] Bassin B, Haas N, Puls H, Kota S, Kota S, Ward K. Rapid development of a portable negative pressure procedural tent; 2020.
[33] Hill E, Crockett C, Circh RW, Lansville F, Stahel PF. Introducing the "corona Curtain": An innovative technique to prevent airborne COVID-19 exposure during emergent intubations. Patient Safety Surgery. 2020;14(1)https://doi.org/10.1186/s13037-020-00247-5.
[34] Quadros CA, Leal MCBDM, Baptista-Sobrinho CA, Nonaka CKV, Souza BSF, Milan-Mattos JC, et al. Environmental safety evaluation of the protection and isolation system for patients with covid-19. medRxiv. 2020:2020.06.04.20122838. https://doi.org/10.1101/2020.06.04.20122838.
[35] Yang YL, Huang CH, Luk HN, Tsai PB. Adaptation to the Plastic Barrier Sheet to Facilitate Intubation during the COVID-19 Pandemic. Anesthesia analgesia. 2020;27. https://doi.org/10.1213/ANE.0000000000004923.
[36] Brown S, Patrao F, Verma S, Lean A, Flack S, Polaner D. Barrier system for airway management of COVID-19 patients. Anesth Analg. 2020;131(1):e34–5.
[37] Asenjo JF. Safer intubation and extubation of patients with COVID-19. Can J Anaesth. 2020. https://doi.org/10.1007/s12630-020-01666-9.
[38] Tan Z, Khoo Deborah Wen S, Zeng LA, Tien Jong-Chie C, LAK Yang, Ong YY, et al. Protecting health care workers in the front line: Innovation in COVID-19 pandemic. J Global Health. 2020;10(1). https://doi.org/10.7189/jogh.10.010357.
[39] Ayyan SM, Raju KNP, Jain N, Vivekanandan M. Cost-effective innovative personal protective equipment for the management of COVID-19 patients. J Glob Infect. 2020;12(2):113.
[40] Sayin I, Devecioglu I, Yazici ZM. A Closed Chamber ENT Examination Unit for Aerosol-Generating Endoscopic Examinations of COVID-19 Patients. Ear Nose Throat J. 2020. https://doi.org/10.1177/0145561320931216.
[41] Russell C. Development of a Device to Reduce Oropharyngeal Aerosol Transmission. J Endodontics. 2020;07. https://doi.org/10.1016/j.joen.2020.05.012.
[42] Tsuchida T, Fujitani S, Yamasaki Y, Kunishima H, Matsuda T. Development of a protective device for RT-PCR testing of COVID-19. Cambridge: Cambridge University Press; 2020; 1–5.
[43] Suzuki S, Kusano C, Ikehara H. Simple barrier device to minimize facial exposure of endoscopists during COVID-19 pandemic. Digestive Endoscopy. 2020. https://doi.org/10.1111/den.13717.
[44] Kinjo S, Dudley M, Sakai N. Modified Wake Forest Type Protective Shield for an Asymptomatic, COVID-19 Non-Confirmed Patient for Intubation Undergoing Urgent Surgery. Anesthesia and analgesia. 2020;08. https://doi.org/10.1213/ANE.0000000000004964.
[45] Anon JB, Denne C, Rees D. Patient-Worn Enhanced Protection Face Shield for Flexible Endoscopy. Otolaryngology Head and Neck Surgery. 2020. https://doi.org/10.1177/0194599820934777.
[46] Straube F, Wendtner C, Hoffmann E, Volz S, Dorwarth U, Engel M, et al. Universal mobile protection system for aerosol-generating medical interventions in COVID-19 patients. Critical Care. 2020;24(1). https://doi.org/10.1186/s13054-020-02969-5.
[47] Filho WA, Teles TSPG, da Fonseca MRS, Filho FJFP, Pereira GM, Pontes ABM, et al. Barrier device prototype for open tracheotomy during COVID-19 pandemic. Auris Nasus Larynx. 2020, https://doi.org/10.1016/j.anl.2020.05.003.
[48] Cordier PY, De La Villeon B, Martin E, Goudard Y, Haen P. Health workers' safety during tracheostomy in COVID-19 patients: Homemade protective screen. Head Neck. 2020. https://doi.org/10.1002/hed.26222.
[49] Chow VLY, Chan JYW, Ho VWY, Pang SSY, Lee GCC, Wong MMK, et al. Tracheostomy during COVID-19 pandemic—Novel approach. Head Neck. 2020. https://doi.org/10.1002/hed.26234.
[50] Bertroche JT, Pipkorn P, Zolkind P, Buchman CA, Zevallos JP. Negative-Pressure Aerosol Cover for COVID-19 Tracheostomy. JAMA Otolaryngol Head Neck Surgery. 2020. https://doi.org/10.1001/jamaoto.2020.1081.
[51] Prabhakaran K, Malcom R, Choi J, Chudner A, Moscatello A, Panzica P, et al. Open Tracheostomy for Covid19 Positive Patients: A Method to Minimize Aerosolization and Reduce Risk of Exposure. J Trauma Acute Care Surgery. 2020;11. https://doi.org/10.1097/TA.0000000000002780.
[52] Shaw KM, Lang AL, Lozano R, Szabo M, Smith S, Wang J. Intensive care unit isolation hood decreases risk of aerosolization during noninvasive ventilation with COVID-19. Canadian J Anesthesia. 2020. https://doi.org/10.1007/s12630-020-01721-5.
[53] Fox TH, Silverblatt M, Lacour A, de Boisblanc BP. Negative Pressure Tent to Reduce Exposure of Health Care Workers to SARS CoV-2 During Aerosol Generating Respiratory Therapies. Chest. 2020. https://doi.org/10.1016/j.chest.2020.04.070.
[54] Pollaers K, Herbert H, Vijayasekaran S. Pediatric Microlaryngoscopy and Bronchoscopy in the COVID-19 Era. JAMA Otolaryngol Head Neck Surg. 2020. https://doi.org/10.1001/jamaoto.2020.1191.
[55] Francom CR, Javia LR, Wolter NE, Lee GS, Wine T, Morrissey T, et al. Pediatric laryngoscopy and bronchoscopy during the COVID-19 pandemic: A four-center collaborative protocol to improve safety with perioperative management strategies and creation of a surgical tent with disposable drapes. Int J Pediatric Otorhinolaryngol. 2020;134. https://doi.org/10.1016/j.ijporl.2020.110059 no pagination.
[56] Tsai PB. Barrier Shields: Not Just for Intubations in Today's COVID-19 World? Anesth Analg. 2020. https://doi.org/10.1213/ANE.0000000000004902.
[57] Lang AL, Shaw KM, Lozano R, Wang J. Effectiveness of a negative-pressure patient isolation hood shown using particle count. Br J Anaesthesia. 2020. https://doi.org/10.1016/j.bja.2020.05.002.
[58] Hellman S, Chen GH, Irie T. Rapid clearing of aerosol in an intubation box by vacuum filtration. Br J Anaesthesia. 2020. https://doi.org/10.1016/j.bja.2020.06.017.
[59] Convissar D, Chang CY, Choi WE, Chang MG, Bittner EA. The vacuum assisted negative pressure isolation Hood (VANISH) system: novel application of the Stryker Neptune TM suction machine to create COVID-19 negative pressure isolation environments. Cureus. 2020;12(5):e8126. https://doi.org/10.7759/cureus.8126.
[60] Wolter NE, Matava CT, Papsin BC, Oloya A, Mercier ME, Salonga E, et al. Enhanced draping for airway procedures during the COVID-19 pandemic. J Am Coll Surg. 2020;231(2):304–5. https://doi.org/10.1016/j.jamcollsurg.2020.04.034.
[61] Campos S, Carreira C, Marques PP, Vieira A. Endoprotector: protective box for safe endoscopy use during COVID-19 outbreak. Endosc Int Open. 2020;8(6):E817–21. https://doi.org/10.1055/a-1180-8527.
[62] Luis S, Margarita H, Javier P, Daniela S. New protection barrier for endoscopic procedures in the era of pandemic COVID-19. VideoGIE. 2020. https://doi.org/10.1016/j.vgie.2020.05.006.
[63] Kobara H, Nishiyama N, Masaki T. Shielding for patients using a single-use vinyl-box under continuous aerosol suction to minimize SARS-CoV-2 transmission during emergency endoscopy. Digestive Endoscopy. 2020. https://doi.org/10.1111/den.13713.
[64] Goenka M, Afzalpurkar S, Jajodia S, Shah BB, Tiwary I, Sengupta S. Cover Page Dual Purpose Easily Assembled Aerosol Chamber Designed for Safe Endoscopy and Intubation during COVID Pandemic; 2020.
[65] Carron JD, Buck LS, Harbarger CF, Eby TL. A Simple Technique for Droplet Control During Mastoid Surgery. JAMA Otolaryngol Head Neck Surg. 2020. https://doi.org/10.1001/jamaoto.2020.1064.
[66] Chari DA, Workman AD, Chen JX, Jung DH, Abdul-Aziz D, Kozin ED, et al. Aerosol dispersion during Mastoidectomy and custom mitigation strategies for Otologic surgery in the COVID-19 era. Otolaryngol Head Neck Surg. 2020. https://doi.org/10.1177/0194599820941835 194599820941835.
[67] Chen C, Shen N, Li X, Zhang Q, Hei Z. New device and technique to protect intubation operators against COVID-19. Intensive Care Medicine. 2020. https://doi.org/10.1007/s00134-020-06072-9.
[68] Sharma SS, Singh DK, Yadav AK, Swain J, Kumar S, Jain DK, et al. Disposable customized aerosol containment chamber for oral cancer biopsy: A novel technique during COVID-19 pandemic. J Surg Oncol. 2020. https://doi.org/10.1002/jso.25962.
[69] Maharaj SH. The nasal tent: an adjuvant for performing endoscopic endonasal surgery in the Covid era and beyond. European Archives of Oto-Rhino-Laryngology. 2020. https://doi.org/10.1007/s00405-020-06149-7.
[70] David AP, Jiam NT, Reither JM, Gurrola 2nd JG, Aghi MK, El-Sayed IH. Endoscopic skull base and transoral surgery during COVID-19 pandemic: minimizing droplet spread with negative-pressure otolaryngology viral isolation drape. Head Neck. 2020;01:01. https://doi.org/10.1002/hed.26239.
[71] Gordon SA, Deep NL, Jethanamest D. Exoscope and personal protective equipment use for Otologic surgery in the era of COVID-19. Otolaryngol Head Neck Surg. 2020;163(1):179–81. https://doi.org/10.1177/0194599820928975.
[72] Wexner SD, Cortes-Guiral D, Gilshtein H, Kent I, Reymond MA. COVID-19: impact on colorectal surgery. Colorectal Dis. 2020;22(6):635–40. https://doi.org/10.1111/codi.15112.

[73] Anguita R, Tossounis H, Mehat M, Eames I, Wickham L. Surgeon's protection during ophthalmic surgery in the Covid-19 era: a novel fitted drape for ophthalmic operating microscopes. Eye (Lond). 2020;34(7):1180–2. https://doi.org/10.1038/s41433-020-0931-z.
[74] Hasmi AH, Khoo LS, Koo ZP, Suriani MUA, Hamdan AN, Yaro SWM, et al. The craniotomy box: an innovative method of containing hazardous aerosols generated during skull saw use in autopsy on a COVID-19 body. Forensic Sci Med Pathol. 2020;04. https://doi.org/10.1007/s12024-020-00270-z.
[75] Gonzalez-Ciccarelli LF, Nilson J, Oreadi D, Fakitsas D, Sekhar P, Quraishi SA. Reducing transmission of COVID-19 using a continuous negative pressure operative field barrier during oral maxillofacial surgery. Oral Maxillofac Surg Cases. 2020;6(3):100160. https://doi.org/10.1016/j.omsc.2020.100160.
[76] Babu B, Gupta S, Sahni V. Aerosol box for dentistry. Br Dent J. 2020;228(9):660. https://doi.org/10.1038/s41415-020-1598-3.
[77] Kulkarni RR, Stephen M, Shashank A, Mandhal LN. Novel method of performing brachial plexus block using an aerosol box during COVID-19 pandemic. J Clin Anesthesia. 2020;66. https://doi.org/10.1016/j.jclinane.2020.109943 no pagination.
[78] Endersby RVW, Ho ECY, Spencer AO, Goldstein DH, Schubert E. Barrier Devices for Reducing Aerosol and Droplet Transmission in Coronavirus Disease 2019 Patients: Advantages, Disadvantages, and Alternative Solutions. Anesth Analg. 2020. https://doi.org/10.1213/ANE.0000000000004953.
[79] Jazuli F, Bilic M, Hanel E, Ha M, Hassall K, Trotter BG. Endotracheal intubation with barrier protection. EMJ. 2020;01. https://doi.org/10.1136/emermed-2020-209785.
[80] Chahal AM, Van Dewark K, Gooch R, Fukushima E, Hudson ZM. A Rapidly Deployable Negative Pressure Enclosure for Aerosol-Generating Medical Procedures. medRxiv. 2020. https://doi.org/10.1101/2020.04.14.20063958 2020.04.14.20063958.
[81] Chen JX, Workman AD, Chari DA, Jung DH, Kozin E, Lee DJ, et al. Demonstration and mitigation of aerosol and particle dispersion during mastoidectomy relevant to the COVID-19 era. Otol Neurotol. 2020. https://doi.org/10.1097/MAO.0000000000002765.
[82] Giampalmo M, Pasquesi R, Solinas E. Easy and Accessible Protection against Aerosol Contagion during Airway Management. Anesthesiology. 2020. https://doi.org/10.1097/ALN.0000000000003430.
[83] Lyaker MR, Al-Qudsi OH, Kopanczyk R. Looking beyond tracheal intubation: addition of negative airflow to a physical barrier prevents the spread of airborne particles. Anaesthesia. 2020. https://doi.org/10.1111/anae.15194.
[84] Hirose K, Uchida K, Umezu S. Airtight, flexible, disposable barrier for extubation. J Anesthesia. 2020. https://doi.org/10.1007/s00540-020-02804-9.
[85] Dalli J, Khan MF, Marsh B, Nolan K, Cahill RA. Evaluating intubation boxes for airway management. Br J Anaesthesia. 2020;14. https://doi.org/10.1016/j.bja.2020.05.006.
[86] 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 Anaesthesia. 2020;13. https://doi.org/10.1016/j.bja.2020.05.001.
[87] Brown H, Preston D, Bhoja R. Thinking outside the Box: A Low-cost and Pragmatic Alternative to Aerosol Boxes for Endotracheal Intubation of COVID-19 Patients. Anesthesiology. 2020;29. https://doi.org/10.1097/ALN.0000000000003422.
[88] Clariot S, Dumain G, Gauci E, Langeron O, Levesque É. Minimising COVID-19 exposure during tracheal intubation by using a transparent plastic box: a randomised prospective simulation study. Anaesth Crit Care Pain Med. 2020. https://doi.org/10.1016/j.accpm.2020.06.005.
[89] Hamal PK, Chaurasia RB, Pokhrel N, Pandey D, Shrestha GS. An affordable videolaryngoscope for use during the COVID-19 pandemic. Lancet Glob Health. 2020;8(7):e893–4. https://doi.org/10.1016/S2214-109X(20)30259-X.
[90] Serdinsek M, Stopar Pintaric T, Poredos P, Selic Serdinsek M, Umek N. Evaluation of a foldable barrier enclosure for intubation and extubation procedures adaptable for patients with COVID-19: a mannequin study. J Clin Anesth. 2020;67:109979. https://doi.org/10.1016/j.jclinane.2020.109979.
[91] Seger CD, Wang L, Dong X, Tebon P, Kwon S, Liew EC, et al. A Novel Negative Pressure Isolation Device for Aerosol Transmissible COVID-19. Anesthesia Analgesia. 2020. https://doi.org/10.1213/ane.0000000000005052 Publish Ahead of Printhttps.
[92] Bai JW, Ravi A, Notario L, Choi M. Opening the discussion on a closed intubation box. Trends Anaesthesia Crit. Care. 2020, https://doi.org/10.1016/j.tacc.2020.06.004.
[93] Pelley L. How a simple plastic box could protect health-care workers across Canada from COVID-19. https://www.cbc.ca/news/canada/toronto/how-a-simple-plastic-box-could-protect-health-care-workers-across-canada-from-covid-19-1.5525262;; 2020. accessed September 7 2020.
[94] Duggan LV, Marshall SD, Scott J, Brindley PG, Grocott HP. The MacGyver bias and attraction of homemade devices in healthcare. Can J Anaesth. 2019;66(7):757–61. https://doi.org/10.1007/s12630-019-01361-4.