The Innovation of Protective Barriers for Airway-related Procedures during the COVID-19 Pandemic in Thailand

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Airway-related procedures are considered a high-risk procedure for droplet transmission to medical personnel, especially during the COVID-19 pandemic period. Many protective equipment aim to limit the spreading of contamination have been emerged. We collect the data, by interviewing the developers and review these locally developed protective barriers by developers, authors and experts.

Many innovations of the protective barriers have been emerged during this period and can be categorized into 3 groups; simple boxes, simple tent, and box or tent with the application of negative pressure onto them. Each model has its own advantages and limitation. These protective barriers may alleviate risk of the viral transmission during the airway-related procedures, however, the operators should still apply standard personal protective equipment according to the risk and institutional recommendation. As the intubation with these protective barriers can be challenging, the operator should exercise the procedure in a simulating environment before applying to the patients.

Keywords: COVID-19, airway-related procedures, protective barriers

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Introduction

Since the outbreak of Coronavirus disease 2019 (COVID-19), the whole world and medical community have been working continuously to contain the outbreak. Unfortunately, the risk of transmission among the health care workers is considered high, partly due to inadequate protection during their duty.[1,2] However, in the time of unprepared crisis, health care resources including personal protective equipment (PPE) are severely limited.[3]

As droplet spreading is the main mechanism of COVID-19 transmission [4], airway-related procedures such as tracheal intubation and extubation are considered high risk procedure for medical personnel especially, anesthesiologists or nurse anesthetists, who are in charge of such procedures[5]. Many protective equipments specifically designed for such procedures were invented. Aiming to limit the spreading contamination[6,7] and minimizing exposure of potential droplets during intubation and extubation[8,9], enclosures, made of transparent plastic[6,7] or acrylic boxes[10,11], covering over patient's head and neck area have been some of an earlier innovation.

In Thailand, the outbreak has slowly increased since early 2020. In times of crisis from the pandemic and shortage of PPE, we are often in a position where teamwork, creativity, and ingenuity is crucial to solve urgent and time pressing concerns, in this case, the shortage of PPE. This evident by many local innovations have been emerged during this period. A variety of designs of locally developed protective cover were invented and used. This article aims to review these

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local emerging innovations. We summarize the advantages and limitations, claimed by the inventors as well as the authors, of different available models of protective barriers during airway-related procedures.

Methods

We collected the information from personal communication, social media and the official account of The Royal College of Anesthesiologists of Thailand from March 30th, 2020-April 30th, 2020. The additional information gained by interviewing the developers and personal opinions of the experts and authors.

Results

Many innovations and modification have been emerged during this period. The protective barriers can be categorized into 3 groups; simple boxes (mainly from acrylic plates with plastic sheets), simple tent (from plastic sheet), and box or tent with the application of negative pressure onto them.

Group1: Acrylic boxes

This information is from the author, Dr. Prok Laosuwan, an attending anesthesiologist at King Chulalongkorn Memorial Hospital. The originally invented box, made of acrylic, was created by Lai Hsien-yung in Taiwan[10]. The local developer intended to make affordable equipment and contribute to where there is limited PPE supply. The cost of each box is about 2,500 THB. In Thailand, with the fundraising by Dr. Laosuwan from social media, at the end of April, more than 1,000 boxes were charitably contributed to many hospitals in rural areas.

How to use:

1 Cover the patient's head and neck with acrylic box.

2 Put on plastic wrap to cover operating holes on the operator side and put plastic cover sheet at the other end of the box to create a close space (Figure 1).

3 Perform airway procedure through two operating holes. Airway equipment or contaminated materials will be pass through the magnet window on the right side.

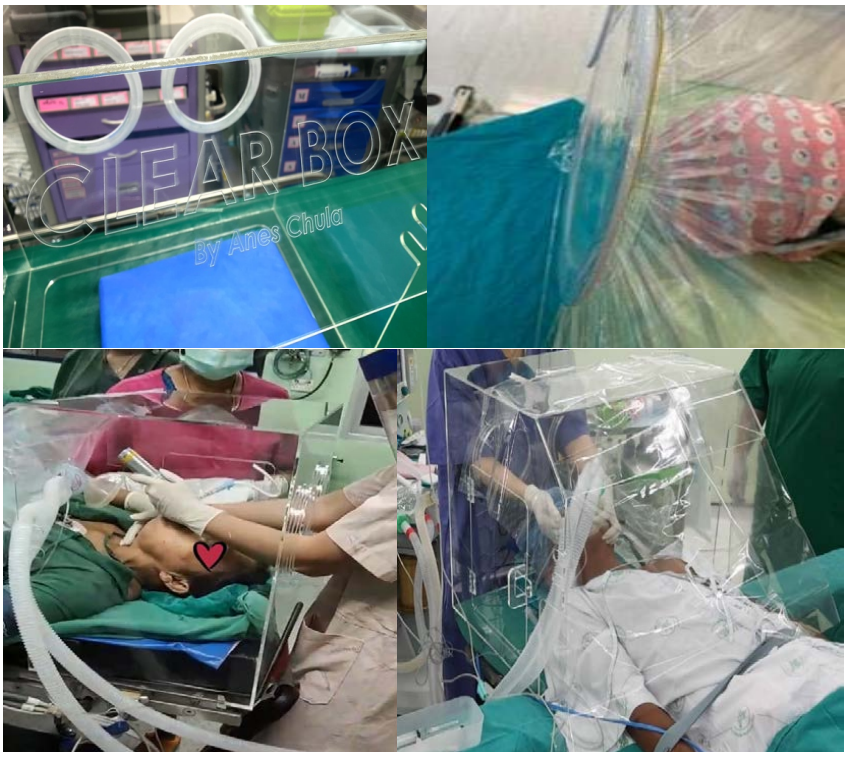

Figure 1 Acrylic box and how to use it

Feedback:

As the boxes have been distributed widely, there are many feedbacks on this product. As the box is light but strong, the overall feedback is positive. However, there are some concerns from users. Firstly, the clearance between the face of the patient and the top part of the box is really tight, thus removing the stylet after intubation can be challenging. The suggestion is, instead of pulling the stylet direct to the ceiling, to change the direction to patient's feet in order to get more free space to pull the stylet.

Secondly, As the box needed to be removed after the airway procedure, there is concern about leaking of the contaminated air from the box. The suggestion regarding this concern is applying suction inside the box, during and for 3 minutes after the procedure, to suck out the contaminated air before lifting the box.

Thirdly, the box is bulky. Some concerns have been raised when the operator faced difficult situations, for example during difficult to ventilate or difficult to intubate.

Lastly, the box still needs to be decontaminated after the procedure. In order to keep the acrylic transparent, Dr. Laosuwan, the developer, suggests that wiping the surface with NaOCl 0.12% (mixing 1ml of a bleach with 49 ml of water) can be performed.

Group 2: Tent

In this group, users make use of plastic sheet, working as a patient covering, with supporting metal frame.

2.1 Metal frame with a cover sheet by Maharat Nakhon Ratchasima General Hospital

This information is from personal communication with Dr. Thidarat Ariyanuchitkul, an anesthesiologist at Nakornrachasima General Hospital on April 1st and April 13th, 2020 interviewed by NZ

Maharat Nakhonratchasima General Hospital is a large tertiary care hospital in the northeastern area of Thailand. Dr. Ariyanuchitkul developed the metal frame with cover sheet, which addressed the aforementioned concerns regarding the acrylic box.

How to use:

1 Make a tent by covering the metal frame with plastic sheet

2 Create two holes on the operator side and operate through the holes

3 After the procedure, take away the frame and leave the plastic sheet on the patient until extubation

4 Extubate under the plastic sheet, then trash both endotracheal tube and plastic sheet at the end

Figure 2.1 Original metal frame

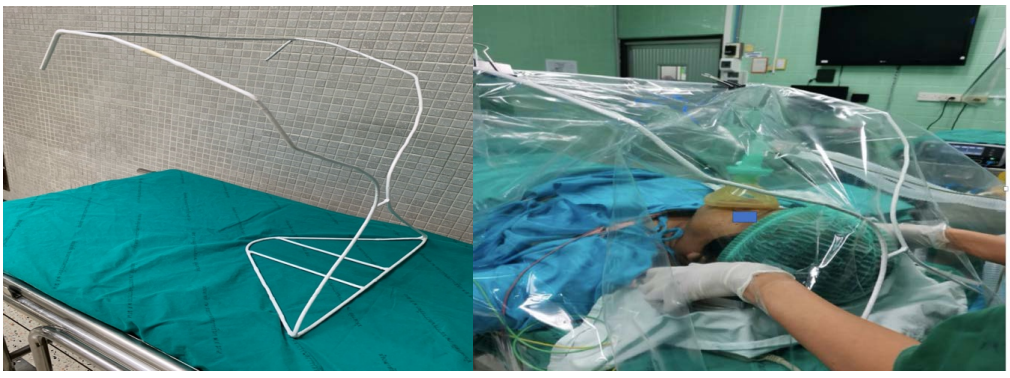

Figure 2.2 New metal frame model

Feedback:

The feedback came from the developer herself. The tent is not only extremely cheap (approximately 300 THB) and light, the plastic sheet is but also disposable. However, as the frame of the original model is quite flimsy and the side of the frame can hinder the operator's hand during the airway manipulation (Figure 2.1), the inventor created the new model (Figure 2.2).

The new model has a stronger frame and stable base which can be tucked under the bed. Additionally, the sides of the frame are bent to the middle in order not to impede the operator's hands during the procedure. Nevertheless, there still can be leakage of droplet through the holes on the operator side.

2.2 Metal frame by Samrong General Hospital

This information is from personal communication with Dr. Parit Wongphaet (psysiatrist), an executive officer at Samrong General Hospital on April 1st and April 13th, 2020 interviewed by NZ

Samrong General Hospital is a large private hospital in a suburb area of Bangkok Metropolitan. Dr. Wongphaet, an executive officer, developed a strong metal arch frame, with bilateral side trays at two ends of the arch. Both trays act as a load-bearing part of the arch and as a space to accommodate airway equipment during the procedure (Figure 2.3).

How to use

1 Make a tent by covering the metal frame with plastic sheet and operate underneath the plastic sheet

2 After intubation, take away the frame and leave the plastic sheet on and extubate under the plastic sheet at the end

Figure 2.3 SGH intubation tent frame

Feedback:

The feedback came from the developer himself. The frame has a reasonable cost (2,000 THB) and strong. However, due to being a semi-open system, there is a chance of leakage of droplets underneath the plastic sheet. The developer suggests applying a larger plastic sheet to minimize the leakage.

Group 3: Tent or box with application of negative pressure

3.1 Negative pressure tent (Airway hood with suction)

This information is from KS and personal communication with Dr Khemchat Wangtawesap., an attending anesthesiologist at Siriraj Hospital on March 31st, 2020 interviewed by NZ

As it says, users apply additional medical vacuum from a wall outlet. There are two suctions for doing this, one for procedural-related the other one for aerosol disposal.

How to use:

The application is like the regular tent, however, upon usage, user applies a suction to clean up the contaminated air. (Figure 3.1.1, 3.1.2 left)

Figure 3.1.1 Airway hood with suction

Mathematically, the inside volume of this tent is approximately 72 liters and the volume of the head & upper chest of patients is around 10 liters so the air volume needed to be cleaned is around 62 liters. The maximal suction pressure a wall outlet suction can reach is 250 mmHg. At this pressure, an approximate flow of 60 LPM can be achieved (Figure 3.1.2 right). The inventor purposes that, with this flow, duration of 3-5 minutes (3-5 half time) should be sufficient to clear up the air inside the box. From our perspectives, if we mathematically generate a graph of the residual particles (percentage) inside the box over time (minutes) (Figure 3.1.3).[12] This graph has been generated by assuming that the exchangeable volume inside the box is 62 liters, the flow made by the suction is 60 LPM. The starting amount of particles is 100%, as well as all the air inside the box, is mixed well throughout. From the graph, at 3 and 5 minutes, there are 5.5% and 0.8% of residual particles left inside the box respectively. In term of elimination, 3 half-times means there is only 12.5% remained while 5 half-times means there is only 3.1% remained.

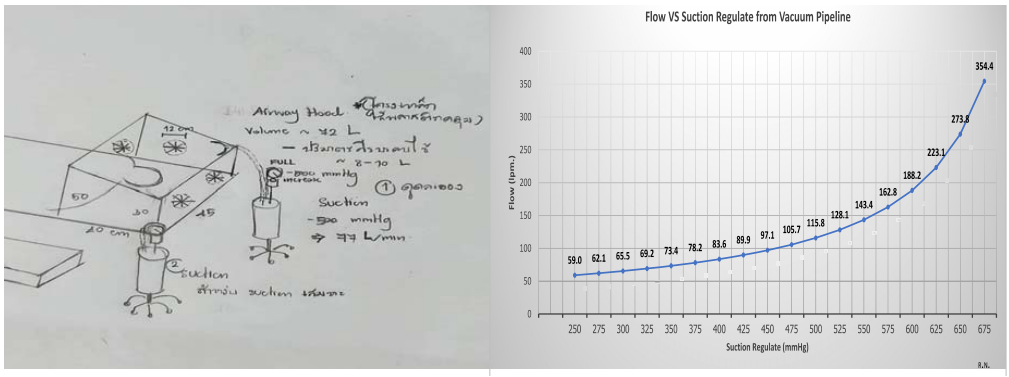

Fig 3.1.2 Left: hand drawing of the box with an application of suction for negative pressure chamber. Approximates of the volume inside the box are also depicted.

Fig 3.1.2 Right: The mathematically generated graph of air flow (liter per minutes) and suction pressure (mmHg), courtesy by Dr. Punnawit Benjawaleemas

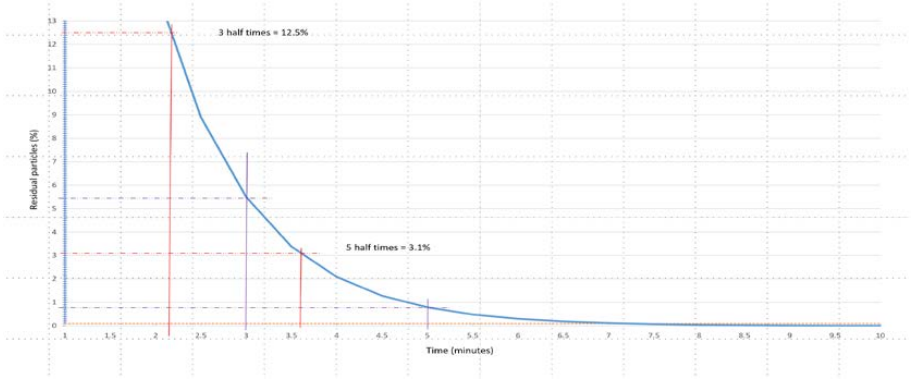

Figure 3.1.3 The mathematically generated graph of the residual particles (percentage) inside the box over time (minutes). Providing that the air volume needed to be clean is around 62 liters and approximate flow of 60 LPM was achieved by suction pressure of 250 mmHg.[12]

Nevertheless, In reality, the mixing of air inside the hood is not as thoroughly as we imagine. There might be a possibility of some particles can be lodged to or dislodged from the box walls. Additionally, from the figure 3.1.1, there is an airway filter attached in series with the suction. In doing so, the maximal suction airflow would drop significantly since we add extra resistance to the air current. In normal circumstances, a suction can do at its best i.e. at maximum if there is no resistance added. However, adding resistance, for example, having a hose on or some occlusion inside the suction, negative pressure increases, and flow decreases. The time needed to clear up is certainly longer than we calculate.

This type of device provides some benefits. They are cheap and light. It is easily disposed because the main component is the plastic sheath. There are some concerns as well. Having extra stuff to work with, i.e. the aerosol suction, is not an easy task to do in order to make it to the highest efficiency. Maintaining a constant negative pressure inside the hood is demanding work. Users need to make sure all sides of the plastic sheath have no leaks, especially, at the seam, around the torso of the patient and at the working ports. In this model, there is no pressure measurement has been mentioned by the inventor.

3.2 Negative pressure box

This information is from the experiment by Assist Prof Varinee Lekpraset and Assist Prof Narut Ruananukun, attending anesthesiologists at Ramathibodi Hospital on April 10th, 2020

The Medical Association of Thailand and Prof. Amorn Leelarassamee have co-designed the acrylic box with the sided suction for clearing the aerosol during intubation and extubation. (Fig 3.2.1)

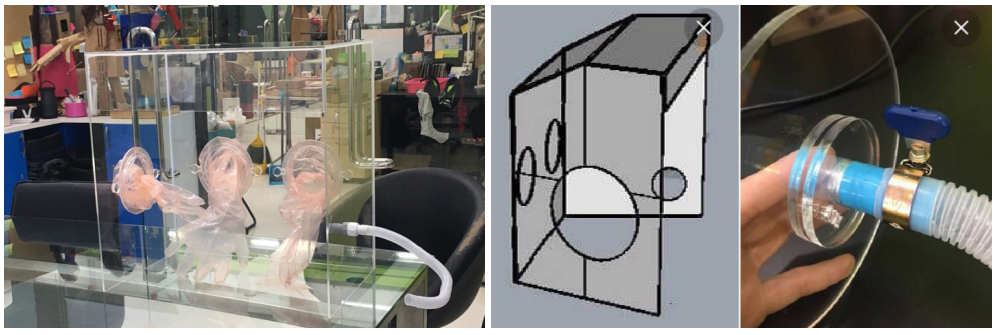

Figure 3.2.1 Negative pressure acrylic box, design drawing, suction inlet

Advantages: Durable and able to connect to the suction for aerosol elimination

Dr. Lekprasert and Dr. Ruananukun from Ramathibodi Hospital have tested the negative pressure box for intubation and extubation and gave some comments as followed;

1. Box shape and size

1.1 The box width is larger than the width of operating table. So, it needs some adjustment by using the arm board to fit the edge of the box (Fig 3.2.2). The box has an open end so that negative pressure cannot be created unless the user has to close the open end with plastic wrap.

Figure 3.2.2 The acrylic box on the operating table

1.2 The box height may be too high if the operator is not tall. The upper edge of the box may obstruct the view during intubation unless the height of the bed is adjustable. In addition, since the operator has to use a video laryngoscope for intubation in the close-space, it may be difficult to pull out the stylet in the acrylic box unless the assistant manipulates the stylet in the tilt position while pulling out. (Figure 3.2.3 left)

Figure 3.2.3 left: Intubation in the negative pressure acrylic box
Figure 3.2.4 right: Creation of negative pressure in acrylic box

1.3 The open end of the box is quite large. Although the inventor recommends the use of a plastic sheath to cover the patient during the intubation, the suction power may not be strong enough to create negative pressure inside the box. In our experiment, we needed to seal the plastic all around tightly to increase the negative pressure from (-0.1)-(0.2) Pa -5) - (-4) ot) Pa. (Figure 3.2.4 right)

2. The suction hole with corrugated tube

We had to modify the suction hole which connected to the corrugated tube in order to connect with the suction port as appeared in the pictures. (Figure 3.2.5)

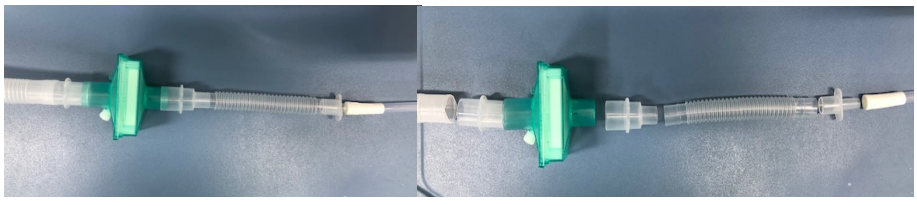

Figure 3.2.5 The suction apparatus of negative pressure acrylic box

3. Suction

The electrical suction and wall suction had different suction pressure which may affect the negative pressure inside the box. The suction power must be high enough to create adequate negative pressure when connecting to the HEPA filter and suction bottles. (Figure 3.2.6) The flow rate may not follow the flow-suction regulate curve which may affect airflow in the box.

Figure 3.2.6 The suctions apply to negative pressure acrylic box

4. Disposable gloves

The veterinary exam gloves are disposable which increase safety since it can be discarded after use. However, the operator has to wear a surgical glove as usual because the veterinary exam glove is very thin.

Comments: The negative pressure acrylic box is suitable if the patient coughs during airway maneuvers such as face mask ventilation, intubation and extubation. However, the experienced operator can intubate the patient using a rapid sequence induction technique successfully and smoothly without aerosol production. From our test, using the acrylic box during intubation requires more time than usual which may compromise the already hypoxic patient. However, the box will be useful if face mask ventilation is needed during difficult intubation and during extubation which the patient can cough unexpectedly.

Overall consideration

1 Theoretically, these protective barriers may alleviate risk of the viral transmission during the airway-related procedures, especially in situations where adequate PPE is unavailable and droplet and aerosol- generating procedures are urgently required. However, there is no guarantee that they can totally prevent infection. The operators should also apply standard PPE according to the risk and institutional recommendation.

2 In any model, the operator's hands are considered contaminated after the procedure. We recommend the operator to take off the gloves carefully and wash the hand up to elbow immediately after removing the gloves.

3 As rapid sequence induction was recommended for the intubation [5], the risk of viral spreading during this period is quite low; The box would be more beneficial in preventing the spreading during the extubation than intubation. Unless the intubation is done in awake and incorporated patients.

4 The intubation in a real situation may be associated with some technical challenging such as obscured view or struggle with the height of the box. The operator should exercise the procedure in a simulating environment before applying to the patients.

5 All of these models are still in the process of development.

Conclusion

There are many emerging innovations of protective barriers for the airway-related procedures during this COVID-19 pandemic in Thailand. The information and opinion from the developers and experts indicate that each model has its own advantages and limitation. The operator should carefully consider every aspect of each model before applying to their own practice in a suitable environment.

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