Negative pressure aerosol containment box: An innovation to reduce COVID-19 infection risk in healthcare workers

Vivek Gupta, Ashish Sahani\(^1\), Bishav Mohan\(^2\), G. S. Wander\(^2\)

Departments of Cardiac Anaesthesia and Intensive Care and \(^2\)Cardiology, Hero DMC Heart Institute, Ludhiana, \(^1\)Department of Biomedical Engineering, IIT Ropar, Rupnagar, Punjab, India

Abstract

Healthcare workers (HCW’s) are at increased risk of corona virus disease (COVID-19) infection during aerosol generating activities. The aerosol box has been used during intubation and extubation to prevent transmission of infection to HCWs. Isolation room with negative pressure has been advocated for COVID-19 patients. The described containment box has been designed to be useful in COVID intensive care unit (ICU) as a multipurpose box which is a cost effective and readily available resource. This innovation combines the containment box with negative pressure generation using central vacuum.

Keywords: Aerosol containment box, aerosol generation, anaesthesia, COVID-19, extubation, intubation, negative pressure

Background

The use of intubation and extubation box made up of acrylic sheet has been described during this COVID-19 pandemic.\(^1\) The mode of transmission of COVID-19 is primarily through droplets and direct contact with the patient or contaminated surfaces; however, airborne transmission may occur due to aerosol generating activities during treatment and these smaller particles remain in the air for longer duration.\(^2\) In spite of the use of complete personnel protective equipment (PPE) the risk of infection in health care workers (HCW’s) remains high. The use of barrier enclosure with ‘Aerosol Box’ during intubation has shown significant reduction in spread of contaminants outside the box preventing major contamination of HCW’s.\(^3\) The use of these boxes may have more relevance in COVID ICUs where multiple aerosol generating procedures (AGPs) are performed during the management of these patients. Moreover, even coughing and sneezing contribute significantly in spreading aerosol in ICU. Negative pressure isolation room has been advocated in the management of COVID-19 patients to prevent spread of infection.\(^4\) But it is impractical and a costly affair in converting every isolation room or ICU with negative pressure. The present innovation has a combination of both containment and creation of negative pressure to reduce the risk of aerosol spread in the ICU, thus offering an additional safety to HCWs. This box has been designed in a manner which allows quick and dynamic interventions in ICU and simultaneously allows the patient to sit comfortably and prevent any restriction or suffocation [Video 1A and 1B]. Moreover this can be made easily with available resources and one tenth of the

Address for correspondence: Dr. Vivek Gupta, Cardiac Anaesthesia and Intensive Care, Hero DMC Heart Institute, Ludhiana, Punjab, India.
E-mail: dr_vivekg@yahoo.com

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cost of the currently available boxes. To our knowledge no such multipurpose box is available in COVID ICU or isolation which can be used continuously or during aerosol generating procedures to reduce the risk of spread of infection in HCWs.

**Description of Negative Pressure Aerosol Containment Box [Video 2A and 2B]**

This Negative Pressure Aerosol Containment Box can be simply made with commonly available resource such as wood to make frame, thick PVC sheet 30 micron, Velcro and pasting and fixing material. An adjustable strap can help in fixing the box on the bed thus allowing patient mobility.

**Dimensions of frame  (Considering long axis of bed)**
- Height 18”
- Width 22”
- Length 17”.

PVC sheet can be pasted and fixed on 4 sides (top, both lateral and front). The head end side or back side is fixed with Velcro on 3 sides (Both lateral and Lower side) and is pasted and fixed on the top/upper side so during emergency management of airway that can be opened (Partially/completely as per requirement) quickly and sealed after task completion. The front side of PVC sheet is cut in semicircular fashion (8” × 8”) on the lower side to adjust the neck as well as allow air to enter to prevent suffocation. Two adjustable straps are attached on Lower end of frame on lateral side which can be tied on bed so it will keep the box fixed to prevent fall even in sitting position. Two more adjustable Velcro is attached to fix it with bed on the head end side to prevent any movement or lifting while opening the head end to perform any procedure [Figure 1].

On the top side a hole can be made and a ½” PVC connector can be fixed along with a small ½” tube to connect to central vacuum (suction) and adjust the vacuum (suction) pressure around 300–400 mm of Hg to create a negative chamber which will prevent aerosol to spread outside the box [Figures 2 and 3].

These boxes are cheap and can be made with limited resources even in small hospitals. The cost of the each box is around 700–800 rupees (around 10-12 USD).

**Possible uses**
- Intubation & Extubation
- Non Invasive Ventilation
- High Flow Nasal Canula (HFNC)
- Nebulization & Oxygen Therapy
- Inter & Intra hospital Transfer
• Isolation Room (can be used intermittently or continuously after counseling if patient is comfortable)
• Procedure room where negative pressure facility unavailable (Cath Lab/Radiology Suit etc.)
• CPR in COVID or COVID suspects.

**Decontamination and Disinfection**

This box can be reused after decontaminating every 6–8 hours to reduce the risk of high viral load inside the chamber using 1% hypochlorite (freshly prepared) spray with contact time of 10 minutes followed by washing with soap and water and making it dry.

**Discussion**

During this period of lock down there has been disruption of supply transport chain globally, which has forced HCWs to work with limited resources. This Negative Pressure Aerosol Containment box can simply be made with available resources and minimum interventions. Moreover the cheap and easy production will encourage the hospitals to use this box on COVID and COVID suspect patients routinely. This Box may provide dual protection during the AGPs[5] and can be used even for longer time or continuously over the patient, if tolerated. The negative pressure isolation room with 10–12 air changes/hour with closed doors and windows have been recommended in preventing spread of any airborne infection especially COVID-19.[4,6] Considering the burden on health care facilities it is impractical and a costly decision to create negative pressure room. The purpose of applying negative pressure in isolation room is preventing spread primarily from airway and lung secretions having highest viral load.[7] The effectiveness of central vacuum (300–400 mm of Hg) for generating negative pressure was evaluated using Smoke test [Video 3].[8] The dual High Efficiency filter at central vacuum system prevents the concern about discharging infected air to atmosphere. This box provides a good alternative by covering the face up to neck thus preventing a direct spread of droplets and aerosols and application of central vacuum creates a negative pressure inside the box providing an additional protection to curtail the further spread of aerosol. Since the box is not airtight (open in semicircular fashion on the neck) it allows air to enter in the chamber thus avoiding discomfort or suffocation to the patient [Video 4]. Oxygen tubing or NIV tubing [Figure 4] can pass easily through this semicircular opening. The comfort, feeling of suffocation and haemodynamics along with oxygen saturation was monitored in a volunteer for more than an hour. Moreover, it has been used in a patient with non-invasive ventilation without discomfort. The flexible PVC sheet does not causes any injury or discomfort to the patient. The flexibility of opening on the back side (head end) will allow even difficult intubation without removing the box, thus maintaining the safe, accurate and swift principle of airway management.[5] The adjustable straps on both the lateral sides will quickly fix the box on the bed and two small straps on head end side will prevent any movement of box while opening on head end for procedures. The light weight of the box is an additional safety feature to prevent injury to patient and HCWs. The design of the box has tried to overcome certain issues of difficult manipulation of laryngoscope, endotracheal tube and bougie and the box can be used in obese and patients with short neck.[9] Though the use of this box limits the use of fiberoptic bronchoscope (FOB). This negative pressure containment box will also help in protecting the assistant or even the surroundings as the front part is covered.[1] However, an appropriate training on manikin is important prior to use on patients to prevent any mishap during airway management in critically ill patients.

**Conclusion**

The various modes of transmission of COVID-19 puts the HCWs at significant risk of infection in ICU in spite of use of PPEs. This kind of innovation is the need of hour to reduce the risk for HCWs without compromising the safety and comfort of the patient in a cost effective manner. This box may provide an additional protection to HCW’s with complete PPE in COVID ICU/isolation with heavy viral load from upper airway and lung secretions. Moreover the design and light weight of the box will not only allow performing ICU procedures safely and effectively but will be helpful during inter and intra hospital transport as well.

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Nil.
Conflicts of interest
There are no conflicts of interest.

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