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Research Paper

IsoPort- Pressure Differential Isolation Chamber Model for COVID-19 Patients

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Abstract
The COVID-19 pandemic has made a huge impact on the healthcare scenario of the world. Due to its easy transmissibility, it has affected a majority of the population in a short time. Healthcare staff like nurses and doctors are at an even higher risk of infection because of their prolonged and repetitive interaction with patients. Isolation chambers can be an integral part of Vital care Units and Intensive Care Units (ICUs). Viral & bacterial matter can be present on surfaces of objects in regular use. A negative pressure environment can drastically curb the spread of viral matter in air. In this study, we have proposed a double-door isolation room model with air pressure differential control to prevent spread of the virus to the outside world. Our model aims to contain the viral air and eliminate airborne pathogens using High Efficiency Particulate Air (HEPA) filters and Ultraviolet (UV) light, along with antimicrobial surface coatings. The isolation chamber has prefabricated panels for short installation time, and are made with low-cost materials.

Keywords: *COVID-19, Quarantine, Pressure Differential, Isolation Chamber, Air Purification, Antimicrobial.*

Introduction

In the COVID-19 pandemic, a significant number of patients in India are not getting the required hospital care. This is due to the rapid expansion and evolution of the SARS-CoV-2 virus[1]. With now several mutated variants of the virus worldwide, a third wave of the virus is on the horizon. India needs to be geared up for the next wave since the second wave had the highest impact in the country[2]. Precautions like social distancing, proper apparel of masks, timely sanitization of hands & contact surfaces, and vaccination are evidently the best prevention methods, according to the World Health Organization (WHO).

The novel SARS-CoV-2 spreads in individuals chiefly by direct contact or through droplets in air spread by coughing or sneezing from an infected individual[3]. Contaminated surfaces hold the virus for a longer period than air. Extensive measures are needed to reduce person-to-person transmission of COVID-19 in this outbreak. Special efforts are necessary to reduce transmission in vulnerable populations including children, health care providers and elderly people [3].

In this study we propose the design and development of a low cost, indigenous negative pressure isolation chamber with air purification unit for patients of COVID-19 to prevent the air contamination, preventing further spread of the contagious viral infection. It will reduce the load on the Healthcare professionals, increase efficiency & accuracy of data and save costs. The isolation facility is also effective for containment of many other contagious airborne infections like Tuberculosis, Swine Flu, etc.[4], [WHO 2009].

In a correspondence by the British Journal of Anaesthesia, a portable isolation unit was made that covered only the top half of the patient wearing it[5]. This could be beneficial for its low costs and higher portability, but can impose risks such as leakage by poor fitting. Another study in the International Journal of Infectious Diseases concluded that high moisture content in an area of a quarantine room marks prolonged SARS-CoV-2 persistence[6]. [Table 1] shows other research papers studied and their conclusions to consider for an isolation facility.

Table 1: Literature Survey

Ref. No.	Study Name	Conclusion
[5]	A multipurpose portable negative air flow isolation chamber for aerosol generating procedures during the COVID-19 pandemic	Portable isolation achieved, along with anaesthesia feature since it is wearable.
[6]	Duration of SARS-CoV-2 positive in quarantine room environments: A perspective analysis	Moist areas induce linger sustenance of SARS-CoV-2
[7]	Detection and infectivity potential of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) environmental contamination in isolation units and quarantine facilities	SARS-COV-2 stays on non-porous surfaces for 3 days in a laboratory environment.
[8]	The effect of pressure differential and care provider movement on airborne infectious isolation room containment effectiveness	Anteroom plays an important role in reducing particle escape, especially when a person moves through the room.

Design of Negative Pressure Isolation Chamber

The best way for personal protection against SARS-CoV-2 is wearing a mask. However, in a hospital environment with a large number of patients, viral matter could be present on surfaces and in the air as well. Thus, healthcare workers need additional protection from the virus. Ideally, a suspected or infected patient should be confined in a negative pressure room with optimal rates of air exchange (> 12 exchanges per hour) to minimize risk of airborne exposure[7].

The isolation chamber is divided in 2 parts: positive pressure anteroom and the main chamber with negative pressure. The main chamber includes a bed for the patient, a vital parameter monitoring machine, additional accessories and a bathroom module with a door.

Air Filtering: 3-stage H13 HEPA filters are fitted in the anteroom and main chamber ducts for efficient capture of 99.5% pathogens of size 0.12-0.25 microns. UV light filters follow high power exhaust fans, to enable termination of any remaining viral matter after air filtering. The energy saving Heating, Ventilation & Air Conditioning unit (HVAC) carries out 12 complete air changes per hour. Fresh air is brought in 6 times per hour. An additional option of a separate air purifier inside the room is also given.

Pressure Control: Ducting is present in parts of the chamber; anteroom, main room and bathroom. The main room and anteroom have one inlet duct coming from an air conditioning unit and one exhaust duct leading to the HEPA filter each. Bathroom has only one exhaust vent. The Anteroom doors are equipped with sensors, for timely activation when doors are opened. Pressure sensors in each room control valves for airflow to enable automatic pressure regulation. With all aforementioned systems in place, an airlock environment is achieved.

Materials Used: Walls of the chamber are made of anodized aluminium, durable polycarbonate sheets and glass. Each of the aforementioned is painted with a layer of antimicrobial & dust-resistant composite, for reduced risk of surface contamination. Since all materials are lightweight and easy to carry, the chamber can be deployed in any room with 4 base points. The chamber size is adjustable due to its modular design.

Air Conditioning: Since the unit can be set up in any room, air conditioning can be provided separately in the chamber, connected to the concerned ducts. For large scale installation in hospitals, the pre-existing hospital Air Handling Units (AHUs) can be modified to fit the chamber. Thermostats are fitted in the chamber to monitor and adjust the air temperature. Humidity of the air is set to ≤60% RH (in accordance with ISHRAE guidelines for air conditioning and ventilation).

[Figure 1] illustrates the prototype design of the isolation chamber with the said features.

Variants: The isolation chamber can be installed as a standalone unit in Type A [Figure 1], or hospitals can opt for multiple chambers in a series having 5 (Type B) or 10 (Type C) isolation rooms [Figure 2], with a common positive pressure anteroom. Each room in the facility is 12x15 ft in area. [Table 2] shows the feature checklist for each type. The common anteroom has a width of 10 feet to accommodate stretchers for bedridden patients. At the time of writing this paper, we have installed our isolation chambers in Wadia Hospital, Mumbai. The installed series of chambers includes 10 isolation rooms [Figure 3]. Two separate air purification units are installed for 5 rooms each.

Table 2: Feature Checklist

Feature Name	Type A 1 room unit	Type B **5 room unit**	Type C **10 room unit**
Area	12ftx15ft	12ftx15ft x5 units	12ftx15ft x10 units
Air Changes	Continuous	12/hour	12/hour
Separate anteroom	Yes	Yes	Yes
Pressure differential	Yes	Yes	Yes
Protected chamber	No	Yes	Yes
UV filters at inlet & exhaust	Yes	Optional	Optional
Separate air purifier in room	Optional	Optional	Optional
Antimicrobial coating	Yes	Yes	Yes
User Safety	Medium	High	High

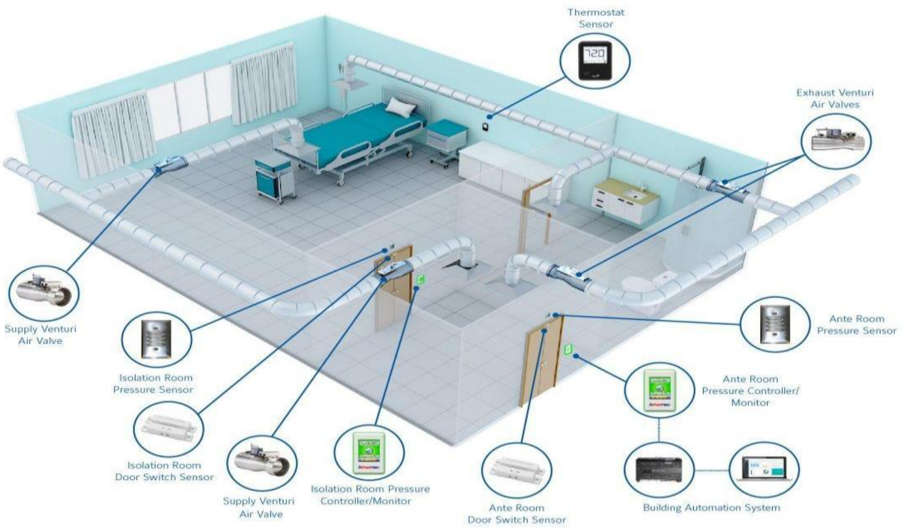

Figure 1: Isolation Chamber Design- Type A

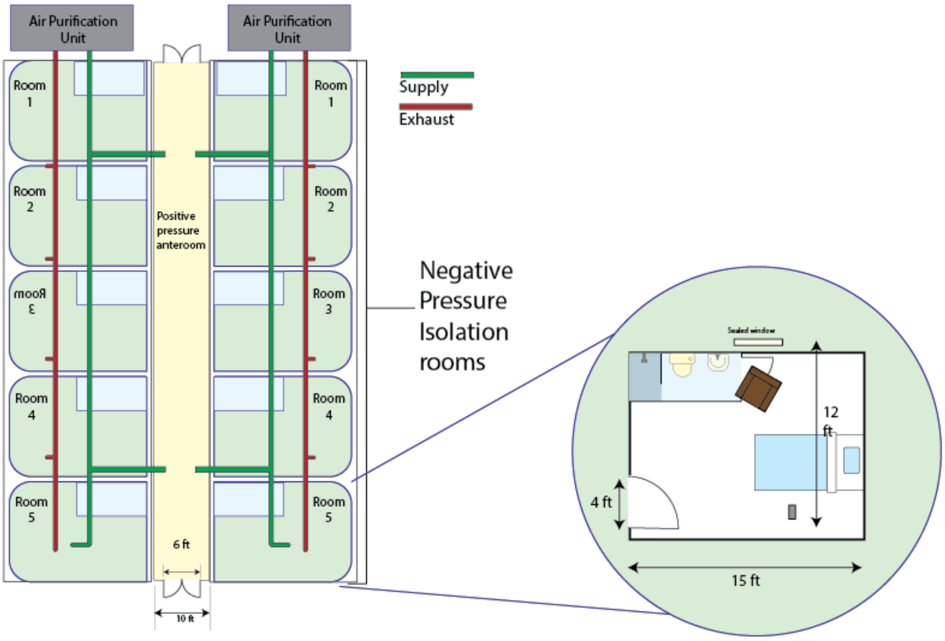

Figure 2: 10-room variant of quarantine facility- Type C

Figure 3: Installed isolation facility in hospital

Discussion

The design goals achieved by the isolation chamber are:

- To be constructed with indigenously available affordable materials.
- Easy installation with minimum assembly time.
- Creating a physical barrier to prevent human-to-human transmission in the containment chamber.
- Creating a negative pressure environment so that the contaminated air does not escape.
- The contaminated air to be purified and then released into the environment.

The proposed design, to our best knowledge, is the first such model in India with the given specifications and affordability. The highly efficient chamber design is made with inexpensive materials, and requires minimum expertise to install due to its portability. Since the materials and equipment inside are durable, maintenance costs will be low. Thus, hospitals can afford large-scale installation in a short amount of time to accommodate more patients while not worrying about cross-contraction of the virus to hospital staff.

Future Scope

The isolation chamber has potential to nullify all risks to healthcare staff and surrounding people in the hospital. The safety and hygiene features of out chamber can benefit from a smart monitoring system for total contactless patient care. Artificial Intelligence (AI) and Machine Learning (ML) can be used with vital monitors to assess patient condition and detect risks at an early stage. Human nurses can also be replaced by nurse robots to visit the patient periodically and provide necessary medication. Additionally, the nursing bot can evaluate the mental state of the patient using face recognition coupled with neural networks, and provide real time interaction with doctors/relatives through robotic telepresence. Furthermore, the isolation chamber can be used as a waiting facility for patients.

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