Review Article

Fast tracking intensive care units and operation rooms during the COVID-19 pandemic in resource limited settings

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Abstract

The ongoing pandemic of COVID-19 has affected more than 43 million people all over the world with about 280000 deaths worldwide at the time of writing this article The outcome of this pandemic is impossible to predict at the present time as the numbers of both, infected patients and those dying of the disease are increasing on a daily basis. China, Italy, France, Spain, Germany, United Kingdom, and USA are the worst affected countries. All these countries have robust health care systems but despite this there has been a huge shortage of health care facilities especially intensive care beds in these countries. A country like India has different challenges as far as medical care during this pandemic is concerned. The need of the hour is to improve the health care system as a whole. In the present pandemic this involves setting up of patients screening facilities for the disease, enhancing the number of hospital beds, setting up of dedicated high dependency units, intensive care units and operation theatres for COVID positive patients. The present article describes in brief the way this can be done in a short time.

Keywords: COVID-19, intensive care unit, operation theatre

Introduction

Coronavirus disease 2019 (Covid-19) emerged in Wuhan district of China in December 2019. This new virus spreads rapidly as a result of which it quickly spread worldwide in a few months and now it has become a pandemic.[1] Of all the people who get infected by this virus, about 5-12% are likely to become critically ill and require admission in an Intensive Care Unit [ICU].[2-4] The number of patients that are admitted to a COVID hospital and thereafter to a dedicated ICU due to this infection varies in different countries, regions, states and depends on the government guidelines regarding admissions and home quarantine. In certain countries, triages regarding ICU admission have been done taking into consideration the patient's age and the associated comorbidities. The number of critical care beds available/100,000 population limited to 0.1-2.5 in low – middle income countries,[5] 2.3/100,000 in India.[6] Therefore, the need at the present time is to have a larger number of critical care beds ready. This can be done either by setting up of 'New' intensive care units for COVID positive patients or by converting existing high dependency areas to full-fledged intensive care units. When an epidemic strikes, there is no time to set up 'New ICUs as per recommended guidelines in a short time; thus the options are - to upgrade HDUs or isolation wards to dedicated ICUs or to convert existing critical care units to COVID ICUs by shifting non-COVID patients to a different area. In acute crisis, even field ICU or mobile ICUs can be worked up as an option. The usual considerations kept in mind while designing any ICU include location, area, the bed strength and the manpower required. For a dedicated COVID ICU, additional issues that should be addressed are a highly infectious pathogen, aerosol transmission, high rates of mortality in ventilated patients, need for protection of health care workers and safe disposal of highly infectious biomedical waste of the patient.

Location and isolation

The ICU for COVID patients should be ideally in an isolated area of the hospital where there is minimal intermingling between COVID and non COVID patients. The availability of piped medical gases – oxygen, compressed air and vacuum is essential. Despite being in an isolated area of a hospital, the ICU should also be easily assessable to other medical experts and diagnostic facilities.[7] We created COVID ICU in a huge hall meant for emergency trauma patients. Ideally this ICU should have single dedicated entry point and a single exit point with adequate rooms for donning and doffing for the health care workers at either ends.

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Access this article online	
Quick Response Code:	Website: www.joacp.org
	DOI: 10.4103/joacp.JOACP_262_20

How to cite this article: Aggarwal R, Bhatia R, Soni KD, Trikha A. Fast tracking intensive care units and operation rooms during the COVID-19 pandemic in resource limited settings. J Anaesthesiol Clin Pharmacol 2020;36:S7-14.
Submitted: 17-May-2020 **Revised:** 19-Jun-2020 **Accepted:** 04-Jul-2020
Published: 31-Jul-2020

Critically ill COVID-19 patients should be kept in airborne infection isolation rooms [AIIR] which are negative pressure rooms.[8] In developing countries, majority of the functioning ICUs are unlikely to have negative pressure rooms. According to a survey across Asian countries, 37% of all ICUs did not have AIIRs.[9] The normal isolation rooms in ICU can be converted into negative pressure rooms by installing industrial exhaust fans as was done in Singapore during the SARS epidemic.[10]

The same has been successfully carried out in our new COVID-19 intensive care unit. The negative pressure was created by installing multiple exhaust fans at one end of the hall; the disadvantage of these being the increased noise levels, decreased efficiency of air conditioning and breach of sterility being open to ambient air. This 'tradeoff' between breach of sterility, loss of air conditioning and noise against negative pressure was acceptable to the intensive care team and the infectious disease committee of our hospital (in view of the pandemic and the need for fast tracking the new ICU). In ideal conditions, exhaust air from these fans should be vented at above the roof level.[11] However, when there is paucity of time, it may not be possible to install such a separate exhaust duct. An alternative solution could to be to ensure that the exhaust air from such intensive care units should be vented out in an area where there is no movement of people. We ensured this for our ICU by cordoning off a 10 meter area from the outer part of the wall where the exhaust fans were installed. Exhaust air should be treated preferably by high efficiency particulate air (HEPA) filtration. This may not be possible in existing facility but should be mandated in new or renovated ICU. The Centers for Disease Control and Prevention (CDC) recommend the negative pressure inside rooms be monitored regularly,[11] but this may not be feasible in all ICUs. The amount of air intake and exit should be such that minimum negative pressure of 2.5 Pa be maintained.

Air conditioning system is a very important component of all intensive care units and in particular when stand alone units are to be commissioned for taking care of patients with a highly infections pathogen which is transmitted through aerosol. The concentration of aerosols can be decreased with increased number of air changes per hour.

The air handling units of the air conditioning system of such areas should be segregated from the rest of the hospital. CDC recommends that there should be minimum of 6 air changes per hour in the isolation rooms and recommends 12 changes per hour for new construction or renovation.[12] Air from the rooms should be either filtered through high-efficiency particulate air (HEPA) filter directly before recirculation or should be exhausted directly to outside.[12] WHO also recommends that in areas where aerosol generating procedures are carried out, the fresh air changes should be at least 12 per hour.[13] However, it may not be possible to increase the fresh air cycles to an ideal number in an existing air conditioning system.

Another important consideration with COVID ICU is to have a proper donning area for the Health care workers [HCW] before they enter the "infected" ICU and dedicated doffing area. A separate donning area at the entry and doffing area at the exit has been advised in the literature[10] and should be made outside the ICU in consultation with infection control specialists. A shower area is also required after the doffing area. Doffing has to be more meticulous than donning to prevent infection. There should be foot operated dispensers for hand sanitizer and a buddy preferably an infection control nurse during doffing who watches and guides all the steps meticulously.

In resource limited settings and in district level hospitals, oxygen manifold and pipelines may not be there. In these settings, critically ill patients can be provided oxygen therapy through oxygen cylinders. Even ventilators can run on oxygen cylinders if the piped gases are not available. However, these ventilators should be able to give a varying concentration of oxygen. For using these cylinders, one must know the duration for which the cylinder is going to last.[14-17]

The capacity of various oxygen cylinders is mentioned in the Table 1.

Oxygen usage in mechanically ventilated patients

Oxygen consumption from a cylinder depends on the FiO2, minute ventilation (tidal volume × respiratory rate), lung compliance, Inspiratory: Expiratory ratio and ventilator make up. Oxygen consumption can vary from 10-60 L/min or even more.

The following example can be used to calculate the length of time an oxygen cylinder would be able to provide oxygen to a mechanically ventilated patient.

[If the consumption 30 liters per minute and the FiO_2 being given is 100%, an H type cylinder will last for 6900/30 i.e., 230 minutes or 3.83 hours.]

Beds and Other Equipment

In ideal conditions, that total bed strength of ICU recommended is between 8 and 12 and area recommended per bed is at least

Table 1: Capacity of various oxygen cylinders

Size	Capacity (in litres) Total oxygen, when cylinder is full	Pressure, when full (psi)	Tare weight in kg (weight, when empty)	Dimensions (O.D. × Length in Inches)	Cylinder factor
B	200	1900	2.27	$3^{1/2}\times13$	-
D	400	1900	3.4	$4^{1/2}\times17$	0.16
E	660	1900	5.4	$4^{1/4}\times26$	0.28
F	1360	1900	14.5		-
G	3400	1900	34.5	$8^{1/2}\times51$	2.41
H (Jumbo)	6900	2200	53.2	$9^{1/4}\times51$	3.14

100 kPa=1000 mbar=760 mm Hg=1030 cm H_2O=14.7 psi=1 atmosphere

150 square feet per.[18] However, for the expected surge of patients with COVID, the number of beds can be increased according to the space available provided the distance between the adjacent beds should be at least of 1.5-2 meters. The head end of each bed must be kept 2 feet away from the wall.

Apart from the general equipment required for a normal ICU, certain equipment are essential for COVID ICU. These are listed in Table 2.

Aerosol-generating procedures may increase the risk of infection to HCW.[19] All the efforts must be directed to minimize this exposure. The suggestions include use of plastic box/plastic sheet during airway procedures, videolaryngoscopy during intubation, closed suction catheter for suctioning, helmet interface during noninvasive ventilation and high efficiency viral filters during ventilation.[19] It is hard to auscultate the chest with a stethoscope after donning a level 3 PPE, therefore repeated use of lung USG is advocated for lung condition and capnography for confirming the correct placement of the endotracheal tube. There is a high incidence of myocardial dysfunction in COVID19 patients[2,20,21] and repeated echocardiography may be required during management necessitating the availability of ECG machine, USG machine with an ECHO probe and defibrillator. Approximately 15% of the COVID-19 patients develop AKI requiring renal replacement therapy and a hemodialysis machine should be installed in the ICU before commission.[22]

The equipment list also includes the segregated bins required for the safe disposal of the waste including patients clothing, bed sheets, urine, stool and other body fluids. It is suggested that all these equipment can be acquired from different departments of the hospital for use solely in the ICU. Once these equipment are stationed inside the ICU they should not ideally be taken to other non COVID areas of the hospital to avoid cross infections. It is unlikely that new devices can be purchased in pandemics, but in case it can be done dedicated equipments should be acquired.

Personal protective equipment

The CDC recommend health care personnel wear Personal Protective Equipment [PPE] which include N95 mask, googles, face shields, long-sleeved gowns, shoe cover and gloves[23] when caring for confirmed cases of COVID-19. It also recommends formal fit test for the masks as N95 masks are effective only if they are tightly fitting. The average penetration of ambient aerosol inside a well-fitting masks is 4% as compared to 33% for poorly fitting masks.[10] A calculated number of PPEs should be procured before initiating the ICU and the continuous supply should be ensured. All health care workers should be donning the same level of PPE in an intensive care unit.

Table 2: List of Equipments required for COVID ICU

Videolaryngoscope
Transparent Plastic box/transparent plastic sheets for aerosol generating procedures
Closed suction catheters
High efficiency viral filters
Helmet interface for NIV
USG machine with ECHO probe
Dedicated portable X ray machine
Arterial blood gas machine (ABG)
Hemodialysis machine
ECG machine

Drugs and pharmaceuticals and laboratory investigations

A complete list of drugs and fluids required for the care of ICU patients and drugs as in the treatment protocol of COVID patients should be made and procured.

It is difficult to transport blood and other fluid samples of the patients outside the ICU frequently to the laboratories, for the risk of transmission of infection. Therefore, as far as possible all the necessary investigations should be performed inside the ICU. An ABG analyzer, glucometers, point of care kits like (trop -I kits) etc. are essential and should be procured before commissioning an ICU. For other special investigations, there should be dedicated corridor/pneumatic tube systems or elevators to the laboratory. All the body fluid samples should be collected in the sterile containers which should then be placed in a 'zip lock'. These are further

placed in specimen transport boxes in an upright position. All these should be discarded as per standard guidelines after use. The laboratory personnel handling should be advised to wear standard PPEs for the laboratories handling infectious materials. COVID ICU should be well connected to radiology department through a dedicated lobby for imaging investigations if required.

Staffing of Health Care Workers

Adequate human resource utilization is one of the most important aspects of ICU management.[24,25] Basic ICU staff includes doctors, nurses, technicians, physiotherapists, and health assistants who are present around the clock. Staffing for COVID ICU requires special attention due to highly infectious rate of this pathogen.[26,27] The important points that should be taken in account during staffing are - first the risk of infection of the staff with COVID -19 virus while caring for the patients,[27] leading to absenteeism and second the maximal utilization of PPE as they are likely to be in a short supply in a pandemic. Although high nurse-to-patient ratios provides better safety and improved outcomes for patients,[28] such may not be feasible in a pandemic. The nurse to patient ratio may be kept between 1:3 or 1:2 for sickest patients. The rostering should be done taking into account the staff illness and need for rest days to counter work stress. The staff may also need to get quarantined after exposure as per local guidelines.

In our set up, we decided that for every 8 patients, 1 consultant, 2 senior residents doctors, 4 staff nurses, 1 technician, 1 physiotherapist and 1 health assistant would be optimal. Of these, other than the consultant and the physiotherapist all are physically present in the ICU at all times. In addition an infection control nurse is on the roll for every shift to aid assistance and overlook the procedure of donning and doffing of all the health care workers. There are pictorial charts put up at both these areas in local language so that all levels of HCW follow the correct methods. As during a pandemic a large number of HCW may be needed, all the hospital clinical staff in our hospital has been made to attend workshops regarding infection control issues in ICU.

It is hard to work after donning the PPE used for COVID in ICU and the staff wearing PPEs cannot do routine activities like drinking, eating or using washroom so prolonged hours of duties should be avoided. On the other hand, limiting the use PPE is also essential due to a short supply during a pandemic. In our hospital, considering the difficulties encountered with the optimum use of PPE, we decided to have 6-hour duty schedule for all categories of health workers. However, this lead to a duty change of the staff late in the night; a couple of rooms were therefore provided in the non-COVID area of the hospital for different categories of HCW so that they could avoid leaving the hospital at odd hours after doffing. Furthermore, the duty reporting times were made different for different category of HCW to avoid a "rush" at the donning and doffing stations.

Communication

Communication with and among the health care workers is a huge problem in an isolated ICU for COVID positive patients. Landline telephone cables for 2-3 phones and internet connectivity must be ensured before starting this unit. In view of the nature of the disease and shortage of Personal protection equipment (PPE), many medical consultations and clinical rounds can be carried out by dedicated smart phones or 'tablets'. The same was also done during the SARS epidemic.[10] In our ICU we ensured high speed internet connections in all ICU areas and presence of cameras that could be operated from a control room to see the patients, cardiac monitors and the ventilator settings before the area was commissioned. These virtual clinical rounds are very essential in this pandemic as it avoids the entry of multiple clinical team members into an infected area thus avoiding exposure to infected atmosphere and conserves PPEs. It is important to note that once the patients are admitted any kind of engineering work (civil, electrical, biomedical, computer related) would require the workers to don proper PPEs to enter the area for renovation work, and installing or repairing of equipment and gadgets. Normal communication between doctors, nurses and other staff is hampered after wearing PPEs. Even recognition of individuals is a problem. In our ICU it is a norm that the names of individuals should be written conspicuously in front and back of the coveralls for easy recognition. Some standard sign language is likely to be of great help. Telephonic communication with the relatives instead of face to face communication should be encouraged whenever possible. The clinical data and the daily records of the patient should be entered and stored in the computer to minimize the use of stationary.

Preparation of protocols

Protocols should be drafted for different procedures in the ICU i.e., admission to ICU, oxygen therapy, intubation, mechanical ventilation, bronchoscopy, extubation, cardiopulmonary resuscitation and discharge. The same was done in our ICU and these protocols were circulated among the staff and printed copies were kept in the ICU. Protocols need to be developed for infection control practices, management and disposal of waste and donning and doffing of the PPE.

Biomedical waste management and disinfection

Disposal of biomedical waste is of utmost important in management of critically ill COVID patients. Clear guidelines regarding the biomedical waste management should be drafted and displayed. These should be self-explanatory. All biomedical waste has to be stored/segregated in color-coded bags by adopting double bagging method. Three red bins to be placed in doffing area one each for goggles and face shields, other for N95 masks and overalls and the third one for disposable PPEs. Freshly prepared 0.5% sodium hypochlorite solution/70% alcohol [Bacillol] should be used for local disinfection. Coronavirus can persist on surfaces, equipment, furniture for up to 3 days and surface cleaning is must.[29] All non-disposable medical equipment should be cleaned and disinfected according to the manufacturer's instructions and hospital policies. The autoclave machine used for the items used in COVID positive patients should be different from rest of the hospital.

Training

Workshops and training sessions should be organized to train HCW in infection control practices, which include hand hygiene, hand washing, donning and doffing techniques. The posters depicting the same need to be pasted in the specified areas in ICU and donning and doffing areas. Teaching sessions are also required for the residents and nursing staff regarding new protocols. Simulation of different scenarios should be practiced on the mannequins. Residents and staff from other departments other than critical care should also be trained.

Morale Boosting of Health Care Workers

Every HCW is concerned with risk of infection constantly. There is a risk of mental health problems like fear, anxiety and depression among the HCW caring for COVID-19 patients.[30] Therefore, counselling sessions need to be held for the staff who were to work in the ICU. Counselling sessions should be organized with different categories of workers and all queries should be answered.

COVID Operation Theatre (COT)

CDC recommends that elective and non-urgent surgeries must be rescheduled in COVID positive patients as there is greater mortality and morbidity if elective surgery is carried out in COVID positive patients.[31] However, a dedicated COT is essential for emergency procedures. The most common surgeries carried out during the pandemic on COVID positive patients are cesarean sections, exploratory laparotomies, tracheostomies, orthopedic and surgical trauma and neuro surgeries. In a busy hospital at least two operation theatres should be dedicated for COVID positive patients- one for obstetrical emergencies and the second for all others. Ideally COT should be in the same building/floor as COVID ICU. The COT should be away from the non COVID operation theatres and the air conditioning system should be separate. The patient shifting protocols from the emergency rooms to the operation theatres should be framed and made available for all HCW. There should be easy and seamless transport facility for patients being shifted from emergency rooms to operation theatres and the ICU. Ideally the entry to the operation theatre should be through a double door and dedicated entry and exit doors for the COT should be properly labelled. All COT doors should be kept closed at all times,[32] and the entry should be restricted for only HCW working in the operation theatre. CDC recommends that the doors of the COT to remain closed for 10 min after aerosol-generating procedures like intubation and extubation so that HEPA filters can remove 99% of the particulate matter. As for the ICU, exclusive donning and doffing areas should be made for OT personnel also. In ideal circumstances, the COT should have negative pressure for the purpose of isolation and minimizing the risk of infection.[33] However, most operation rooms have positive pressure air circulation. An increased number of air changes/hour may decrease the viral load in the COT,[33] but it may not be possible to do so. As an alternative option, exhaust fans can be installed in the operation theatres create negative pressure taking care that the exhaust gases should be vented at the top of the building.[11] However, OT sterility would be an issue with this option. The exhaust gases can be treated with either through HEPA filters, chemical treatment or ultraviolet irradiation.

The air handling unit of the COT should be separated from other areas of the hospital. Minimum of 12 air changes should be ensured every hour. If it is not possible, then central air conditioning can be shut off and split air conditioners can be installed inside the complex. Along with split air conditioners, there must be some provision of fresh air intake with small window openings and exhaust by natural exfiltration.[34] The room temperature should be maintained between 24-30°C and relative humidity must be maintained between 40-70%.[34]

All OT personnel should wear proper PPE including cover-alls, N95 masks, goggles, face shield, shoe cover and two pair of gloves while in the operation theatres. The number of persons required in the surgical procedure should be kept to minimum. Only limited number of items should be kept in the operation theatre to restrict contamination. All the anaesthesia

and surgery equipment should be dedicated. Like in the ICU, other than the routine operation theatre equipment some items are essential for COT. These are - video laryngoscope with all sizes of blades, transparent acrylic boxes or transparent plastic sheets for aerosol generating procedures, closed suction catheters, ultrasound machine and high efficiency viral filters. A difficult airway cart and a fully loaded drugs trolley should also be present in a COT. As far as possible, disposable equipment and drapes should be used for all patients. The patient should be directly wheeled in the operation theatre instead of pre-anesthesia room. While giving general anesthesia, two HME filters should be placed – one between the tracheal tube and the circuit and other between expiratory limb and machine. Charting and record keeping should be done electronically.

The procedure of the disposal of the infected body fluids, and other soiled disposable items should be clearly defined. All the HCW should be aware of these procedures. After the surgery, surfaces should be cleaned and disinfected with EPA approved hospital disinfectants. The surface disinfection of equipment can be done with 75% alcohol solutions and floor and wall disinfection should be done with 1% sodium hypochlorite solution.

In conclusion, dedicated COVID ICU and operation theaters are the pressing needs of the hour as the whole world is engulfed by this pathogen. In a pandemic, there is no time to set up a new ICU or OT as per guidelines suggested by different regulatory bodies. However, small innovations and rearrangements can make things happen, particularly in resource-limited settings.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

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