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Practice Forum

Rapid expansion of temporary, reliable airborne-infection isolation rooms with negative air machines for critical COVID-19 patients

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More airborne-infection isolation rooms are needed in centers that treat severely affected coronavirus 2019 patients. Wards and rooms must be carefully checked to ensure an ample supply of medical air and oxygen. Anterooms adjacent to airborne-infection isolation rooms are required to maintain pressure differentials and provide an area for donning/doffing or disinfecting medical equipment.

A novel human coronavirus, severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), which emerged in Wuhan, China, in late 2019 is causing a pandemic. As of March 27, 2020, over 500,000 cases have been diagnosed and there have been 23,335 deaths.[1] The numbers of infected patients and related deaths are markedly increasing worldwide. Resources, including medical personnel, medicine, and medical equipment, are in great shortage, as are airborne-infection isolation rooms (AIIRs). Patients with severe coronavirus 2019 (COVID-19) disease need aerosol-generating procedures such as intubation with mechanical ventilation or tracheal suction. To prevent the spread of infection to medical personnel or other hospital patients, rapid expansion of AIIR capacity is critical in centers to which severely affected patients are referred.[2,3] We would like to share our experience and emphasize some essential points in building temporary AIIRs for COVID-19 patients with severe signs and symptoms.

WARD/PATIENT ROOM SELECTION

Chungbuk National University Hospital is an 810-bed (including 47 beds for intensive care) referral hospital in Cheongju, South Korea with approximately 2,300 employees and 4,000 outpatient visits per day. Chungbuk National University Hospital had an airborne-infection unit composed of 5 AIIRs, which were opened in 2015. It is one of the government-designated referral centers for severely affected COVID-19 patients, and it needed to increase the number of AIIRs urgently. To achieve this, the first step was to select adequate ward and patient rooms in respect to the flow of medical personnel and equipment. For most critical patients who need extracorporeal membrane oxygenation, mechanical ventilation, or continuous renal replacement therapy, the room needs to be large enough to allow such procedures, equipped with a suctioning device, medical air, and oxygen. For rooms with ventilators, a medical air supply needs to be present. In rooms equipped with an oxygen supply, but not equipped with medical air, oxygen therapy is achieved with portable ventilators or high-flow oxygen therapy devices. Considering the size, function, and distribution of patient rooms in the hospital, we selected 2 wards in the same building as the pre-existing airborne-infection unit.

MAKING ANTEROOMS BY PARTITIONING

Anterooms are necessary to maintain the pressure gradient of AIIRs and reduce the migration of infectious particles from the isolation room into the corridor. In addition, an anteroom provides space for health care workers to put on or take off personal protective equipment (PPE), and to disinfect medical devices, sample bottles, and specimen cups leaving the patient's room. Thus, the anteroom is considered to be a buffer zone between the patient's room and corridor, and has a crucial role for infection control in AIIRs. Expanding AIIRs with negative air machines needs the partitioning of rooms or corridors to be used to make anterooms. Staff preparing temporary AIIRs need to be extremely flexible when designing and building an anteroom. The location of the restroom and sink, the alignment of

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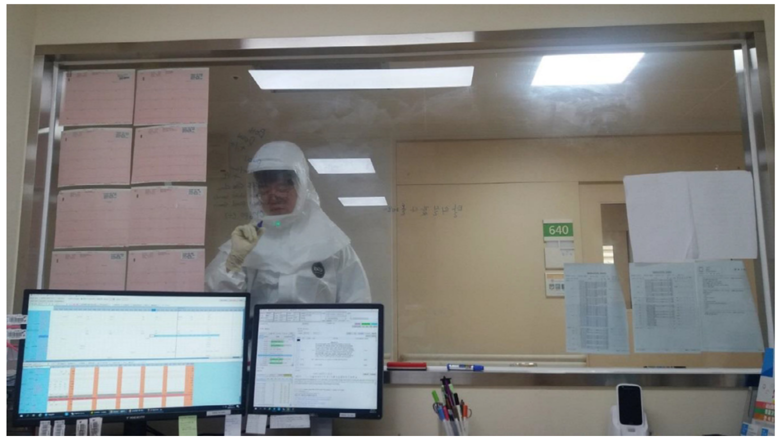

Fig 1. A health care personnel (HCP) writes on the transparent part of the partition to communicate with other HCP. The transparent panel is useful for rapid and accurate communication when caring for critical COVID-19 patients.

patient beds, and the location of windows where the flexible duct from the negative air machine is connected should be reviewed thoroughly when designing the partition. The partition should include a transparent panel through which medical personnel can communicate with one another (Fig 1). Different types of anterooms have been applied in our newly expanded AIIRs (Fig 2). For rooms located at the end of the corridor (635, 636), a shared anteroom was made by partitioning the end of the hallway, since these rooms were for patients infected with the same pathogen. For rooms adjacent to the middle part of the corridor (632, 633, 634), anterooms were prepared within each room after removing superfluous patient beds. We decided to make an oblique partition to avoid locating the restroom inside the anteroom (room 634, blue line) after some trial and error. With the oblique partition (Fig 3A), we could make anterooms large enough (compared with the green line partition, Fig 2) to maintain door interlock when moving the portable X-ray machine or isolation carts. Mirrors were placed in each anteroom to help medical personnel check their PPE status both before entering patient rooms and when removing PPE to avoid contamination.

GENERATING NEGATIVE PRESSURE

Reliable and stable negative pressure is one of the basic elements of an AIIR.[4] Negative air machines are capable of generating high air flow and have been traditionally used to facilitate air changes in industrial facilities. The machines we used had embedded High Efficiency Particulate Air filters to prevent spreading of pathogens or dust through the exhaust ducts (Fig 3). Patient rooms and negative air machines differed with respect to size and efficiency, respectively. Therefore, "trial and error" is inevitable to some extent. In order to generate maximum pressure differentials, the walls and ceilings of the rooms were sealed with vinyl and tape and the gaps between the window and the window frames were sealed with tape and silicone gel. We tried to ensure a constant high pressure differential by placing dual portable devices in each room and maintain adequate negative pressure in case one of them broke down or was switched off inadvertently.

The Centers for Disease Control and Prevention (CDC) and Healthcare Infection Control Practices Advisory Committee recommend pressure differentials > -2.5 Pa between the AIIR and the corridor, and ≥ 12 air changes per hour.[5] Korea Centers for Disease Control and Prevention recommends > -2.5 Pa pressure differentials for between both the patient room and anteroom, and the anteroom and corridor.[6] All our expanded AIIRs achieved a pressure differential of at least -8 Pa (up to -15 Pa in certain combinations) when both pressure gradients were combined. The pressure differentials were continuously monitored by using differential pressure transmitters applied on the walls between the patient's room and anteroom, as

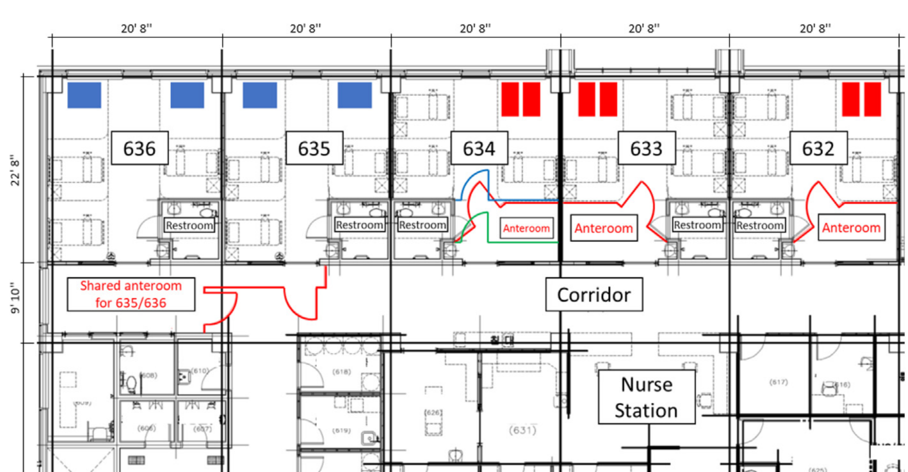

Fig 2. Blueprint (partial) of the ward with temporary airborne infection isolation rooms. Negative air machines are shown in blue and red boxes according to type. Partitions for anterooms are colored in red. In room 634, partitions that were tested but found to be inadequate are shown by blue and green lines.

Fig 3. Examples of airborne infection isolation rooms (AIIR) and equipment installation. (A) Example of an AIIR with oblique partitioning (room 633). (B) Installation of negative air machines (model WS-H-1200, Wosem Co., Ltd., Cheongju, South Korea) with exhaust ducts connected to windows. (C) Magnified view of another type of negative air machine (model ARDC-1502, ASKO Co., Ltd., Seoul, South Korea) connected to the window and powered by wall outlets. (D) Display of the differential pressure measured by a pressure transmitter (model MDP-100, MST Co., Ltd., Seoul, South Korea).

well as between the anteroom and corridor (Fig 3) to allow for easy verification of the pressure differential. Once a negative air machine became available, it was possible to install it and complete partitioning, sealing, fixing of the pressure transmitter with a display to the walls, and equip the room with CCTV in 1 day.

PATIENT MONITORING SYSTEM AND DOOR-LOCK DEVICE

In general, access for medical personnel to patients in AIIRs is more difficult than for ordinary patient rooms. To negate this problem, Korea CDC suggested a patient monitoring system that included video surveillance, usually by closed-circuit television, as a requirement for nationally designated AIIRs in South Korea.[6] In addition, to provide critical care to severely affected COVID-19 patients, patient rooms that could contain equipment to monitor all the general vital signs, including an electrocardiograph, were selected for conversion to temporary AIIRs. For some patients referred from a psychiatric hospital that had a large nosocomial outbreak of COVID-19, we made a device that could be turned on and off to control the sliding doors between the patient's room and the anteroom to prevent the patient's egress. For the temporary AIIRs, we applied a similar manual system to the doors between anterooms and patient rooms to prevent unintended door opening, especially by patients with mental illness or delirium.

HEALTH CARE PERSONNEL ARE ONE OF THE MOST IMPORTANT PARTS OF OUR FACILITY

As there was a small decrease in workload in the intensive care units, additional health care personnel (HCP), especially those who had work experience in a respiratory department or intensive care unit, were relocated to the newly prepared AIIRs. They helped each other by sharing their experience of critical care and managing devices including the mechanical ventilator, continuous renal replacement therapy, and extracorporeal membrane oxygenation. With excellent leadership and communication, HCP in these new AIIRs perform their job optimally.[7] We believe that this effort is reflected in the comparatively low mortality rate of COVID-19 patients and low infection rate of HCP in South Korea. We hope that sharing these key points in respect to the urgent expansion of AIIRs is a useful contribution to combating the SARS-CoV-2 pandemic on the frontline.

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