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Main Points of Ventilation Design for Infectious Wards

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Abstract

There are five main routes of infection of infectious particles, namely contact infection, droplet infection, airborne infection, vector infection and vector-borne organism transmission. The design idea of the infectious negative pressure isolation ward is to remove pollutants, cut off the vector of infectious virus transmission, and prevent the escape of pollutants. When designing clean air conditioners in infectious wards, consideration should be given to both satisfying the comfort of patients and improving the removal efficiency of bacteria as much as possible, that is, removing the polluted air exhaled by patients. To this end, in the design process, many aspects need to be considered, for example, the use of appropriate return air way to optimize the air flow organization.

Keywords

Infectious wards, Ventilation design, Architectural design.

1. Introduction

People are paying more attention to the basic prevention and control of these infectious diseases through SARS, avian influenza, H1N1 and the increasingly severe Corona Virus Disease 2019 outbreak trend. The spread of infectious diseases in the population involves the following basic links that only a few links work simultaneously to form a chain of infection: the source of infection, the route of transmission and susceptible people. Therefore, isolation wards are the most effective facilities for controlling the source of infection and cutting off transmission routes in the absence of artificial immunization methods.

2. Transmission Routes and Characteristics of Infectious Diseases

2.1 Contact Infection

Contact infection is the most important and common way of infection in hospital infection. It can be divided into two types: direct contact infection and indirect contact infection.

2.1.1 direct contact infection

Direct contact infection mainly refers to infections that occur through direct contact between body surfaces, or physical transmission of microorganisms from confirmed cases or suspected patients. Direct infection generally occurs between medical staff and patients or between different groups of people in a hospital health treatment environment.

2.1.2 indirect contact infection

Indirect contact infection mainly refers to some inanimate objects that have been contacted by the diagnosed or suspected patient, which carry viruses on them, so that others may be infected once they come into contact.

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2.2 Droplet Infection

When the patient speaks, coughs, or sneezes, a large amount of mucus droplets containing pathogens are sprayed from the nasopharynx and suspended in the air. Others such as some suction devices and bronchoscopes are also sources of droplets. When infectious particles are trapped in the droplets, if they are inhaled by susceptible people, they will deposit on the eye membranes, nasal mucosa or mouth of these people, and infection will occur. All respiratory tract infections such as measles, diphtheria, whooping cough, SARS, covid-19, etc. can be transmitted by air droplets. Do not confuse the concepts of droplet infection and airborne infection because droplet particles are large and will not be suspended in the air forever.

2.3 Airborne Infection

Airborne infections include the spread of droplet nuclei and flying dust. As mentioned above, although the droplet size is large and will not be suspended in the air forever, the droplets have a large surface area and can quickly evaporate in the air. The factors that determine the evaporation rate of droplets are: the size of the droplet and the partial pressure difference of the water vapor in the air and the surface of the droplet. When the relative humidity is very low, the droplets can evaporate quickly. During the evaporation of a droplet, the concentration of its dissolved matter increases, and the droplet will become smaller until the water vapor pressure of the droplet is equal to the water vapor pressure in the atmosphere. If the saturation pressure of the droplet in equilibrium is greater than the partial pressure of water vapor in the atmosphere, the remaining water will also evaporate, and the dissolved matter of the droplet will form crystals. The residue of the evaporated droplet contains the same organisms as the original droplet, called the core. The size of the core is usually about 5 μm or less. As the water evaporates, the mass of the droplets is reduced, so the settling velocity of the droplets is reduced. Large landing, small can float in the air and move with the airflow.

2.4 Vector Infection

When the food, water, medicines, medical equipment and equipment delivered are contaminated and then used again by other patients, the infection is called vector infection.

2.5 Carrier-borne Organisms

Carrier-borne biological transmission refers to a method of spreading germs through vector arthropods (such as mosquitoes, fleas, lice, mites, flies, mice, etc.).

3. The Main Points of The Isolation Ward Layout

The purpose of the overall design of the infectious ward is to prevent bacteria from escaping and cross-infection of patients with different diseases. Measures such as pollution zones, zone pressure control, and buffer rooms should be taken.

3.1 Cleanroom Partition

Infectious disease hospitals should try to avoid urban densely populated areas, such as schools, residential areas, water sources, and other important facilities that may cause harm according to the overall urban planning, and choose high-level, geologically stable and flat sections as far as possible to dominate the urban areas for years Downwind. According to the requirements of the "Publication of SARS Patients' Architectural Design Requirements" issued by the Ministry of Health, the general layout of infectious disease hospitals should be divided into restricted areas, isolation areas and isolation zones between them. The restricted area is the living management area and the logistics supply area; the isolation area is the medical work area; in order to control cross infection, the interval between the restricted area and the isolation area is recommended to be about 30m.

The outpatient department and the inpatient department are strictly divided into clean areas, semi-contaminated areas and contaminated areas, and buffer zones are established between the areas. The suspected ward and the confirmed ward, the clean passage and the polluted passage must be set separately, and the house layout should be arranged in accordance with the procedures of

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consultation-inspection (medical department)-treatment (ward)-monitoring (ICU). During the architectural design, the layout should be rationally arranged, and the cleanliness and sewage flow lines should be strictly divided. Medical personnel should enter the work area according to the work flow of the clean area-semi-polluted area-polluted area. place.

The entrance and exit of each functional inspection department must be set up with a mandatory sanitary passage room. Medical staff and patients should use different channels. Medical staff use medical staff working corridors (clean areas) and ward corridors (semi-contaminated areas). Medical personnel entering and exiting the wards must pass through the mandatory sanitation passage room. The passage room should include: changing rooms, shower rooms and toilets and other sanitary facilities. Medical personnel entering and leaving the ward from the corridor of the ward must pass through the buffer room. The buffer room should be equipped with mobile water hand-washing facilities and misaligned doors. The entrance and exit of the Intensive Care Unit (ICU) must have a compulsory hygienic passage room. The patient enters the ward through a peripheral corridor (contaminated passage).

The logistics in the ward also needs to be properly arranged. The clean medicine and food are transmitted to the ward through the medical corridor and the double-door sealed transfer window set in the buffer room of each ward. The clothing and tableware used by the patient are sent out through the dirt transfer window provided between the patient room and the patient corridor, and then sent to the nutritious kitchen and laundry room after disinfection. The pass-through dressing room and the compulsory hygienic passage room mentioned in the above clauses all play the role of buffer rooms. It can be seen that reasonable partitions can fully play the role of buffering and reduce the chance of medical staff being exposed to germs and infecting diseases. The design of the buffer room should be considered in the design of infectious hospitals.

3.2 Zoned Pressure Gradient

Isolation wards can be divided into protective isolation wards and infectious negative pressure isolation wards. Protective isolation wards mainly protect patients with low environmental resistance, such as burn patients, organ transplant patients, blood patients, etc., in order to maintain a sterile indoor environment In a clean room, the indoor air pressure must be greater than the outdoor air pressure. The infectious negative pressure isolation ward mainly treats patients with airborne diseases (such as SARS, measles, chicken pox, tuberculosis, throat tuberculosis, etc.), mainly to isolate patients to protect medical staff, visitors and the environment, etc., in order to prevent For the escape of pollutants, it is necessary to keep the indoor air pressure lower than the outdoor air pressure, and the negative pressure isolation ward can effectively reduce the escape of germs. According to the "Guidelines for the Design of Hospitals for the Treatment of Infectious Atypical Pneumonia Patients" by the Ministry of Health and the Ministry of Construction, the negative pressure should be maintained in the isolation ward. For the bathroom in the ward, the bathroom should be under negative pressure relative to the ward to prevent polluted air from flowing into the ward. Therefore, referring to the recommendations of the Australian Standing Committee for the Control of Infectious Diseases regarding the negative pressure gradient of adjacent compartments of negative pressure isolation wards greater than 15Pa, the following values can be taken: the negative pressure value of the ward is -30 ± 5Pa, and the negative pressure value of the toilet is- 35 ± 5Pa, the negative pressure between the buffers is -15 ± 5Pa. In order to ensure the pressure difference between the rooms, a pressure difference meter should be installed in each room to maintain a constant pressure difference by maintaining and changing the air supply and return air volume. During the maintenance of the air conditioning system, the air return fan should be regularly repaired to avoid failures. Cause bacteria to escape. In order to maintain the negative pressure in the room, numerical simulation, analysis of the pressure value, flow rate and wind speed of each measurement point in the room, and the study of gas leakage during negative pressure control can also improve the air conditioning and ventilation scheme.

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3.3 Setting of Buffer Room

The buffer chamber is of great significance in preventing the escape of pollutants. According to the principle of clean air conditioning, for different adjacent areas, such as clean areas and unclean areas, polluted areas and semi-polluted areas, and different polluted areas, it is often necessary to adopt pressure difference control to ensure that the relatively low-pressure areas are difficult to penetrate the polluted air Relatively high pressure area. When the required differential pressure value is too large, the differential pressure control is not easy to do; on the other hand, when people enter and exit between rooms with different cleanliness levels, it is easy to bring contaminants in or out at the moment of opening and closing the door. Affect the cleaning effect, so you should use a buffer room to buffer and improve the isolation effect. Because the area of the buffer room is small (generally no more than 5 ~ 6m3), the number of air changes is large (generally dozens of times per hour). Within 2-3 seconds of entering and exiting from another door, the polluted gas will be diluted, thereby reducing the pollutant gas from being taken out of the ward, adding a buffer room, and the pollutant isolation capacity can be increased by about 19 times. After the buffer room has been self-purified for a period of time, the internal air becomes clean again. Therefore, when using the buffer room, when people or objects pass through the buffer facility, the pollutants brought from the isolation ward will be diluted and purified, and the medical personnel enter the clean area The pollutants brought out by the time are greatly reduced.

As mentioned in Article 5.3 of the “Code of Design for Infectious Diseases Hospitals”: the observation wards and ICUs of large infectious diseases hospitals should be equipped with negative pressure isolation cells, each with 1 bed, and a buffer transition cell. between. Article 5.5 mentions: there should be a double-door closed transmission window between the severe infectious disease room and the corridor, and a buffer transition room between the sick room and the corridor, and the doors should be staggered to avoid airflow backflow. It can be seen that the buffer zone is an important part of the intensive care unit and the isolation and isolation ward. In the design of clean air conditioning, the significance of setting the buffer zone should be fully considered and the buffer zone should be designed reasonably.

The buffer facilities used for people or things to enter and exit different clean rooms include Airlock Room, BufferRoom, and Air Shower. They are all set up between different clean rooms for buffering. In a closed room, the two doors that enter and exit cannot be opened at the same time. The air lock chamber does not process the air in it, but only acts as a buffer, which cannot effectively prevent the intrusion of external pollutants, because when a person enters the air lock chamber, the polluted air has been brought into the air lock chamber and when the person walks In the air lock chamber, it will bring the polluted air into the clean room; the buffer chamber will send clean air, so it has the function of compensating the pressure difference and clean air, ensuring the clean level of the clean room to be entered; air blowing The shower room uses a nozzle to spray a high-speed air flow to make the clothes shake, thereby blowing off the dust on the clothes surface, and also greatly reducing the pollutants brought into the clean room.

According to the "Technical Specifications for Clean Operation Department of Hospitals" (GB 50333-2002) mentioned in China, no air blowing room should be installed in the flow channel. A buffer room should be set up at the car change place. There must be a buffer room between the negative pressure clean operating room and the room with serious pollution and its adjacent area. The buffer room should have a cleanliness level and be at the same level as the side with high cleanliness, but should not be higher than 1000. The area of the buffer room should not be less than $3m^2$. The more common buffer facilities used in isolation wards are also buffer rooms, which are of great significance in preventing the spread of infectious diseases.

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4. Ventilation System Control

4.1 Supply and Exhaust Port Settings

Each floor system is set independently, even if there is a problem with the ventilation system of any floor, it will not affect other floors. The mechanical air supply and exhaust system of the cleaning area, semi-polluted area, and polluted area of each floor is set according to the area. The air supply of the air supply system is taken from the outdoor air in the cleaning area, and it is sent to the indoor cleaning area from the air supply port after the two stages of primary and intermediate efficiency filtering; It is led to the roof and discharged at high altitude after three stages of primary, intermediate and high-efficiency filtration to ensure that outdoor air is not polluted. The filter is equipped with a pressure difference detection and alarm device, so that the filter can be replaced in time to ensure that the system air volume and air pressure operate within the design range. In order to achieve a stable and reliable cascade pressure difference in each area, the self-balancing constant air volume air outlet is used for the design air supply and exhaust air outlets. The self-balancing air outlet is set in the upper part, the self-balancing air outlet in the ward is set in the lower part of the room, and the remaining self-balancing air vents are set in the upper part of the room.

4.2 Air Flow Direction Control

The air flow direction control should first prevent the supply and exhaust air short circuit. The blower inlet is located as far as possible upstream of the dominant wind direction, and keeps a certain distance from the exhaust fan outlet;The location of the air supply and exhaust vents should be such that clean air first flows through the possible working area of medical personnel in the room, and then flows through the pollution source into the air exhaust vent; the air supply vent should be set at the upper part, and the air exhaust vent in the polluted area (patient room) should be The lower part of the room, but the bottom of the air outlet of the ward should not be less than 100mm from the ground, so as not to disturb the polluted air close to the floor of the room. Secondly, the supply and exhaust branch pipes of different rooms (especially the exhaust branch pipes) should be arranged independently as much as possible, and should not be shared. It is necessary to install air-tight check valves on the supply and exhaust branch pipes to prevent cross-flow and reverse flow in each room. Cross-contamination.

4.3 Positive and Negative Pressure Control

The mechanical air supply and exhaust system should reduce the pressure in the ward from the clean area → semi-polluted area → polluted area in turn. The clean area is a positive pressure area, and the contaminated area is a negative pressure area. The air supply volume in the clean area is greater than the exhaust air volume to ensure that it is positive pressure, and the air volume in the polluted area is greater than the air supply volume to ensure that it is negative pressure. In order to keep the pressure gradient stable, the air supply branch pipe or the air outlet should be set with an air volume device; the air supply and exhaust pipes should be strictly sealed, and the pipeline should pass through the inside and outside walls of the ward building, and the corresponding sealing measures should be done according to the building materials. The outer protective structure of the negative pressure isolation ward should be constructed with tightly-sealed construction materials. The negative pressure isolation ward should be equipped with a differential pressure sensor to detect the negative pressure value or to automatically adjust the ventilation system without setting the air volume. Exhaust volume.

5. Conclusion

Negative pressure isolation ward is a relatively complex system with strict safety requirements, which can't tolerate any mistakes. This requires the designer to consider all aspects of the design, fully understand the user's use requirements and operation. In the actual work process, the main line of ensuring the safety of medical staff and the safety of the external environment has been put in the first place from the plane layout, so that the built-up negative pressure isolation ward has reasonable cost, safe and reliable operation, and truly protects the lives of people.

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