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The Condition of Isolation During the COVID-19: A Review

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Abstract. Following the outbreak of the COVID-19 pandemic, attention has been paid to the function of buildings to isolate the virus and the impact of buildings on the mental health of patients. This article discusses the architectural design of the COVID-19 isolation through a literature review. Current research related to the COVID-19 isolation condition focuses on the design of ventilation, fluid dynamics, clinical environmental medicine, and the application of architectural psychology.

Keywords: condition of isolation, indoor air quality, ventilation, medical environment, mental health

1. Introduction

With the development of the architectural design discipline, people generally pay attention to the built environment, and the development of research and application of architectural psychology has played a positive role in promoting the field of architectural creation [1]. Architecture not only needs to meet people's physical and functional requirements but also gives specific care to people's psychology. People also began to pay attention to the research of the medical environment and developed clinical environmental medicine [2]. Hospital design requires proper functions and advanced technology from a physiological point of view and pays attention to embodying the psychological needs of patients in the environmental design. These are all manifestations of the development of modern architecture to a higher level. Coronavirus disease 2019(COVID-19) is a contagious disease caused by severe acute respiratory. As of 7 July 2022, there have been 550,218,992 confirmed cases of COVID-19, including 6,343,783 deaths, reported to WHO, which makes it one of the deadliest in history [3]. The isolation sites and hospitals have played an enormous role in preventing and controlling this disease outbreak. Isolation of infected people and close contact can effectively prevent the continued spread of the epidemic. In reality, however, many isolated sites are poorly managed, resulting in clusters of infection and spreading outwards. Following the outbreak of the COVID-19 pandemic, attention has been paid to the function of buildings to isolate the virus and the impact of buildings on the mental health of patients. This article hopes to discuss the design of isolation buildings through a literature review. The analysis was done by searching Google Scholar, ScienceDirect, Scopus, Semantic Scholar, and other databases for journal research papers for comparison. A combination of keywords including COVID-19, epidemic, isolated hotel, hospital, ventilation, airborne, aerosol, indoor environment, and mental health were used for the literature search. However, very few studies covering all of these concepts could be found during the COVID-19 pandemic. Therefore, this paper is supplemented by references to some relevant information not in the context of the pandemic.

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2. Effective architectural design of the COVID-19 isolation

At present, some scholars have begun to pay attention to the design of the COVID-19 isolation condition. For example, Bangwal et al. argue that the hotel industry will shift its research focus to building design for health and safety in response to current and future infectious diseases. They conducted a health follow-up of 302 participants in a LEED-certified hotel in India. These participants are all hotel employees. They spent time in hotels as the pandemic broke out and spread across the globe. The findings show that current hotel building designs need to be updated as they directly affect employee health and performance, and these symptoms may further impact India's economy and society. The most important thing is to connect occupants with nature to reduce fear and struggle in a pandemic [4]. Similarly, Jacobs et al. also tracked the health of occupants of 58 LEED-certified buildings. They found that buildings with better acoustics, indoor air quality, layout, heat dissipation, ventilation, and other design features lowered respiratory infections at 18 months and improved the participants' health by 8%. Related technologies include non-contact technology, controllable thermal settings, and layout [6,7].

2.1. Ventilation and fluid dynamics

The World Health Organization recommends increasing the supply of fresh indoor air as an effective way to reduce the concentration of virus particles in enclosed spaces, thereby reducing the risk of infection. Therefore, adequate building ventilation is essential to ensure the health and safety of occupants. Ren et al. applied a stable Eulerian CFD model to find appropriate dimensions of physical barriers to limit the spread of airborne pathogens in open offices during coughing. They treated the exhaled pathogen droplets as a continuous phase and solved the species transport equation to determine its spread indoors. The findings suggest that a 60 cm high physical barrier can effectively prevent the spread of pathogens [8]. Despite these efforts, a fundamental gap in these studies is that estimates of infection risk require cumulative viral load, physical distancing is not the only determinant of infection prevention with airborne pathogens, and exposure time is equally critical [8]. The viral load gradually reached the minimum infectious dose with increasing exposure time [8]. On the other hand, maintaining safe social distancing is not realistic in some places due to high concentrations of people or a lack of sufficient space to ensure proper distancing between all occupants [8]. In response to this situation, Motamedi et al. developed a model to explain the accumulation of exhaled airborne pathogens under different ventilation conditions in confined spaces. They used CFD technology to digitally simulate the droplets exhaled during the speaking event and investigate different ventilation strategies simultaneously. The results show that infection in exposed occupants is not only a function of airborne pathogen concentration but also strongly depends on the duration of exposure, making ventilation strategies particularly important [9]. The further extension of the thermal plume across the office strongly depends on the ventilation strategy chosen and the location of the occupants, which in turn affects infection transmission [9]. In a ventilated room, there is a strong interaction between the thermal plume and the room airflow, which affects the transmission of airborne pathogens [9]. Ren et al. investigated three ventilation strategies in a COVID-19 inpatient ward using computational fluid dynamics. When a patient coughs or sneezes, the droplets containing pathogens are sprayed at a speed of more than 11 m/s [10]. Therefore, the inpatient ward has higher requirements for ventilation strategies, and the number of air changes per hour needs to reach more than 12 times [10]. The three ventilation strategies devised by the authors all use a ventilation mechanism to move small particles out to the exhaust. The research results show that ventilation strategy 1 discharges 86.1-88.7% of small particles, ventilation strategy 2 discharges 83.4-85.4% of small particles, and ventilation strategy 3 discharges 64.3-67.3% of small particles, so the effect of 1 is the best, and 2 is better than 3 [10]. Since particles can reach ceilings and walls and spread in all directions, the authors believe that ceilings and walls deserve further study [10].

In addition, since high ventilation rates can dilute contaminants and reduce virus concentrations to a large extent, which is difficult to achieve by relying on natural ventilation in buildings, it is necessary to install mechanical ventilation systems at isolation sites [11]. HVAC is mainly used to

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control the increased probability of infection. However, if implemented improperly, causing air to recirculate indoors, it may become a source of virus-carrying aerosol transmission. In the current situation, recirculation of air in indoor environments should be prohibited, especially in centralized air conditioning systems [12]. Some studies recommend maintaining negative pressure and high relative humidity in hospital intensive care units (as SARS-CoV-2 viruses are mainly found in intensive care units), using adequate mechanical ventilation rates [13]. Studies have shown that high temperatures and relative humidity can reduce the risk of infection, as these conditions can make the virus less active [14]. ASHRAE suggested increasing the outdoor air ventilation by lowering the population in buildings. It is also recommended that the system be run at maximum outside airflow for 2 hours before and after the building is occupied [15].

2.2. Medical environment and mental health

At the same time, an important related area is an organic connection between the design of various parts of the medical environment and the mental health of patients, and research in this area can be referenced for the design of buildings isolated from COVID-19. The environment and psychology of the patient in the hospital, psychology, and disease, are mutually influenced [16]. An uncomfortable environment can cause psychological anxiety and fear. This change in mental state, in turn promotes profound physical alienation [16]. A good level of medical technology and medical environment can reduce and eliminate the psychological pressure on patients, and adjust the psychological factors of patients, thereby enhancing the body's ability to resist disease. Zhi et al. focused on the organic and sequential nature of the hospital space environment. The spatial environment of hospital buildings, whether it is the whole or part of the building, indoor layout or outdoor space, artificial landscape or natural environment, should organically and completely reflect and adapt to the psychological needs of patients. The patient's psychological intention is "expectation" before arriving at the hospital, so the hospital site selection should pay attention to the appropriate service radius and convenient traffic conditions [17]. Patients come to the hospital with a sense of hope, so the entrance to the hospital and the external environment reflect stability, calmness, and a clear orientation [17]. When the patient is in the outpatient clinic, the psychology is more urgent, and they expect to gain a sense of trust in contact with the doctor, so the space environment requires quietness, kindness, and a certain degree of privacy [17]. Hospitalization is often considered to have entered a white world with a cold atmosphere, so the design needs to create a suitable living atmosphere and visual landscape so that the clinical environment is in line with the psychological state of the patient [18].

In particular, the study by Hale et al. (2005) showed that a sense of belonging was predictive of the subjects' health. Sargent et al. (2002) took Navy recruits as research objects and found that a sense of belonging can slow down the occurrence of depression and play an essential role in the mental health of patients. Bay et al. (2005) conducted a case study of traumatic brain injury patients and concluded that increasing a sense of belonging can significantly reduce the symptoms of post-traumatic depression. The study by Newman & Lohman found that patients lacking a sense of belonging have obvious negative emotions, and severe patients even have suicidal behaviors. Lengen & Kistemannb analyzed the spirit of place from 10 aspects of neuroscience combined with the characteristics of belonging, which has a direct relationship with the analysis, memory, connection, and utilization of various spatial information. Mohammad et al. highlight that building a sense of community belonging can create a memory in the old city, bring people back to their youthful days, and bring a sense of comfort to the local elderly. From the research results of Birnbach et al., it can be seen that in the design of architectural space proximity, the relevant architectural scale factor is the most critical factor affecting the proximity of hospital building space, which can avoid the subconscious psychological gap. At the same time, a factor that has a greater impact on the sense of belonging is environmental greening [26]. Allowing patients to go to the outdoor environment around the hospital during rest can significantly meet the daily leisure requirements of patients. Therefore, increasing the greening and plant configuration in the indoor and outdoor environment and improving the space range for indoor patients to rest will enhance the patient's sense of belonging to the hospital environment to a certain

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extent. The realization of the hospital design's expectation of the patient's inpatient environment, to a large extent, promotes the patient's dependence on the inpatient environment, thereby forming a sense of belonging [26]. The warm interior decoration of the hospital building is an important carrier of the hospital's meticulous design. It is reflected in the color design, lighting design, and even a painting in the ward, which contains the careful care of the hospital designer, which is of great significance for enriching the daily life of patients [26]. During the implementation of COVID-19 isolation measures, the patient's leisure needs, activity space, and needs to be cared for are often ignored, which will cause patients to feel unfamiliar with the environment [27]. Lack of belonging will stimulate loneliness and fear in patients [22]. Creating a suitable environment for communication can relieve the depressed mood and lack of security, so patients can show a more positive attitude towards interpersonal communication and a good psychological state. The formation of a sense of belonging has a more significant effect on the loneliness of patients [21].

However, it must be acknowledged that temporarily converted buildings during the COVID-19 pandemic often have difficulty meeting the ventilation standards of hospital isolation wards and have no space to take care of the psychological needs of patients [28]. The heating, ventilation, and air-conditioning systems of many retrofitted buildings cannot recreate hospital isolation rooms. One cannot expect a hospital with good airflow when one puts 500 or 600 patients in the open area of a conference center [28]. For the Fangcang shelter hospitals built in China, the above-mentioned concepts of "connecting occupants with nature" or "allowing patients to move around to the surrounding outdoor environment" also seem difficult to achieve [29]. However, the converted building can still serve as an isolation center for mild COVID-19 cases so that the hospital can focus on the care of critically ill patients. Some technologies can be applied to improve conditions in temporary or converted isolation centers, such as windows made with materials that are less friendly to microbes (such as copper) or electronically switchable privacy glass (also known as e-glass or smart glass). The risk of surface transmission can be reduced [28]. Although not meeting the design standards of a hospital, architectural psychology can be applied to the selection and design of isolation centers. People's psychological activities come directly from visual stimuli. Although buildings made of the same material have the same shape, the difference in color coordination or color matching will create different psychological feelings of warm or cold, ornate or plain, comfortable or restless [30]. The visual effect can change the shape and scale of the architectural space, so it has become an effective means to adjust the image of the space [1]. The architectural spaces that are not restrained from each other and can be connected or interspersed with each other can be closed or open. They connect and interlace with each other, which can produce mutual penetration and extension of space, giving people psychological comfort [31]. In addition, negative spaces in public spaces, such as dead spaces or non-attributed space, make people feel fearful and uneasy, so the isolation center needs to avoid such negative spaces [1].

3. Conclusion

This literature review discusses the isolation conditions of the current outbreak, with particular attention to airborne ventilation and the psychological impact of the isolation environment on people, as well as possible solutions for further improvement.

The temporarily remodeled buildings during the COVID-19 pandemic are challenging to meet the ventilation standards. Mechanical ventilation is essential, and it needs to satisfy an appropriate mechanical ventilation rate where high temperature and relative humidity can be maintained without negotiating with thermal comfort. Indoor air should not be recirculated, and using one hundred percent fresh air requires mechanical ventilation systems that consume a lot of energy, so renewable energy could be considered as an alternative. This could be used as an opportunity to move towards sustainable smart cities.

At the same time, it is challenging to cater to the psychological needs of patients in isolation and those in close proximity who are not yet infected. In particular, architectural psychology has been introduced into the architectural design for many years, but it has not received the attention it deserves

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in the design practice of the condition of isolation. It should be an active factor in future architectural design. It is possible to create spaces for patients to exercise and relax, taking into account the actual situation. Increase the greenery and planting in the indoor and outdoor environment to improve the range of spaces for patients to rest indoors. Rational use of space layout and colour distribution to improve patients' sense of belonging and relieve depression. Using design to enhance people's sense of belonging to buildings and ensure people's psychological needs for safety is particularly important for people under increased pressure in the post-pandemic era.

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