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Adapting Existing Hospitals for Infectious Disease Prevention and Control

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***Abstract-* Currently, there is a deficit efficient and contextualized design strategies to aid in infection prevention and save health professionals. Thus, the paper's objective is to validate how the room we enthrall can be made safer from the perspective of architectural design with the aim of creating rules for politicians and highlighting the role of the architect in battling diseases. Two hospitals have been considered to apply these conditions to adapt with new polices of infection control. The modifications have revealed good results that the hospitals have been divided into three sections, triaging, isolated patients, and normal patients.**

***Keywords*: Covid-19, Infection, Ventilation, Adaptive Design**

1. INTRODUCTION

The operation to prevent and control infections should include healthcare design. Contagious complaint prevention and control design solutions must be incorporated into hospital architecture. Organization for World Health (WHO) discusses the prevention and management of infection complaints (IPC) as a technique based on science and a workable resolution designed to protect patients and healthcare staff from injury or health difficulties brought on by infection [27].

During the outbreak of extensively medicine-2006 eradication of TB resistance, the sanitarium's building's architectural style took a big portion of the responsibility [3]. The charge is that the constructed terrain has a natural connection to mortal health and well-being. In partnership with Lateef and according to a recent report by the Center for Disease Control (CDC) on the COVID-19 method of transmission [3]. Striking a balance between the idea of open access design and the necessity of control mechanisms to reduce the prevalence of infections has become crucial. According to studies, climate change and unpredictable rainfall patterns have an impact on the built environment as well as the global onset, rejuvenescence and redistribution of infectious diseases [28, 16].

The goals include looking into how medical technology has developed, how infectious diseases relate to architectural space and suggesting design tactics for infection prevention and management (IPC). The study intended to consult written sources, conduct interviews and speak with healthcare experts. There is no doubt that the present pandemic has fundamentally altered the way we consider and create hospital architecture.

2. REVIEW OF THE ELABORATION OF MEDICAL ARCHITECTURE AND EPIDEMIC CONDITIONS

Hospital architecture has occasionally changed to meet the needs of the recovery procedure. There has, according to Guenther, Vittori [12] and Cameron [6], always been a connection between health and armature. They continued by saying that both medical and architectural professionals are aware of the relevance of appropriate buildings in the healing process. Early in the Middle Ages, after the fall of the ancient countries, hospitals were dominated by social functions rather than medical practices, which was caused by the poor status of medical knowledge [24].

Nonetheless, between the sixth and eighth centuries, hospitals were established in Western Europe. Around the 12th and 13th centuries, however, the knowledge of classical and Eastern healers began to spread throughout Europe [21].

The most significant medical developments in ancient Greece and Egypt are entwined with theological principles, sanctuaries and preachers have significant roles in efforts to identify, analyze, and treat complaints. Many of the early sanitarium designs were reminiscent of seminaries that were built around a court and were frequently situated on the outskirts of towns or large cities, and the sick were cared for by monastic organizations [24, 5].

The Schola Medica Salernitana, an Italian monastic hospital's 9th-century innovation, is a good example of such a structure [5]. According to Tesler [24], this institute was still the first of its kind in Europe in the thirteenth century for teaching medical professionals, scientists, and allocating practicing licenses.

The modernistic hospital was created four hundred years ago, claims Costeira [7]. The Hotel- Dieu, one of the best and largest hospitals in Paris in the middle of the eighteenth century, makes this very obvious. The hospital wards were frequently placed next to other wards with contagious cases, and the facility declined to a horrible state characterised by darkness, inadequate ventilation, dirt and other conditions. Consequently, a commission was created to evaluate architectural ideas suitable for the circumstance and direct research and studies to produce a clear answer for the hospital [5]. The "pavilion" plan, which was first implemented at the Hospital Lariboisiere, built in 1854, was the outcome of the problem's confluence of events, the commission's growth, and Dr. Tenon's important efforts [10].

The 1860 discovery of the transfer of origins was another crucial event that transformed medical architecture [7]. This manifested itself in the isolation of cases and complaints in a certain kiosk. Louis Pasteur's research supported the necessity to stop infection and complaint spread by separating cases and eradicating medical prejudice [4]. The theories behind separating diseases sparked a genuine revolution in medical equipment. The growth of the kiosk model, the establishment of modern medicine and the unique obligation to pay attention to the healthcare environment are the forerunners of contemporary hospital design. Italian-born Florence Nightingale (1820–1910) was born in Florence, is deserving of mention. Her groundbreaking training in nursing, note-taking, and statistics profoundly contributed to the telling of hospital progress. Her involvement in the Crimean War (1853–1856) helped lay the groundwork for healthcare kiosk models that provided air, case rotation, lighting, and hygiene. This improved case reclamations much further and decreased infection rates. The multiple case ward conception, sometimes known as the Nightingale ward, was maintained in this form, as depicted in Figs. 1 and 2 still hold true in current practice.

It is crucial that patients are kept in an appropriate hospital setting in order to stop the spread of disease inside the hospital and/or community. Clinical spaces in hospitals should be particularly constructed to lessen the risk of nosocomial transmission. Some countries have suggested a particular style of plastic isolator with one or two beds of negative pressure [3].

Fig. 1: Victorian hospital ward [6]

Fig. 2: Design strategies for infection prevention [10]

3. METHODS OF INFECTIOUS DISEASE TRANSMISSION

Origins, germs, and pollutants are dangerous because they may travel from one location to another. Pollutants migrate from one location to another in the air or water medium, where their spread is influenced by their natural and chemical components as well as the surrounding environment. Pollutants do not just stop at their primary origins [1]. Even though remedial buildings are intended to provide health care, some of them are among the most vulnerable locations, necessitating the design of a sustainable entrance. Infections can also spread through contact, air, or driblets, either directly from the source of pollution to the case or laterally through a central path [19]. This has a significant negative impact on the health of both cases [18].

Airborn infection diseases were not handling in hospital operation reports in the past. As a result, it had no airborne infection management policy when XDR-TB cases first started to emerge [27]. The study underlines the various roles that architects play in advancing healthcare. Therefore, it is necessary to examine the modalities of illness transmission in order to comprehend the steps to take in containing infections from an architectural perspective.

- Airborne and Droplet Transmission
- Transmission across water
- Surface or Contact Transmission

4. SUITABLE DESIGN BASICS FOR INFECTION PREVENTION AND CONTROL

Similar architectural environments can support or prop the suppression of infectious conditions when they are developed and created with a specific goal in mind. Important elements of sanatorium sanitation and infection prevention are cross ventilation and natural light [10]. Based on implemented tactics, domestic, commercial, residential and hospital spaces for infection, forestallment and control designs can be modified as shown below.

4-1 Design for social distancing:

Avoiding numerous frequent dangers requires planning for social isolation [15].

• Ignoring the way that bodies captivate space. Designers usually underestimate the overall distance between people when calculating social distance. Contact (edge-to-edge) distance is what we refer to as "social distance," therefore when designers determine grids or distance labels on the sidewalk, they must take into consider the actual area that people occupied.

• Ignoring the impact of time. Safe space and implicit exposure time should both be taken into account, especially if the situation calls for the occasional, fleeting irruption of social distance.

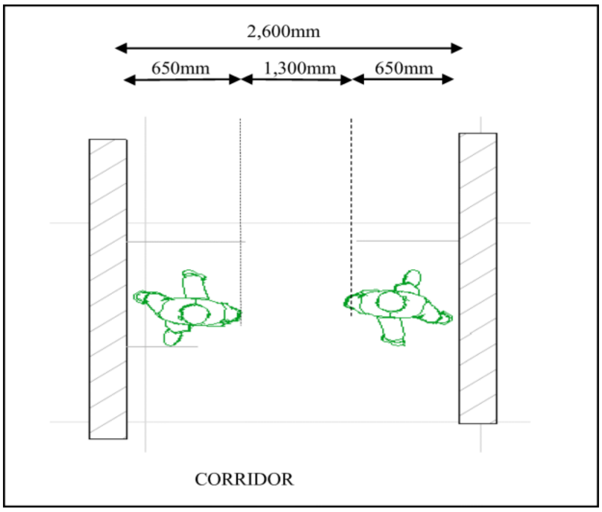
• Assuming Pets in traffic are always there. Contrast has a significant impact on maintaining compliance in lane-grounded movement and direction since not everyone goes at the same speed.

• Overlooking secondary impacts. In neighboring communities, the architecture of one building could have an impact on social distance (on the road, at stations, and so forth]. A large queue outside, for instance, can disrupt other lines within.

Waiting rooms, corridors, stairwells, and the lobby of the entrance should all have enough space to provide a fragmented social distance of at least 1000 mm. Because aerosol driblets only travel a short distance of 1000 mm to 2000 mm before settling on shells, this would not only reduce contact transmission but also [23] provide a safe distance. Avoid waiting rooms, double-bank corridors, open-end lobbies, and other spaces with little to no airflow.

The situation has gotten so terrible that the layout of the hallways and lobby needs to be reviewed in order to accommodate not only beds, wheelchairs, squats, trolleys and other medical equipment but also the safe distances mandated by the CDC. Regarding safe separation inside hospital space, the UK Department of Health's [25] recommendation of a corridor width of 1500 mm is modest. As a result, this study recommends a minimum corridor width of 2600 mm, as shown in Fig. 3.

By requiring a minimum social distance of 1000 mm and bilateral freeboards of 300 mm, this takes into account the reality that human movement isn't quite linear.



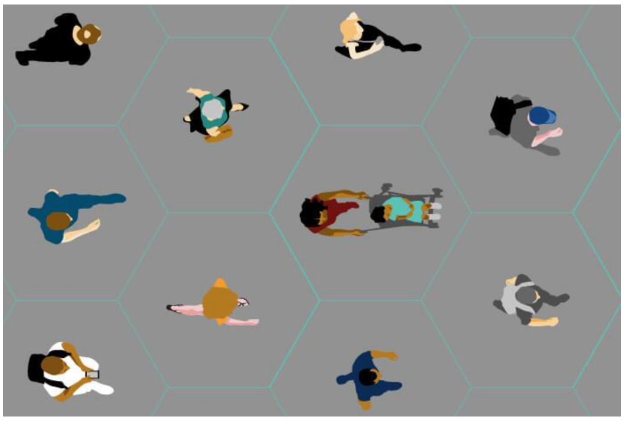


Fig. 3: Social distance [25]

4-2 Designing for Daylight or Sunlight Enhancement

There is evidence that strategically positioned windows and lights in structures can aid in patient care and stop the transmission of airborne illnesses. Evidently, before the discovery of antibiotics, sunlight and fresh air were seen as key infectious illness prevention methods [20]. In addition, Solly [23] reported that direct sunlight through glass may well kill bacteria bacillus in a few minutes or hours depending on the thickness of the layer of bacteria exposed. Diffuse sunlight seen near windows in buildings may likely kill bacteria in five to seven days.

It naturally follows that there should be enough openings to let light into hospital wards, rooms, offices, corridors, and stairwells as part of infection prevention and control. [20] Buildings with improved exposure to sunshine and external air may reduce the survival and spread of infectious diseases, benefiting occupants' health in the process.

In modern healthcare facilities, the sunlight does not play an important role in infection control that the hospitals will be sealed and depend on mechanical ventilation and electrical light fixtures. The use of mechanical ventilation and electrical lighting is the norm in modern healthcare facilities because sunlight does not play a significant role in the prevention of infection.

The light fixture should be anti-bacterial type and its frame does not have any cracks. In addition to its intensity (lux) should cover the space. Two light fixtures should be added having one built in battery or UPS to cover the power off cases. The light should be white and LED to overcome the electric transformer inside normal types.

4-3 Design with adaptable finishing supplies and building techniques

Recent studies on Covid-19 virus reveal that exhibits diverse behavior has a distinct lifetime on various surfaces. Coronavirus barely lives for four hours on copper surfaces [2], but is more stable on plastic and steel (up to 3 days) than spongy materials like cotton, leather, or cardboard [24 h]. Therefore, planners need to reconsider how used materials are chosen, how material specifications are considered, and how surfaces are handled. A prior investigation by Nightingale [20] discovered that the building industry's use of plaster, which contains innumerable microscopic spaces, was thought to be the breeding ground and propagation pathway for pathogenic elements. Our study suggests the following in light of the aforementioned findings:

- All surfaces should be [hygienic materials) clean and smooth, whether they are made of glass, PVC, or another material that satisfies the specifications or are painted with antibacterial paints.
- All of the furniture in the patient area should be easily washable.
- Specify materials with copper plating or infusion for regularly touched areas like bed rails and stair rails.
- Plan sink placement and design to facilitate cleaning and stop waste from spilling into delicate care areas.
- Smooth, high-solidity plaster with a de-coagulant mixture in concrete screed. Use POP screed to smooth down the wall surface after cement plastering and reduce tiny gaps. You may also utilise covering materials like unique paints, but you should avoid utilising textured paints that include fine sand.

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• Hospital's entrance doors, To improve automatic opening and closing, sensors should be placed into curtains in public areas with significant circulation. By significantly reducing contact with the doorknob, this will stop transmission.
• It is advisable to limit the number of entry into public areas in order to effectively monitor adherence to CDC regulations.
• Sinks with motion sensors to further reduce the likelihood of transmission. There shouldn't be as many flat surfaces for particles to rest on in controls and equipment, and there shouldn't be as many nooks and crannies for dirt to collect.
• Lessening the presence of ledges and other horizontal surfaces can help stop the transmission of disease.

4- 4 Design to enhance ventilation

Ventilation is one of the most important parameters that may participate in infection. Air movement within a space is generally referred to as ventilation. In order to soothe nosocomial and other epidemic illnesses, ventilation is essential. Recent studies have demonstrated that an appropriate ventilation rate can significantly reduce the risk of airborne diseases spreading between healthcare facilities and public areas [30, 14].

An optimal ventilation rate can dramatically lower the danger of airborne infections spreading between healthcare facilities and public spaces, according to recent research [30, 14].

The carbon dioxide dick-gas technique was advocated by Escombe, Eduardo, Victor, Manuel, and David [8] in their study to dissect the pre-revision and post-revision scripts of the room. The objective was to evaluate how the waiting area and consultation room's risk of TB transmission had altered. The outcome showed an average of 72 drops in the estimated TB transmission threat for cases and healthcare personnel [interquartile range: 51–82]. A good ventilation system may be the key to preventing the spread of epidemic diseases like COVID-19 in hospitals, schools, businesses and other locations. All areas that deal with infection sources are given negative pressure, including labs, isolated rooms inside the ER, ICU, NICU, and CCU. The rooms or corridors next to them are under negative pressure. Under the immediate vicinity, there is a pressure of 5 to 30 pascal. One of the most serious cases of AII that could spread illness to hospitals requires additional negative pressure, total exhaust, anti-room, and inside toilets. To prevent particles from spreading to others through open space, the expelled air should pass through a HEPA filter. . On the other hand, the operating room zone, standard ICU, NICU, and CCU should have positive pressure, incoming air should pass through a HEPA filter, and the temperature should range from 16 to 23 Co. One of the most important areas for applying positive pressure is the person protective environment (PPE) [20]. The study therefore recommends the following design steps.

Healthcare facilities must have acceptable cross ventilation.

• Regulation of the quantity and quality of air entering or leaving all medical facilities where patients receive care.
• Maintain differing air pressures between adjacent regions as negative or positive.
• Creating laminar airflow patterns inside operating rooms for certain clinical procedures.
• Using total exhaust or a large air volume to dilute infectious particles
• Open ends should be present in all corridors to ensure proper ventilation.

Enable the hospital building's natural ventilation by using the court design to produce an interlaced ventilation channel, employing the court area as an ecological cloverleaf space and conducting the overall building structure design on subcaste/open space. The design strategy (open-ended corridor and courtyard) boosts ventilation rate (ACH- air change per hour, which can range from 2-24 ACH based on) hence greatly lowering the risk of infection. All patients and employees should be encouraged to breathe fresh air.

4-5 Redesign to adaptations

Providing a location that is well-organized and big enough to handle tasks linked to drugs. The layout shouldn't be rigid. However, it must be adaptable enough to juggle shifting healthcare needs and adhere to modern regulations from healthcare outfit producers, providers, and controllers. Given that hospitals are unable to automatically keep their windows open in bad weather, It is crucial to realise that just because doors and windows are present does not mean that they will always be utilised to allow for air circulation [2, 13). The new COVID-19 outbreak is one example of a new difficulty that should be easily accommodated by an adaptive architecture.

It is essential to assess the preventative measures used during the pre-antibiotic era as a result of the emergence of the new coronavirus, increased bacterial resistance and absence of a vaccination against current outbreak [11]. It is crucial now more than ever since bioterrorism may represent a new threat to public health indoors [26, 27]. Pathogen Continuity is also favored by the contemporary architectural technique of creating hospitals or healthcare facilities that prioritise comfort and beauty [22].

5. THE APPLICABLE STUDY

This strategy has been applied in dealing with some hospitals to suit the conditions and requirements of pandemics, through several dimensions. The first one is the design development of the hospital building to separate the movement paths, the second dimension includes dealing with ventilation, the third dimension is lighting, and the fourth dimension is interior finishes and their resistance to infection.

5-1 Example-1

Figure 5 shows the ground floor of U-shape hospital consisted of basement, ground, and two floors. The ground floor has main entrance in the middle of the building, the right wing is the emergency together with operating theater while the left wing is the outpatient department, pharmacy, and management.

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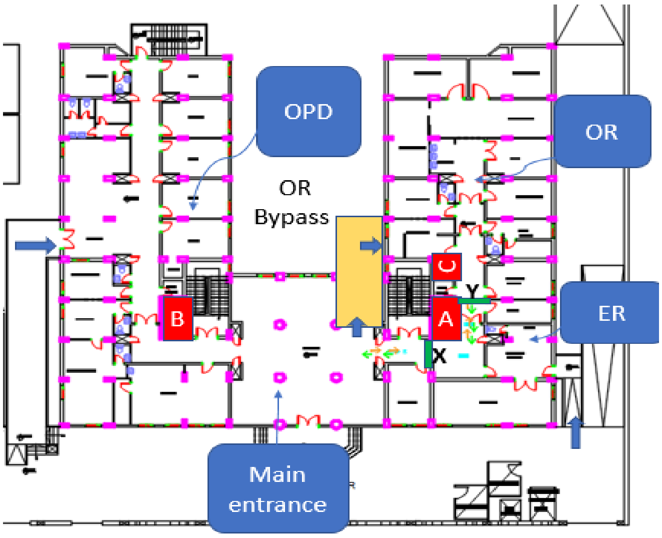

Fig. 4: Social distance [researchers]

The first floor is ICU on the right section while the left zone is Cath-lab and CCU. The second floor is inpatient wards and NICU. Basement contains sterilization, laundry, morgue, and general stores. The hospital has three entrances in ground floor (main entrance, ER, OPD) and two for basement.

At Normal Situation.

- Patients come to emergency department to be checked & distributed to OR (operating rooms) in the same floor or to ICU / inpatient in the typical floors via elevator A in right zone. Patients from wards come to operating rooms by using the same elevator (A).

Problem at Covid-19

- Patients come to emergency and be converted into ICU will use elevator A which cross Patients that use the same elevator to enter OR from other departments and / or sections.

Solution

- To have an external part (orange zone (new designed area)) to bypass the crossed area and allow patients to use elevator B on the left section passing through this area to reach for OR.
- Close doors (X, Y) in the same floor to let patients move from ER directly to first floor via elevator A together with closing door X in first floor in the same place.
- Close elevator door on the second floor
- In this scenario, we have isolated area for covid-19 separated from normal area.
- A check point has been constructed outside the hospital to triage normal patients to go through outpatient department or covid-19 patients to enter from ER department (triage).
- Staff has two rooms: one for wearing special uniform for dealing with patients and one for take off this uniform through exit (movement separation).
- The ventilation has been converted into negative pressure inside ER. Also at ICU the ventilation has been converted into negative instead of positive pressure (ventilation).
- All finishing materials have been used anti-bacterial materials.

5-2 Example-2

In this example, the hospital consists of two basements, lower and upper ground in addition to two typical floors. The lower ground having OPD, Radiology, Lab, Pharmacy, and endoscopy while upper ground as indicated in figure-6 contains main entrance, ER department, septic ORs, and zone for in-patient. The first floor contains inpatient rooms (wards), and the second floor contains major operating rooms, ICU having positive and negative rooms together with part for inpatients.

Fig. 5: Social distance [researchers]

At Normal Situation.

- Patients come to emergency department to be checked & distributed to OR (operating rooms) or ICU in the second floor or inpatient in the typical floors via two adjacent elevators. {atients from wards come to operating rooms by using the same elevators.

Problem at Covid-19

- Patients come to emergency and be converted into ICU will use elevators which can be used from other patients (normal ones).

Solution

Separated part should be created and not cross with normal patients. So A, B, and C doors have been closed together with closing elevators in this floor. The part behind the main reception has been separated to hospital and will be converted into isolated area and all rooms have converted to the isolated ICU.

- To have separated section to not cross with normal patient and allow patients to go directly to this section through ER entrance
- Normal patient will go to OPD and special ER in lower ground from OPD entrance.
- Close doors (A, B, C) in the same floor to let patients move from ER directly to isolated area.
- Close elevator doors on the upper ground floor to prevent using of these elevators for two types of patients (normal and isolated).
- Use septic ORs for patients in case of need operations.
- In this scenario, we have isolated area for covid-19 separated from normal area.
- A check point has been constructed outside the hospital to triage normal patients to go through outpatient department or covid-19 patients to enter from ER department (triage).
- Staff has two rooms: one for wearing special uniform for dealing with patients and one for takeoff this uniform through exit (movement separation).
- The ventilation has been converted into negative pressure inside ER. The rooms (ward zone have fans to get negative pressure that the split AC used in this area.
- All finishing materials have been used anti-bacterial materials.

6. Discussion

Based on the discussed strategies to deal with pandemics, and through the introduced dimensions, design development of the hospital building to separate the movement paths, and ventilation modification, lighting, and furniture are the main parameters.

Two hospitals have been separated into two zones. One for normal part and one for isolated area.

7. Conclusion

Regarding the deficit of effective and contextualized design strategies to support infection control, the flexible design can be adapted to fit the requirements and to get separated area to deal with covid-19 patients. The two illustrated examples have used special materials in finishing and some design modifications to have the separation. The most critical point was Air condition in the separated areas to be converted into negative pressure.

Design tactics can be quite helpful for preventing and controlling infections (IPC). It has become necessary to use a multidisciplinary approach in order to combat the ongoing (Covid-19) outbreak. Additionally, it suggests providing training in public health to engineers and architects who are directly involved in designing or building health-care facilities. This is due to the possibility that buildings with increased or decreased access to natural light could significantly impact the microbial populations in interior dust.

Architects must step up and do their share to stop the coronavirus from spreading. Early on in the design, specification-writing and construction processes, this can be accomplished. Daylight should be used as part of the hospital's lighting plan since it not only prevents the spread of diseases and viruses, but also because it eliminates the need for artificial lighting, which will help save energy and the environment. The adaptable design makes it simple to meet new requirements.

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