OVERVIEW OF MICROORGANISM CROSS-CONTAMINATION PREVENTION VIA DOOR HANDLES AT HEALTH CARE CLINIC UTILISING 'TOUCH-LESS CONCEPT DOOR

Nadiah Alwani Mohd Nesfu
Norhidayah Md Ulang
Faizal Baharum

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Nadiah Alwani Mohd Nesfu,
School of Housing, Building and Planning, Universiti Sains Malaysia 11800, Penang, Malaysia
Email: nadiahalwani@gmail.com,
Norhidayah Md Ulang, School of Housing, Building and Planning, Universiti Sains Malaysia 11800, Penang, Malaysia
norhidayah.mu@usm.my*,
Faizal Baharum, School of Housing, Building and Planning, Universiti Sains Malaysia 11800, Penang, Malaysia
faizalbaharum@usm.my

ABSTRACT

A health care facility is a place where people come to seek treatment when they are ill. Despite essential, the facility also well-known for its un-hygienic environment and potentially leads to health hazards such as healthcare-associated infections (HCAI). HCAI are infections acquired by patients while getting treatment at hospitals or ambulatory surgery centres caused by bacteria, fungi, viruses, or other, less frequent pathogens in the health care facility). Prolonged hospital admissions, increased antibiotic resistance in microorganisms, a substantial rise in the financial load on health care systems, higher treatment expenses for patients and their families, and an increase in mortality are all HCAI's consequences (ICU, One of the frequent touches surfaces in a health care facility are door handles. Hence, the research is to study the effectiveness of the 'Touch-less concept door,' a.k.a TCD; it intends to reduce the microorganism surface contamination and the infection risk. TCD is a simple, cost-effective, and lowtechnology concept approach and does not require tedious maintenance. This door fabricates by the appointed door fabricator, and mounts at CE Room 2, the busiest room in the OPD of Sungai Dua Healthcare Clinic. The efficacy of TCD is determined by comparing microorganism loads at the existing doors in CE Room 1 and CE Room 3. Before TCD installation, five days of surface sampling activity was conduct to determine the existing bacterial condition. The data reveals an average CFU/mL bacteria load of 1.33, 0.63, and 0.35 for CE Room 2, CE Room 3, and CE Room 1, respectively despite the doorknobs are sanitised three times throughout the facility's operation hour. Meanwhile, the after TCD installation data reveals an average CFU/mL of 0.183 and 0.626 for CE Room 1, and CE Room 3. However, the average CFU/mL of bacteria load for CE Room 2 is 0.038 CFU/mL (point A: copper push plate) and 0.098 CFU/mL (point B: samples swabbed within 250mm below the push plate placement). This amount lessens 90 % compared to the CE

Room 2 average number of bacteria detected previously. The finding indicated that the introduction of spontaneously antimicrobial surfaces, i.e., copper push plate reduced the microbial cross-contamination on the TCD adding with the push door concept. In summary, the TCD could be an alternative engineering solution to reduce or eliminating microorganism cross-contamination on its animate surface compared to the conventional door. Thus, by mounting the TCD in the health care setting, the HIA potentially be reduced along with the AMR.

Keyword: Healthcare, Cross-Contamination, Microorganism, Prevention, Touch-less Door

BACKGROUND

A health care facility is a place where people come to seek treatment when they are ill. This facility is commonly known for its unhygienic environment with the presence of microorganisms and usually avoided by people especially during the crisis due to the high potential risk of cross-contamination. Malaysia Health care provider is divided into two categories that are the governmental base (Ministry of Health: MOH) and non-governmental base (private sector). As a governmental agency, MOH also acts as a regulatory body to monitor and ensure the best health care services are given to the public. Health care facilities under MOH supervision consist of 145 hospitals, 2838 health care clinics (including Village and Mother & Child: MCH Clinics), 196 Community Clinics, and 688 dental clinics (KKM,2020). The agency categorized its facilities into several types and functions with the main purpose of providing the best health care services possible with an acceptable waiting hour.

Minimization of patient load and waiting hours could help in reducing the health risk of patient and Health Care Worker (HCW) as previous research shows only 66.1% of HCWs had good infection prevention practices HCW is considered as a 'backbone' in the health care facility. The non-compliance of HCWs following standard operation procedure (SOP) of infection prevention practices could put other health care facility occupants at risk because throughout of operating hour, the facility will be occupied by patients, visitors, suppliers, and Facility & Maintenance[1]

Team.

Due to Covid-19 Pandemic, an Online Appointment Service for Health Care Clinics was introduce in April 2020 to shorten the patient waiting period (KKM, 2020). Although the service only available for severe or mild cases this service seems could manage to control patient load coming into the health care premise hence the risk to patients and HWCs can be reduced The introduction of this service as well shows MOH had an awareness of the risk of infection that could happen inside the health care facilities. By referring to Table 1, it can conclude that Health Care Clinics could be considered as the first layer of patients diagnosed.

Despite the HWCs factor, the health care facility environment and hygiene also play an important role in contributing to the risk of infection. As the operations of health care facility, door handles seem to be a most frequent touched surface by health care facility occupant due to its function that required mechanism force to open a door. Odigie and co-worker (2017) reported that E-Coli and Bacillus Subtilis were determined as the most predominant bacterial present at a door handle.

Table 1

: Type of Health Care Facility under MOH Supervision (KKM website).

Health Care Facility	Function	Services Available
Hospital	Reference center after patient seeks for treatment from clinics. The patient will be advice either for an appointment with a specialist or ward.	● Emergency Wards ● Maternity Wards. ● Patient Wards. ● Specialist Clinics. ● Operation Theater.
Health Care Clinics	The patient is diagnosed and prescribed by a Medical Practitioner and a referral letter to undergo a further checkup will be issued if needed.	● Out-Patient Treatment. ● X-Ray. ● Laboratory ● Pharmacy
Community Clinics	The patient is diagnosed and prescribed by Medical Assistance. This facility only caters to severe/mild cases. A referral letter to Health Care Clinic / Hospital will be issued if needed.	● Out-Patient Treatment. ● Pharmacy
Mother and Child Health Care Clinics (MCH)	Health care service provided for a pregnant woman and children where the patient will be diagnosed by a Medical Practitioner / Family Medicine Specialist.	● Mother and Child Checkup. ● Pharmacy.
Village Clinics	Provide health care checkups for mothers and children by Medical Assistance Staff Nurse / Community Nurse.	● Mother and Child Checkup. ● Pharmacy.
Dental Clinics	The patient is diagnosed and prescribed by a Medical Practitioner (Dental Officer) and a referral letter to undergo a further checkup will be issued if needed.	● Oral Checkup and treatment.

The presence of microorganisms at the door handle can generate a significant potential of cross-contamination to the health care facility occupant Different door

opening mechanism provides different contamination pattern and this is closely related to a suitable door design. Figure 1.1 shows the transmission potential relation towards door handle types and the user interaction with several doors in the clinic (Wojgani, 2012 & Yatmo el. al., 2018).

Figure 1.1: Transmission Potential Relation Towards Door Handle Types and the User Interaction with several Doors in Clinic.

The prevention taken to tackle this current situation is by doing a routine sanitization procedure (cleansing procedure) held by a concession company appointed. The concession company will conduct cleansing activities according to the cleansing schedule agreed However, the output of this process highly dependable on the personnel conducting the cleansing activity. Therefore, HCWs and patients visiting the facility are still at risk for a microorganism cross-contamination issue.

The installation of an automatic door system in all CE Rooms is predicted as the best solution to avoid cross-contamination since no area on the door is going to be touch. However, the installation price of an automatic door system is predicted high compared to a manual door. Furthermore, an automatic door is consists of several components to functionalize it. The components required in an automatic door system are; *Activation Sensor*, *Door Operato*r, *Safety Sensor*, *Power Button*, *Maintenance Switch*, and the door panel itself, which require high cost for maintenance. A Plan Preventive Maintenance (PPM) activity need to be conducted to ensure the system installed can be long lasting (KKM, 2015). Hence, this can affect the operational cost of the facility and not economics for a government-oriented facility.

THE HEALTH SERVICES IN MALAYSIA

Malaysia has made considerable strides in providing its people with access to healthcare and has been more competitive than many other nations that are best recognized as universal health coverage models (Rannan-Eliya et al., 2016). Ministry of Health (MOH) controlled healthcare in Malaysia. An effective and widespread two-tier health care system was implemented in Malaysia. It consisting of a government universal healthcare system that co-exists with a private healthcare system (Quek, 2009). Figure 2.1 depicted an overview of Malaysia's health care system.

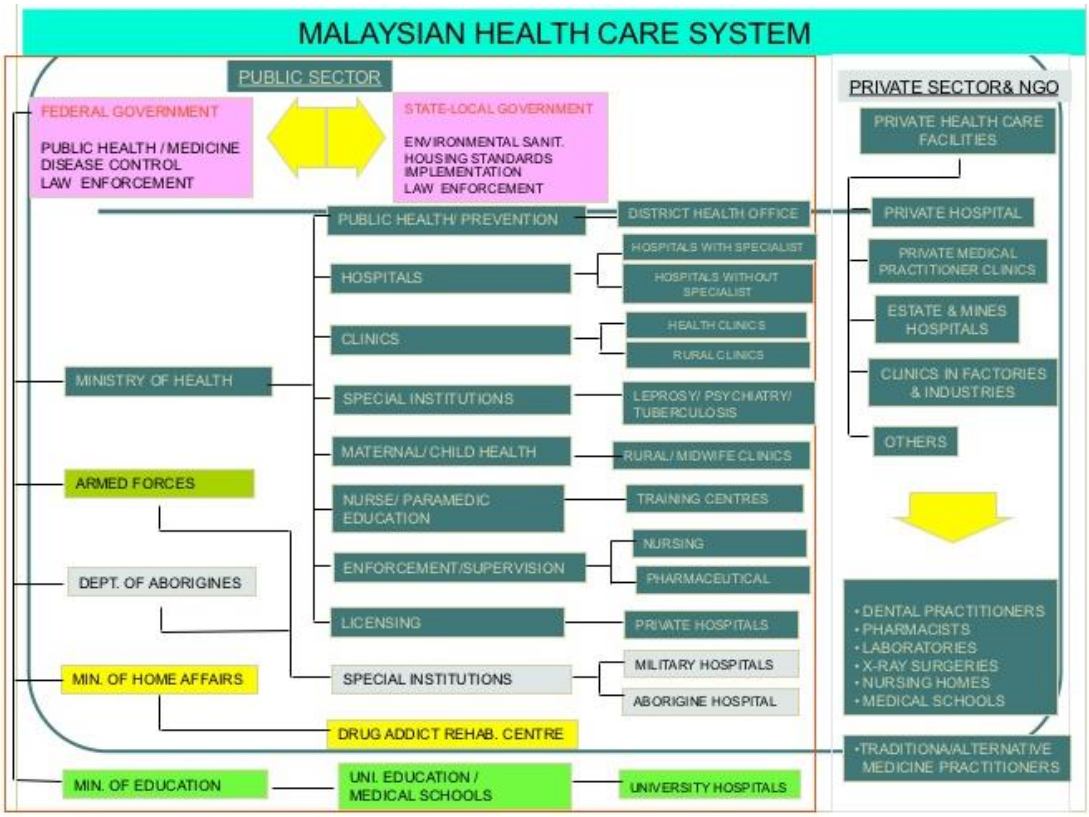


Figure 2.1: The overview of Malaysia's health care system (Ahmad, 2010).

The private health care system predominantly caters to the urban population and those who afford to pay, while the government health care system offers access to all (including civil servants) with a minimum payment mostly subsidized by the government (Suleiman, 2002). As the government medical system provides a wide variety of facilities and services at an affordable price, it is the preference for the majority of Malaysians to pursue their health care and treatment. Hence, this study focus only on government healthcare facilities.

The Out-Patient Unit of Health Care Clinic.

The Potentials Risk within Health Care Facility

Health care facilities are a place where people seek treatment. As for that different kinds of people with a different kind of illness visit the health care facilities. Aware of the situation, the health care facilities can be classified as a place where healthy people at risk of being infected with other diseases. The potential of cross-contamination is high especially during a health crisis.

The severity and adverse complications of infections associated with health care (HAIs) due to cross-contamination infection have been well acknowledged in the literature for the last few decades. HAIs are considered an undesirable result. It is viewed as an indicator of health care quality, adverse outcomes, and an issue of patient safety that can be preventable

Four major types of infectious agents are identified, namely: bacteria, viruses, fungi, and protozoa (Debta et al., 2020). Besides, the prions have recently been recognized as a new class of infectious agents. However, only a few harmful microbes, for example, less than 1 % of bacteria, can invade our body, it can cause infectious diseases such as flu and measles (NIH, 2007). The infection diseases caused by microbes are responsible for more deaths globally than any other single caused, per

the health care experts. The prolonged microbial infection and exposure will lead to an establishment of antimicrobial resistance (AMR) (Prestinaci et al., 2015).

The AMR occurs when microbial such as bacteria and fungi can destroy drugs that are meant to kill them. In layman's terms, AMR can be defined as bacteria that cause infections that are often already immune to prescription antibiotics. During the treatment of an infection, bacteria might even become resistant. Immune bacteria do not respond to antibiotics and continue to cause infection [2, 3](JHM, 2021). The AMR phenomenon is something that needs to be taken seriously especially on the antibiotic resistance in bacteria. The bacterium caused widespread or multiple infections that have established resistance over many decades to most new antibiotics introduced on the market[4, 5] (Lee Ventola, 2015).

Around 2.8 million antibiotic-resistant infections happen per year in the United State of America, according to the study. More than 35,000 individuals die as a result of AMR. In 2017, 223,900 cases of *Clostridioides difficile* (*C. difficile*) were reported with at least 12,800 people died. *C. difficile* is a type of bacteria that infected everyone and will reoccur even after you've finished taking your antibiotic. It caused diarrhea and colitis (inflammation of the colon) which are life-threatening[6, 7]

In 2020, WHO reported an increase of AMR activity of 4.1 % to 79.4 % for *Klebsiella pneumoniae (K. pneumonia)* towards a last-resort treatment medicine (the carbapenem antibiotic). The AMR has spread to all regions of the world and cause life-threatening pneumonia. Initially, *K. pneumoniae* is just a common intestinal bacterium. It was reported that *K. pneumoniae* is a common example of HAIs in new-borns and intensive care unit patients, which caused influenza, bloodstream infections, and infections (WHO, 2020).

Apart from that, the AMR activity towards ciprofloxacin and fluoroquinolone that treat the infection of *Escherichia coli* infection at the urinary tract have been observed worldwide. The rate of resistance activity varied from 8.4 % to 92.9 % with some countries in the world reported the treatment ineffectiveness towards more than half of the patients. Thus, an alternative antibiotic, colistin is used as the last resort treatment of the life-threatening infections caused by carbapenem-resistant *Enterobacteriaceae* (such as; *E.coli, Klebsiella*, etc). However, in several countries and regions, bacteria resistant to colistin have also been detected. If the AMR activity persists, it might be no effective antibiotic treatment available to treat such disease at the moment [2, 8]

According to the National Surveillance of Antibiotic Resistance (NSAR) program in Malaysian hospitals, there is an increasing number of cases in *Acinetobacter baumanii* resistant to meropenem (49 % in 2008 to 61% in 2016). In Malaysia's hospitals, the emergence of beta-lactamase producers (ESBL) among *Enterobacteriaceae* has become a major concern. Besides, the resistance of *Streptococcus pneumoniae* is now 31 % to erythromycin; one of the most common antibiotics used in the treatment of infections of the respiratory tract in primary care. The effectiveness of antibiotics in the world is decaying, and if this continues without any action, infectious diseases that the country has managed to curb in the past may come back[9, 10]

In the midst of fighting the COVID-19 pandemic, the AMR might become a thread. Data from five countries showed that 6.9 % of the COVID-19 patients who required intensive critical care were identified to have viral respiratory infections combined with bacterial co-pathogens (3.5 % diagnosed concurrently and 14.3 % post-COVID-19). These infections usually lead to morbidity and mortality. The AMR might worsen in the current situation as COVID-19 treatment involved the overuse of antibiotics[11] (Langford et al., 2020; Strathdee et al., 2020).

The Type Microbial Cross-contamination

Health care facilities environment, objects/instruments, and HCW are likely to get colonized with a diverse group of microbial agents. The transmission of microbial in a health care setting can occur, (1) from the patient to the HCW, (2) from the HCW to the patient, (3) from one patient to the other, (4) from the health care office to the community, (4) from patient to a surface, and (5) from a surface to one patient, visitor, or HCW (Umar et al., 2015).

The most important and frequent mode of transmission in the health care setting is thru contact transmission. Contact transmission can be defined as an infection that is transmitted through direct or indirect contact with an infected person (Medical Dictionary, 2012). Figure 2.2 depicted the transmission modes for the spread of infectious diseases.

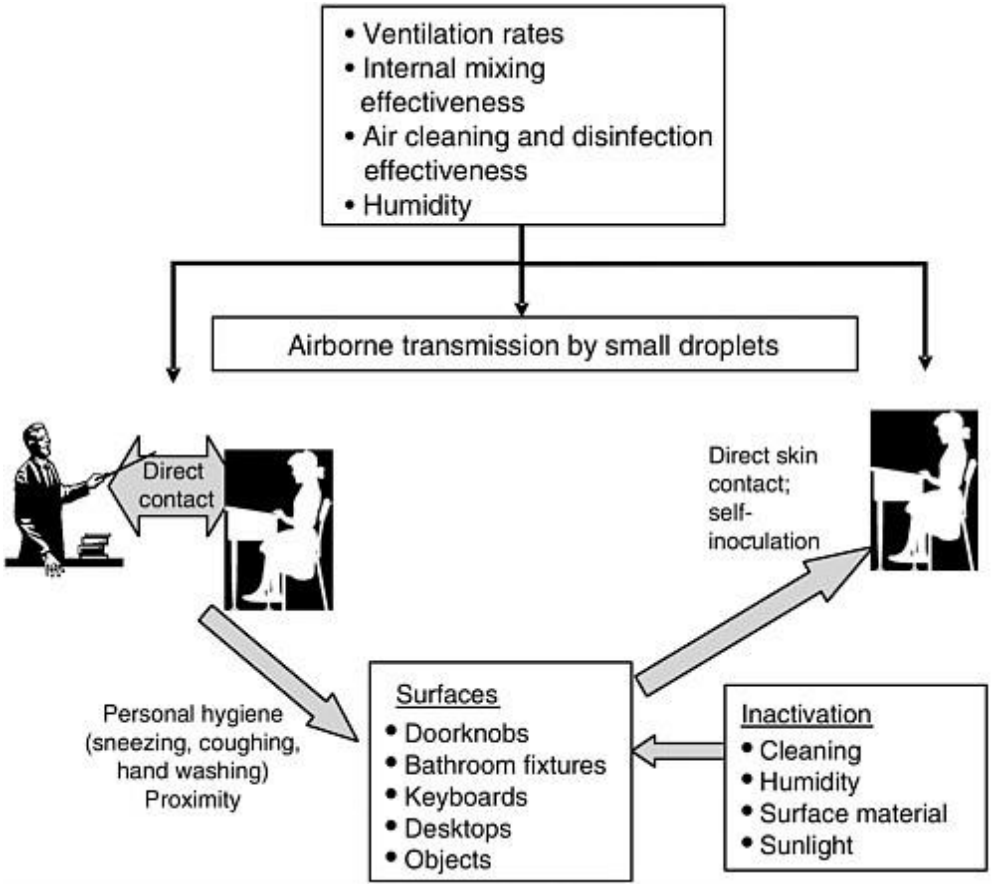


Figure 2.3: Transmission modes for the spread of infectious diseases (NRC, 2007).

The skin of HCW can be contaminated by the patient's organisms and transiently transmitted to a susceptible patient who develops an infection from that organism indicating an indirect contact transmission mechanism from one patient to another (Kutter et al., 2018).

Another circumstance of indirect contact transmission is the surface of health care facilities; such as a chair, tabletop, wall, and doorknob that was touched by the infected patient, which subsequently in contact by other health care worker and carried to another patient. The organisms are likely to be spread to health staff, patients, and visitors from objects of frequent contact in hospitals. Figure 2.4 describes the chain of infection.

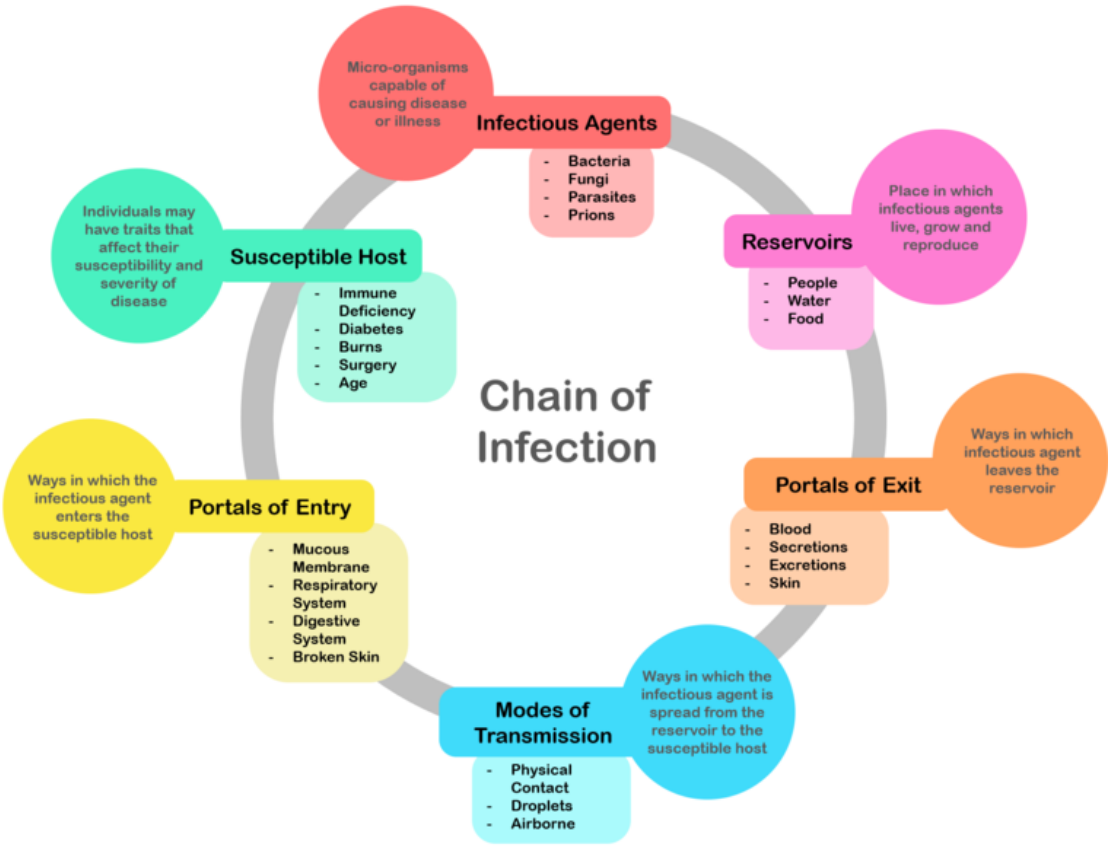


Figure 2.4: The chain of infection (Physiopedia, 2020)

As doorknob is a highly accessible surface in health facilities, several studies have been conducted to identify the type of microbial presence on the doorknob. In health care facilities, Gram-positive and Gram-negative bacteria have been reported to live up to months on dry, inanimate surfaces (Kramer et al., 2006). Nosocomial bacterial pathogens such as *Staphylococcus aureus* (MRSA) methicillin-resistant, *Enterococci* (VRE) vancomycin-resistant, *Pseudomonas spp*., *Acinetobacter spp* are more stable in the setting of the health care facilities. On the other hand, well-known pathogens such as; *Streptococcus pneumoniae*, *Streptococcus pyogenes*, and *Haemophilus influenza*, after excretion from patients, are delicate, fastidious, and rapidly inactivated, thus have does not survive on inanimate surfaces.

Bhatta and co-workers studied the bacterial contamination of frequently touched objects in a tertiary care hospital in Pokhara, Nepal. The study showed that 219 bacterial isolates were recovered from 181 out of 323 samples collected from biometric attendance devices, elevator buttons, and door handle. About 44/219 were *Staphylococcus aureus (S. aureus)* with 12/44 displayed multidrug-resistant characteristics. The isolated *S. aureus can be divided into two categories which are*, 16/44 were methicillin-resistant *S. aureus* (MRSA) and 28/44 were methicillin-sensitive *S. aureus* (MSSA) (Bhatta et al., 2018).

In a study of eight typical surfaces often engaged by the patients, relative patients, and HCW every day are made of various materials (aluminum, ceramic, plastic, and wood) were sampled (bed lockers, bed rails, medical tables, door handles radiant warmers, incubators, washing sinks, and trolleys). The results were according to the type of material with the pattern of contamination shows a statistical significance of P-value=0.0044. The prevalent contamination on aluminum surfaces, ceramic surfaces,

and wooden surfaces sampled were *S. aureus*, *Klebsiella pneumoniae*, and *A. baumannii* respectively (Saka et al., 2017).

In the case of coronavirus or other respiratory viruses, the transmission happens due to the inhalation of a respiratory droplet and infectious aerosols as well as direct or indirect contact with a respiratory droplet via a contaminated surface. The study conducted by Moore and co-workers detected almost no surface contamination in intensive care units (ICUs) but identified around 27 % surfaces contaminated with SARS-CoV-2 RNA within general wards, including patients bed and door handle (Moore et al., 2020). In a similar study at Zhongnan Medical Center in Wuhan, during the COVID-19 outbreak between 7–27 February 2020. About 626 surface swabs were carried out and the objects such as; desktop/keyboard (16.8%), self-service printers (20.0%), and doorknob (16.0%) were found to be the most contaminated objects (Ye et al., 2020).

As the doorknob is frequently used by a various range of people at the health care facilities and the literature review evidence showed that the pathogens permanently contaminate the surfaces (especially doorknob), making the health care facilities setting become a source of highly transmissible microbial. Hence, this study will focus on the microbial cross-contamination on the doorknob of Sungai Dua and Gelugor Health Care Clinic, Penang.

The Microbial Cross-contamination Prevention Practice

Concerning the Covid-19 pandemic, the online appointment service used by Health Care Clinics since April 2020 has been launched by MOH to shorten the patient waiting time (MOH, 2020). This showed that MOH had an awareness of the risk of infection that could happen inside the health care facilities. Evidence showed that crowded health facilities with sick people in close proximity to one another increased the tendency that patients passed their microorganisms (caused by sickness) to those nearby (Dancer, 2008). Hence, minimization of patient load and waiting hours could help in reducing the health risk of patients and HCW.

Apart from that, human behavior played a crucial part in breaking the infection chain. The infection agents could be transmitted from one individual to another, by the spread of droplets or large particles via coughing, sneezing, or wheezing, or self-inoculation that came from contact with contaminated surfaces. Practicing good behavior such as wearing a mask during the pandemic, and regularly washing hands or sanitized will reduce the risk of infection (Bazaid et al., 2020).

The human behavior practices that can help in breaking the infection chain are as follow (NHMRC, 2012):

- Practice hand hygiene. This could be with soap and water or using a hand rub based on alcohol.
- Ensure the hands are dry after washing the hands with soap and water. Up to 1000 times more bacteria are transmittable via damp hands compared to dry hands.
- The use of alcohol-based hand rubs are the efficient way to perfom hand hygine.
- Change you habit, by coughing or sneezing into your elbow to lessen the spread of germs.
- The tissue need to be disposed instantly follow by performing hand hygiene when you cover your mouth and nose with tissue when coughing or sneezing.
- Routine cleaning of all surfaces with detergent and alcohol-based rub to remove the contamination from surfaces.

- To provide a protective shield against germs, gloves are also used in education and care facilities.

Since infection prevention in all health care facilities is taken seriously in the current pandemic situation, There has been ongoing disagreement about the possibility of infection among patients from contaminated surfaces of health care facilities. The cleaning process itself is subject to controversy around the world over speeds, methods, facilities, benchmarks, monitoring, and surface cleanliness standards (Dancer, 2009). Additional problems occur with cleaners themselves, as several of them undergo inadequate preparation for what they are expected to do, and sometimes showed insufficient professionalism in carrying their duty (Dancer, 2011).

Apart from that, the imperfect disinfection of the environment and surrounding healthcare facilities can increase the risk of infectious diseases and prove to be a health hazard (Doll et. al, 2018; HICPAC, 2003). A recent study demonstrated that it is possible to reduce the presence of microbes on the doorknob provided they are regularly cleaned. The result showed that the cleaning process is important, however, it is not practical. The statement is supported with a finding of Wojgani and co-workers as more than 20% microbial were detected on the doorknob even it is being cleaned regularly (Wojgani et al., 2012)[4, 7, 12].

Although cleaning does not show a realistic outcome, it is important to look for other potentially creative ways to minimize microbial contamination on the surface of the health care facility. Due to a series of publications linking surface pollution with an increased risk of HAIs, the role of the environment in harboring and transmitting multidrug-resistant species has become clearer. The prevalence of antimicrobial resistance is also growing, which contributes to higher HAIs-related morbidity and mortality. Hence, the purpose of this study is to minimize the risk of microbial cross-contamination and spread through the doorknob using an engineering solution.

The Engineering Solutions Method

It is not easy to refine the health care facility's design to restrict microbial spread. Several variables, such as the age of the building, space constraints, and use should be considered before the decision is made, according to the engineering solution approach. Figure 3.1 depicted the flow of the engineering solution design process.

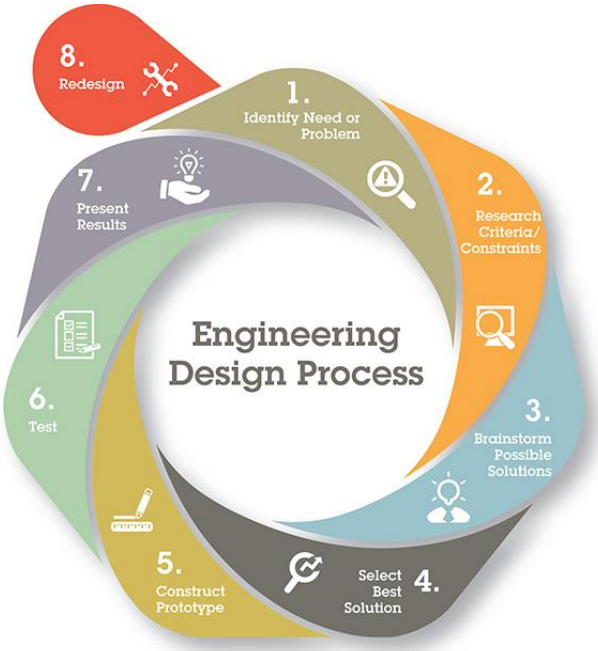


Figure 3.1: The engineering solution design process flow (Jenkins, 2015).

Out of other variables, door design is identified as the most easily manipulating variable of health care facilities. Besides, most of the cross-contamination and spread of microbial was through the doorknob. Thus, it is important to consider it to limit the indirect contact transmission via doorknob by designing a touchless concept door. Hence, this study will focus on the effect of door design towards microbial cross-contamination at Sungai Dua and Gelugor Health Care Clinic, Penang.

The Door Design: The Pro and Con

The door at the health care facilities requires the highest hygiene and cleanliness requirements. Various factors such as quality, cost, and speed should be considered. The door, specifically the doorknob, are the objects frequently used by HCW and patients in health care facilities. As a result, the doorknob harbor potential pathogens and might act as the main source of infectious agents in health care facilities. Automatic door usage may be a way to minimize the spread of microorganisms acquired from door handles, however, in most health care clinics, it is not feasible.

Cleaning does not seem like the practical solution in combating infection due to contact transmission. A single touch of a contaminated hand was sufficient in some situations to result in a confluent plate (Wojgani et al., 2012)[13-15]. Thus, the use of different door design and mechanism or spontaneous antimicrobial surfaces are a potentially revolutionary approach to reducing surface microbial contamination. There are several kinds of door handle; some require, depending on the design, a mechanism to rotate, turn, pull, or push.

A pilot project was performed by Babiarz and colleagues to determine the feasibility of using a sanitizer-dispensing door handle. Each moment the door handle is used to open the door, the user's hand is dispensed with waterless hand sanitizer (Figure 3.2). It has been shown that improving rates of compliance with hand hygiene (HHC) reduces nosocomial disease. The HHC was compared between the regular wall-mounted dispenser and the door handle with the sanitizer-dispensing (Babiarz et al, 2014). However, due to the low baseline compliance, the observed marginal improvement in HHC was possibly exaggerated.

Waterless hand sanitizer is nebulized onto a user's hand from the top of the handle

Figure 3.2: The prototype of sanitizer-dispensing door handle (Babiarz et al, 2014).

Muirhead and co-worker designed a novel prototype of antimicrobial door handles. A steel-framed door handle with a vertically aligned handgrip portion encased by a specially prepared surface material was designed and tried (Figure 2.7). The surface material contained a self-transmitting antibacterial fluid to continuously moist the grip of the door handle. Hence, it is self-sanitizing with no power, moving parts, or pressurized containers. During regular duties in a microbiology laboratory, the test device inhibited hand contamination. The antiseptic covered surfaces are presumed to manage bioburden accumulation, with the potential to reduce the risk of further transmission to hands touching the device (Muirhead et al., 2017)[16-18]. However, the long-term effectiveness is still unclear.

Figure 3.3: Steel framed prototype antimicrobial door handles (Muirhead et al., 2017)

Intending to prevent direct contact by hand in order to reduce the spread of microorganisms through health care workers, a novel device to supplement existing door handles was design by Chen and co-workers. A low-cost, readily available supply

and durability material, namely, polylactic acid were used in the development of the novel device (Figure 3.3). The hands of the ten HCW before and after operating the door showed similar aerobic colony counts. Hence, the new door handle extension system mentioned is a viable solution to minimizing cross-contamination with health care facilities surfaces and the spread of diseases in hospital environments (Chen et al., 2020). However, the human behavior factor will lead to mishandling of the door handle and resulting in a microbial cross-contamination issue.

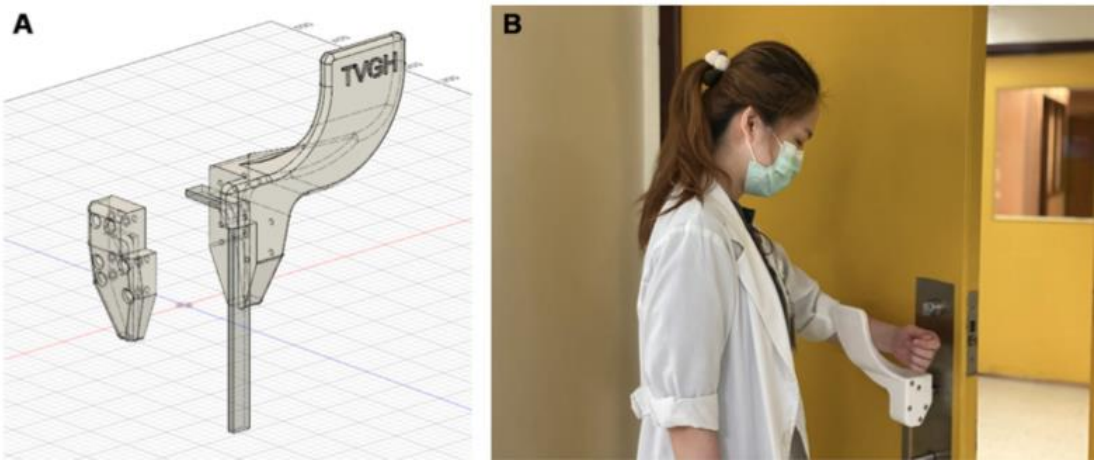
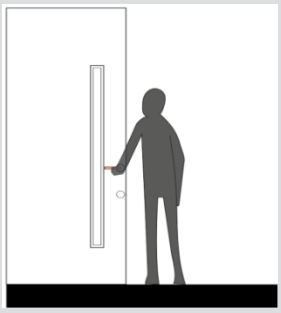
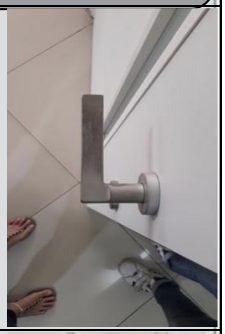
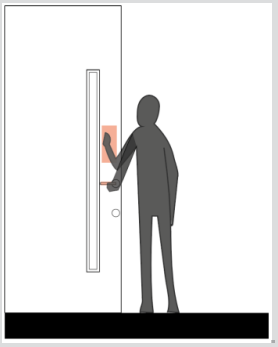
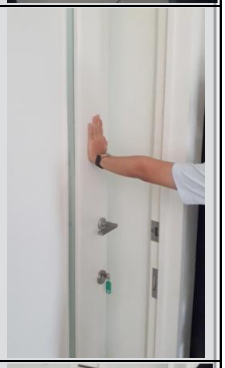
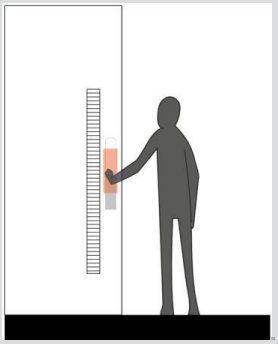
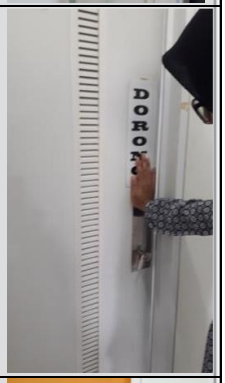
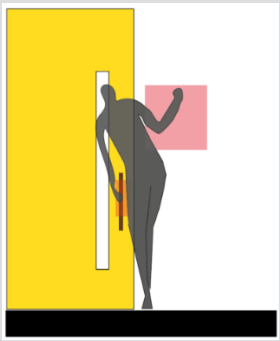


Figure 3.3: (A) The design of this novel device. (B) An image demonstrating how to operate the door by using the door extension device (Chen et al., 2020).

In all types of healthcare facilities, doors are present and are necessary for access from one room to another. The doors operating mechanism required contact between the body of the user and part of the door, especially the hands. Although the design of the door handle can seem trivial and largely overlooked at the design level, it is one of several "trivial" design features that could silently compromise microbial transmission control (Yatmo et al., 2018; Wojgani et al., 2012)[19-21]. The door handles markup the greatest portion of contact with the hands and was exposed to the contamination. Table 2.3 tabulated user interaction with different types of doors in the clinic.

The various types of door design cause different forms of human interaction during the operation process. Variables such as door shape, door handles, and opening direction define the surface of the contaminated area at the door and around the door. Healthcare environment design has a direct effect on the behavior of individuals and the likelihood of microbial transmission. Some designs have a greater potential for microbial contamination in the case of door design due to the behavior of the user's service. In evaluating door design styles for healthcare settings, results from this research may be used for consideration (Yatmo et al., 2018)[9, 10, 22-24].

Table 3.4: User interaction with different types of doors (Yatmo et al., 2018)

No.	Description	Illustration (Possible Contaminated Area Highlighted in Red)	On-Site Images
1	User Interaction with Single Swing Door with Lever Handle		
2	User Interaction with Modified Single Swing Door		
3	User Interaction with Single Swing Door with Metal Plate		
4	User Interaction with Yellow Sliding Door		

Another approach is the use of spontaneously antimicrobial surfaces in tackling the microbial cross-contamination issue. These techniques required an in-depth study to develop 'self-disinfecting' surfaces thru coating medical equipment or painting the

surface with metals such as silver or copper, or the application of polymeric materials with persistent antimicrobial properties.

Silver has been used as an antimicrobial agent for decades. It is antimicrobial properties were vastly appreciated in medical applications where silver nanoparticles coated the implanted instruments for antimicrobial effects. The use of silver for its antimicrobial properties is increasing in numerous fields, including the medical, consumer, agricultural, and industrial sectors. This might lead to a troubling situation where bacteria started to show resistance to silver, one of the few promising options of current antibiotic groups (Sim et al., 2018)[17, 21].

On the other hand, Ellingson and co-workers introduced a layer of antimicrobial surface (AMS), that was applied via electrostatic spray technique. The AMS was a quaternary ammonium polymer coating with the ability to disrupts the cell membranes of microbes, which lead to cell lysis. The AMS coating can limit bacterial survival on surfaces for up to 15 weeks by bonding to the surface, aa a protective antimicrobial barrier has been developed. (Ellingson et al., 2020)[9, 10, 22, 23]. However, optimal methods of implementation and long-term consequences are still unforeseen.

The copper and its alloys, such as; brass and bronze surfaces are antimicrobial. They display a characteristic to kill a broad range of harmful microbes relatively quickly and with a high degree of efficiency, often within two hours or less. In the past ten years, an abundance of peer-reviewed antimicrobial efficacy studies have been performed on the efficacy of copper in destroying *E. Coli* O157:H7, *Staphylococcus aureus* (MRSA) methicillin-resistant, *Staphylococcu*s, *Clostridium difficile*, influenza A virus, adenovirus, and fungi [16, 19, 20]

Salgado and co-worker determined the effect of copper alloy-surfaced placement in an intensive care unit (ICU) with the risk of HAI. The preliminary result showed that the patients cared for in ICU rooms with copper alloy surfaces substantially having a lower rate of HAI incident and/or VRE or MRSA colonization compared to the patients treated in regular rooms[17, 21]). However, to evaluate the clinical impact of copper alloy surfaces in massive patient populations and environments, additional studies are required.

About 50 % of five French long-term health facilities were incorporated with copper alloy handrails and door handles. To study bacterial contamination, Colin and his co-workers collected 1400 samples on copper and control surfaces over three years after the copper alloy handrails and door handles installation. The in vitro activity against methicillin-resistant *S. aureus* (MRSA) was tested.

Additionally, some copper door handles samples were also taken from the different facilities, and *in vitro* analyses were conducted methicillin-resistant *S. aureus* (MRSA). The result showed that the copper door handles and handrails revealed significantly lower contamination levels compared to control surfaces. The copper door handles and handrails showed substantially lower levels of contamination relative to control surfaces. Therefore, the use of surfaces containing copper and its alloy throughout healthcare facilities could be are promising agents in halting the spreading of environmental bacterial contamination (Colin et al., 2018).

Hence, this study will focus on improving the design of the door as well as incorporated the spontaneously antimicrobial surfaces to reduce and eliminate the microbial cross-contamination Health Care Clinic. The relevant findings will be demonstrating a novel strategy for infection control related to microbial cross-contamination via engineering solution.

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