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Ko, Youngho
Associate Research Fellow

Prevention and Control of Healthcare Associated Infections through Architecture
– Focusing on Outpatient Facilities –

Introduction

After the Middle East Respiratory Syndrome (MERS) outbreak swept Korea in 2015, the Korean government and relevant institutes provided various countermeasures to prevent and control the outbreak of this infectious disease. Because the MERS pathogen is transmitted through the air, those countermeasures have focused on enhancing the system performances of Heating, Ventilating, and Air Conditioning (HVAC). The government also asked that healthcare facilities prepare adequate negative pressure units, including improvement of the human resource management and control programs. Those countermeasures were criticized, however, for not considering the peculiar culture of Koreans in using healthcare facilities (e.g., voluntary, sometimes obligatory, visiting his/her family or friends who are sick, and preference for visiting a general hospital rather than a clinic for an initial medical examination).

The infection prevention efforts in Korean healthcare facilities can be regarded as mostly responses to pathogens transmitted by air and are likely to ignore other healthcare associated infections (HAIs) that are more prevalent in Korean society such as a Tuberculosis Bacilli (TB) infection, a Methicillin-Resistant Staphylococcus Aureus (MRSA) infection, or other infections which are mostly transmitted by direct/indirect touch or by exhaled droplets. Last

MERS outbreak in Korea and the responses also revealed issues and problems in Korean healthcare related to facilities, programs, and systems.

This research, examines the physical and architectural healthcare environments in Korea which could influence the prevention and control of healthcare associated infections. This research also reviews Korean laws and systems related to healthcare environments to propose how the Korean government could improve the prevention and control of healthcare associated infections, especially in the physical and architectural settings.

Definitions of Healthcare Associated Infection (HAI)

This study, first of all, reviewed how major relevant institutions have defined healthcare associated infections (HAIs) as seen in Table 1.

Table 1. Definitions of HAI by Major Institutions

Institution	Definition of HAI
World Health Organization (WHO)	"An infection acquired in hospital by a patient who was admitted for a reason other than that infection. An infection occurring in a patient in a hospital or other health care facility in whom the infection was not present or incubating at the time of admission. This includes infections acquired in the hospital but appearing after discharge, and also occupational infections among staff of the facility."[1]
	"Infections acquired during hospital care which are not present or incubating at admission. Infections occurring more than 48 hours after admission are usually considered nosocomial."[2]
Centers for Disease Control and Prevention (CDC)	"Health-care-associated: an outcome, usually an infection, that occurs in any health-care facility as a result of medical care. The term 'health-care-associated' replaces 'nosocomial, the latter term being limited to adverse infectious outcomes occurring only in hospitals."[3]
	"Nosocomial: an occurrence, usually an infection, that is acquired in a hospital as a result of medical care."[4]
Korea CDC	"Nosocomial infectious disease means an infectious disease which occurs in patients or hospital facility staff members that was not present or incubating at the time of admission."[5]
Wikipedia	"An infection that is contracted from the environment or staff of a healthcare facility."[6]

Through the HAI definitions review, this study found that the definitional features of HAI have been extended to more general and inclusive concepts in terms of occurrence, target, time, and the infection itself as shown in Table 2.

1) WHO (2002), "Prevention of hospital-acquired infections", WHO, p. 1.
2) WHO (2002), "Prevention of hospital-acquired infections", WHO, p. 4.
3) CDC (2003), "Guidelines for Environmental Infection Control in Health-Care Facilities", U.S. Department of Health and Human Services, p. 204.
4) CDC (2003), "Guidelines for Environmental Infection Control in Health-Care Facilities", U.S. Department of Health and Human Services, p. 206.
5) Korea CDC, "Nosocomial infectious disease", http://cdc.go.kr/CDC/contents/CdcKrContentView.jsp?menuIds=HOME001-MNU1132-MNU1138-MNU0112&cid=14706, 2016.9.23.
6) WIKIPEDIA, https://en.wikipedia.org/wiki/Hospital-acquired_infection, 2016.8.23.

Table 2. Definitional Features of HAI by Major Institutions

Field	Definitional Feature of HAI
Place (Where)	Every healthcare facility environment where medical or healthcare service is provided
Target (Whom)	Every patient, visitor, medical team member, or staff member who was admitted for a reason other than that infection
Infection (What)	Infections which were not present or incubating at the time of admission
Time (When)	Infections occurring more than 48 hours after admission

The Importance of Architectural Prevention and Control of HAI

Causes of HAI transmission and transmission modes of the HAI pathogen were also examined to determine the importance of architectural prevention and control of these infections. According to the WHO (2002)[7], HAI is not an endogenous but an exogenous infection, and an exogenous infection can be categorized as an environmental infection or a cross infection, depending on the mode of pathogen transmission. The HAI occurs when a pathogen from an infected person admitted into a healthcare facility, or from an infected medical appliance, infected medicine, or infected environment is transmitted directly or indirectly to an uninfected person who is admitted into the healthcare facility. The healthcare facility's environment is then closely related to the occurrence of HAI. The association between healthcare architectural space and the occurrence of HAI was conceptualized by Zimring et al. (2013) as seen in Figure 1.

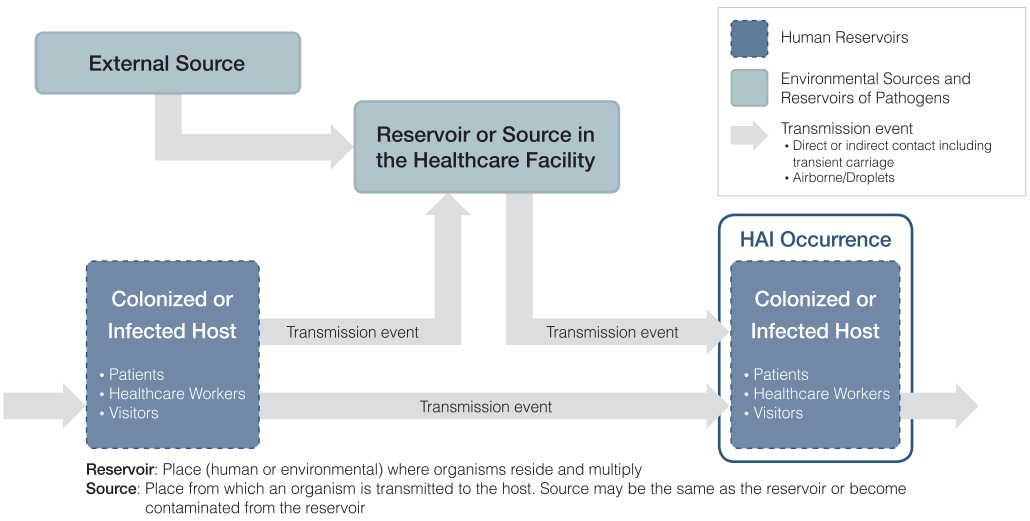

Figure 1. Conceptual Framework for the Chain of Transmission

※ Source : Zimring. C., et al (2013), "The Role of Facility Design in Preventing the Transmission of Healthcare-Associated Infection: Background and Conceptual Framework", *Health Environment.*

7) WHO (2002), "Prevention of hospital-acquired infections," WHO, p. 2.

The importance of architectural prevention and control of HAI transmission was highlighted in an accident causation model as shown in Figure 2. This model represents a HAI occurrence as an accident and illustrates various layers to prevent transmission events. The built environment of a healthcare facility is the very first defense layer in this model. Other defense layers such as equipment, organization, guidelines and so on are required, however, they come after the layer of the built environment. This means that the prevention and control of HAI can be effectively achieved through architectural preparation.

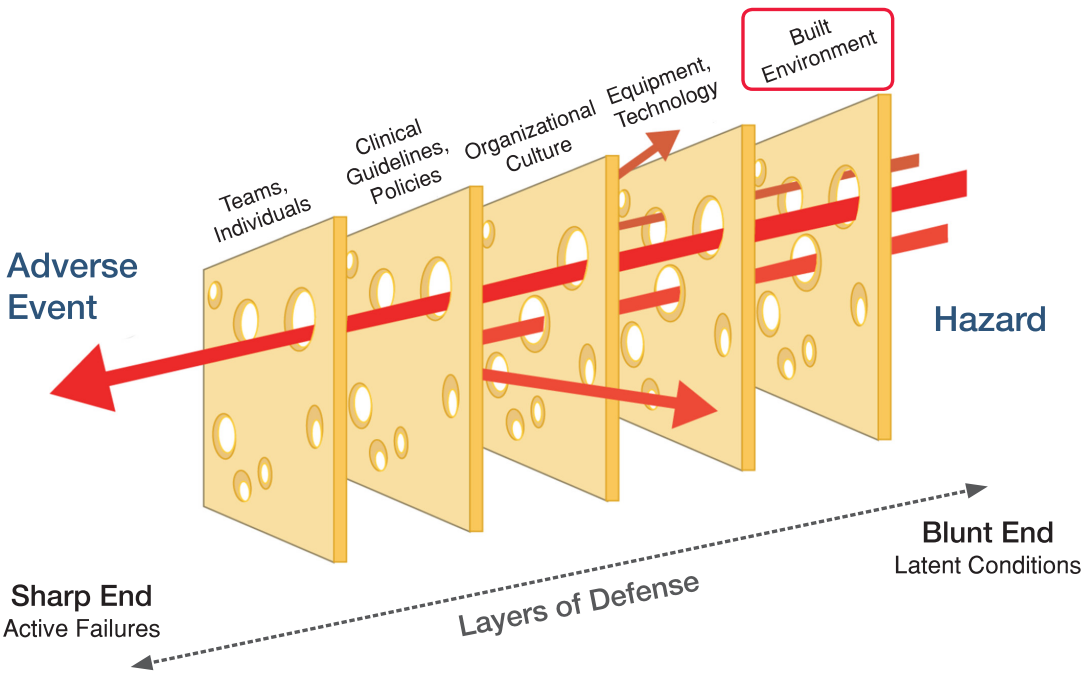

Figure 2. An Accident Causation Model

※ Source : CHD (2015), "A Brief Guide: Using the Safety Risk Assessment Tool in Healthcare Facility Design & Construction", *Center for Health Design*. p. 6.

HAI occurs in an architectural space and the built environment of a healthcare facility. The Korean government and relevant institutions, therefore, need to understand the importance of proper architectural preparation for HAI prevention and control. Because various measures such as programs, plans, and management are all things delivered within the architectural space and built environment, those software-driven measures can be efficient and successful when a hardware-driven built environments is properly equipped.

Architectural Consideration of the US for HAI Prevention and Control

The US Facility Guidelines Institute (FGI) provides "Guidelines for Design and Construction of Hospitals and Outpatient Facilities." The architectural and construction design guidelines cover general and specific types of facilities and departments, taking as their primary principle, "Do Not Harm." US medical institutions voluntarily adopt the facility guidelines into the planning, designing, construction, and post maintenance steps of facility buildings to guarantee the ability to control and prevent HAI.

The FGI highly recommends that HAI prevention and control ability from the very first facility building design to post maintenance be reviewed by a Safety Risk Assessment (SRA). The SRA is conducted by a review committee, and the committee should include administrators, clinicians, infection preventionists, architects, other design professionals, facility managers, safety officers, security mangers, users of equipment, and support staff shown in Table 3. The review components of the SRA are as listed in Table 4.

Table 3. Safety Risk Assessment Committee Member Expertise (M: Mandatory, N: As needed)

Expert	Safety Component						
	Infection Control	Patient Handling	Patient Fall Prevention	Medication Safety	Behavioral Health	Patient Immobility	Security
Frontline caregivers from clinical departments affected by the project	M	M	M	M	M	M	M
Facility management staff	M	M	M	M	M	M	M
Performance and/or quality improvement experts	M	M	M	M	M	M	M
Safety specialists	M	M	M	M	M	M	M
Security specialist(s)					M		M
Infection preventionists	M	M		M			M
Architects, interior designers, and/or engineers	M	M	M	M	M	M	M
Human factors specialists	M	M	M	M	M	M	
Other appropriate individuals based on the nature of the projects	N	N	N	N	N	N	N

※ Source : FGI (2014), "Guidelines for Design and Construction of Hospitals and Outpatient Facilities", FGI. p. 40.

Table 4. Safety Risk Assessment Components

Assessment	Facility Type/Area	Project Scope
Infection control risk	All	1. New construction 2. All renovations
Patient handling and movement	Areas where patient handling, transport, transfer, and movement occur	1. New Construction 2. Major renovation and renovations changing functional use of space 3. Minor and minimal renovations where patient handling occurs
Fall prevention	Any area to which a patient or family member has access	1. New construction 2. Major renovation and renovations changing functional use of space 3. Minor and minimal renovations where patient falls may occur
Medication safety	Medication safety zones	1. New construction 2. Major renovation and renovations changing functional use of space 3. Minor and minimal renovations where medication preparation, processing, and distribution occurs
Behavioral and mental health risk	Any area where behavioral health patient care is provided	1. New construction 2. Major renovation and renovations changing functional use of space to include care of behavioral health patients 3. Minor and minimal renovations where behavioral health patient treatment occurs
Patient immobility	Inpatient locations	1. New construction 2. Major renovation and renovations changing functional use of space to inpatient use 3. Minor and minimal renovations where inpatient care occurs
Security risk	All	1. New construction 2. All renovations

※ Source : FGI (2014), “Guidelines for Design and Construction of Hospitals and Outpatient Facilities,” FGI, p. 40.

The Center for Health Design in the US developed a Safety Risk Assessment Toolkit to improve the effectiveness of the Safety Risk Assessment. This checklist toolkit helps the SRA committee review how a healthcare facility building implements infection control, patient handling, falls, medication safety, behavioral health, and security. The checklist also classifies check-up questions from high to low according to generic risk likelihood, and includes a rationale for each question as listed in Table 5.

Table 5. Selected Checklist Examples of the Infection Control Section of the Safety Risk Assessment Toolkit

What is being discussed? (Design Consideration) Why should this be considered? (Rationale)	Generic Risk Estimate
Include an adequate number of negative isolation rooms for patients with airborne infections in patient care areas based on the projected number of such patients during normal and contingent surge operations. Contaminated air flowing from rooms where patients with airborne infections stayed was reported to increase the risks of infections among patients and staff in nearby spaces.	Highest
Provide a sufficient number of hand hygiene devices to support convenient use by staff, patients, and families. Hand hygiene is considered the single most important method of infection prevention because pathogens are often transferred via the unwashed hands of staff, patients, and families. The number of hand hygiene devices is an important factor significantly impacting hand hygiene. More sinks, gel dispensers, and other hand hygiene devices likely make it easier for staff, patients, and families to access the devices and clean their hands when needed.	Highest
Select interior finish materials for patient care areas, especially highly touched surfaces, that area easy to clean, disinfect, and maintain or that contain antibacterial characteristics in order to minimize the risk of surface contamination. Research shows that the contamination of environmental surfaces may serve as a link in the chain of infection transmission. Certain surface materials have been reported to be easier to clean, disinfect, and maintain and are associated with a lower risk of contamination.	Highest
Include physical separation/isolation methods in rooms to prevent cross-transmission between patients. Direct and indirect contact constitutes a major route of pathogen transmission between patients. Reducing the chances of direct/indirect contact between patients through physically separating and isolating patients, especially the provision of single-bed patient rooms, has been associated with significantly lower risks of HAIs and better health outcomes.	Med -High
Position sinks location so that splashes from the sinks cannot reach the patient zone or clean supplies. Water splashes from sinks to nearby patient care areas have been found to increase the risk of contamination and infection transmission of water-borne pathogens. Research has found that the location and orientation of sinks and hand hygiene devices are important factors that impact the possibility of water being splashed from sinks reaching nearby patient care areas.	Med -High
Identify and assess environmental fixtures that likely serve as reservoirs of pathogens. According to multiple recent epidemiological reports, without proper maintenance and cleaning, certain environmental fixtures could become reservoirs of pathogens and cause outbreaks of infections. Precautions should be taken to reduce the risk involved with environmental features known to be potential reservoirs of pathogens.	Med -Low

※ Source: CHD (2015), "Safety Risk Assessment for healthcare facility environments," Center for Health Design. pp. 21-35.

Beyond the FGI's guidelines, the SRA, and the assessment toolkit, the US Centers for Diseases Control & Prevention offers "Guidelines for Environmental Infection Control in Health-Care Facilities" to provide facility equipment guidelines for various departments such as wards and outpatient areas. The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) also published a handbook about standards and criteria for healthcare facility equipment such as the air pressure for negative isolation rooms, ventilation, temperature, and filter capacity.

Limitations of Korean Laws and Guidelines for Architectural HAI Prevention and Control

Relevant Korean laws and systems such as the Medical Service Act, the Building Act, and institutional guidelines were examined to consider establishment of proper architectural prevention and control of HAI. The Korean Medical Service Act classifies a healthcare facility into three classes by primary patient types as shown in Table 6. The hospital-level medical institution is divided into hospitals and general hospitals according to the number of beds and departments as seen in Table 7. Concerning the built environment of the healthcare facility the Enforcement Rule of Medical Service Act also provides facility standards and criteria for each type of medical institution. A rule for the intensive care unit of a general hospital to have more than 10㎡ of space for each patient bed is an example of architectural HAI prevention and control.

Table 6. Healthcare Facility Classification according to the Korean Medical Service Act

Class	Feature
Clinic-level	A medical institution in which a doctor, dentist, or oriental medical doctor provides medical services primarily to outpatients
Midwifery Clinic	A medical institution in which a midwife assists in childbirth and provides health services, education, and consultation for pregnant women, nursing women, postpartum women, and newborn babies
Hospital-level	A medical institution in which a doctor, dentist, or oriental medical doctor provides medical services primarily to inpatients

※ Source: "Medical Service Act," Article 3 (Medical Institutions).

Table 7 . Hospital Grouping according to the Korean Medical Service Act

Group	Requirement
Hospitals	3. A hospital, dental hospital, oriental medical hospital, or intermediate care hospital shall be furnished with not less than 30 patient beds
General Hospitals	4. A general hospital shall be equipped with at least 100 patient beds 5. A general hospital with at least 100, but not more than 300 patient beds shall have at least seven specialized departments 6. A general hospital with more than 300 patient beds shall have at least nine specialized departments

※ Source : "Medical Service Act," Article 3-2 (Hospitals, etc.), Article 3-3 (General Hospitals).

The Korean Building Act also provides rules for building a healthcare facility, however, architectural prevention and control of HAI is difficult to find. The rules and standards in the Building Act are mostly focused on improving the safety, function, environment, and aesthetic views of buildings. Even though the Building Act purports to promote public welfare, building standards for prevention and control of HAI in healthcare facilities are not included. According to the Building Act a healthcare facility should apply requirements to building constructions, building permits, construction supervision, etc., as shown in Figure 3. However, it is hard to find a process to determine if the design and construction of a healthcare facility includes architectural considerations for HAI prevention and control.

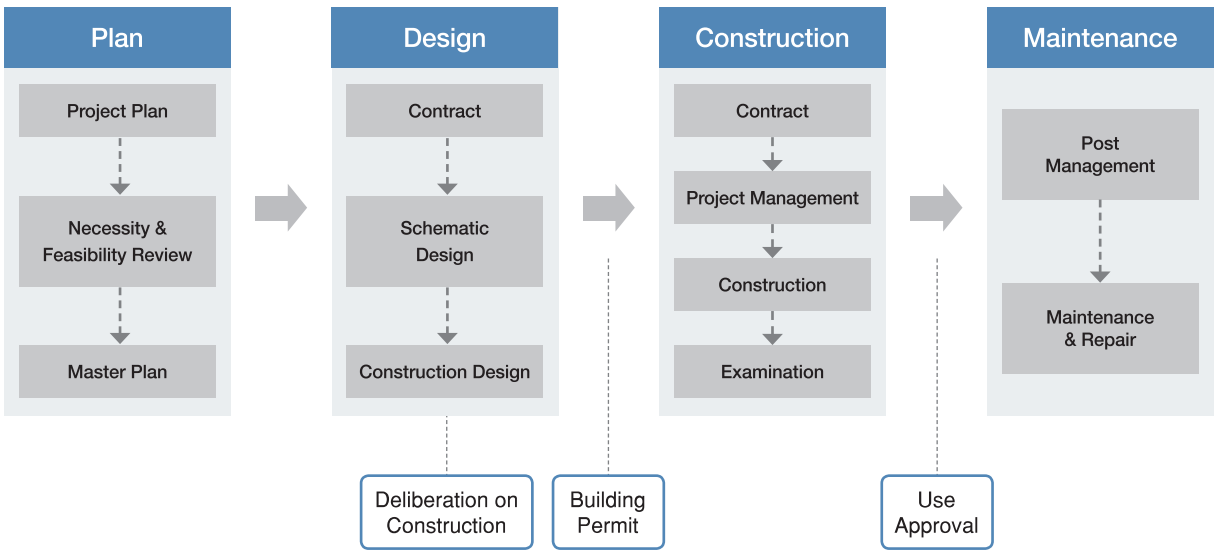

Figure 3. Building Processes according to the Korean Building Act

The Korean Centers for Disease Control & Prevention prepared guidelines for an infectious diseases specialty hospital providing HAI prevention and control facility design standards for various departments such as wards and outpatient areas. The Ministry of Health and Welfare of Korea also recommends that medical institutions have accreditation on medical services and programs. This accreditation, however, does not focus on the healthcare facility's built environment but on program operations and systems, concerned with HAI prevention and control.

Field Survey of Korean Medical Institutions for Architectural Prevention and Control of HAIs

This study completed a field survey on the prevention and control of HAI through architecture in six selected medical institutions in Korea. All medical institutions selected for the survey had more than 300 patient beds (i.e., general hospitals) and had experienced a MERS outbreak in 2015. The survey was conducted in August-September, 2016, and focused on the outpatient areas of each medical institutions because the outpatient area is the very first place where patients go to be admitted into a healthcare facility and is also usually the entry point for families, visitors, and healthcare workers. The outpatient areas of a general hospital in Korea typically have many people waiting, paying for service, resting, and meeting others. So, it is highly likely that HAI pathogens transmission by air, droplets, and direct/indirect touch can occur. Based on the review of guidelines and research for architectural HAI prevention and control through architecture, this study complied the survey components shown Table 8.

Table 8. Components for a Survey of HAI Prevention and Control in Outpatient Areas through Architecture

Zone / Category	General Admission	Outpatient Dept. Admission	Waiting for Examination	Examination	Public Restrooms
Spatial Structure	• Design of waiting area	• Design of waiting area	• Design of waiting area	• Uneven/ unnecessary space	-
Isolation of Infectious Patients	• Waiting area design that considers infectious patients • Scale of waiting area • Isolation of admission between outpatients and inpatients	• Waiting area design that considers infectious patients • Scale of waiting area • Isolation of waiting areas among departments	• Waiting area design that considers infectious patients	-	-
Admission Area	• Measures / spatial isolation to prevent HAI transmission	• Measures / spatial isolation to prevent HAI transmission	-	-	-
Finishing	• Materials that are easy to clean, sanitize, repair, and replace	• Materials that are easy to clean, sanitize, repair, and replace	• Materials that are easy to clean, sanitize, repair, and replace	• Materials that are easy to clean, sanitize, repair, and replace	• Materials that are easy to clean, sanitize, repair, and replace
Hygiene	• Installation of hand sanitizers and masks • Encourages use of hand sanitizers and masks	• Installation of hand sanitizers and masks • Encourage to use of hand sanitizers and masks	• Installation of hand sanitizers and masks • Encourage use of hand sanitizers and masks	• Installation of hand sanitizing equipment • Installation of touchless equipment	• Wall installation of sanitary ware • Installation of touchless equipment

A survey of architectural HAI prevention and control in waiting areas found them to be at high risk of transmitting HAI pathogens due to a lack of isolation. A survey on the circulation of patients in outpatient areas showed that a new patient (i.e., a visitor for the first medical examination) was likely to use three different waiting areas during the examination, and an outpatient visitor for the second or further medical examination was likely to use two different waiting areas. The waiting areas were a mix of alcove and hall types. Each waiting area or room was shared by three different outpatient departments on average. Only one out of six

medical institutions provided a physically isolated waiting room for infectious patients. Chairs in waiting areas were installed with a 570mm gap between each (i.e., somewhat dense for prevention of HAI transmission). Some departments even installed benches in waiting areas, which would increase the chance of HAI transmission by air, droplets, or direct/indirect touch.

All outpatient waiting areas for admission and examination in six medical institutions did not install hand hygiene equipments or mask kiosks. There were no recommendations or encouragement to use masks or hand sanitizers by the healthcare workers. Isolation between healthcare workers and outpatients in admission areas was not provided in most cases.

Figure 4. Surveyed Outpatient Waiting Areas (easy for HAI transmission)

※ Source: by author

Public restrooms in outpatient areas were surveyed and were found to have a lack of prevention and control of HAI transmission due to inadequate finishing materials and sanitary ware installation. Not all public restrooms installed a mopboard nor touchless door opening system. Some public restrooms did not install an entry door. Sinks and urinals were touch/touchless, however, closet bowls were all a touch-based system. Most urinals and closet bowls were installed on the floor.

Figure 5. Surveyed Restrooms in Outpatient Waiting Areas (hard to keep sanitized)

※ Source: by author

Policy Suggestions to Achieve Architectural HAI Prevention and Control

This study suggests that the definition of HAI in the Infectious Disease Control and Prevention Act be amended to be more inclusive of place, target, infection, and time (refer to Table 2). Article 2 (Definitions) of the Infectious Disease Control and Prevention Act defines "nosocomial infectious disease" as an "infectious disease occurred to patients, expecting mothers, etc. in the course of undergoing medical activities, which are publicly announced by the Ministry of Health and Welfare, as they require surveillance." This legal definition, however, targets patients and pregnant women, and does not include healthcare workers and visitors who were admitted into healthcare facilities or the built environment where HAI transmission occurs.

This study proposes to add standards and criteria for HAI prevention and control to the Medical Service Act, to prepare a Korean Safety Risk Assessment Toolkit (refer to Table 5), and to operate an assessment system (refer to Table 4) with the establishment of a review committee (refer to Table 3).

Effective enforcement of architectural HAI prevention and control for Korean healthcare facilities will be achieved when the architectural consideration starts from the facility planning step through the design and construction steps to the post-maintenance stage. Even though the Korean Building Act provides various rules for deliberation on construction, building permits and use approvals, reviews specialized for an HAI prevention and control system for healthcare facilities are not required. This research, therefore, suggests that an HAI safety design-construction review system in a series of healthcare facility building processes should be enforced in order to guarantee architectural HAI prevention and control as indicated in Figure 6.

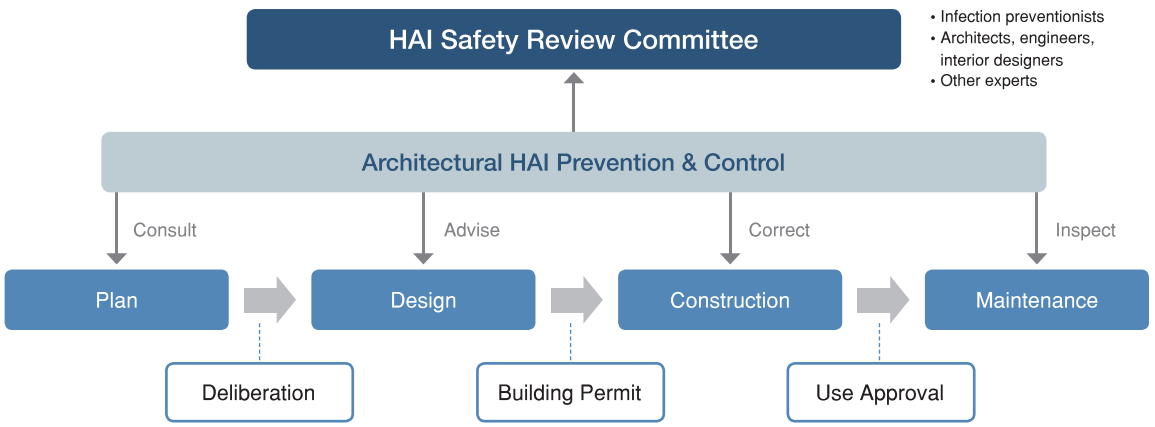

Figure 6. HAI Safety Review System for Healthcare Facility Building Processes

Conclusion

HAI is likely a man-made accident. This means that HAI can be prevented and controlled. The measure and delivery have limitations, however, because of the characteristics and transmission routes of various pathogens, the operation and management conditions of various facilities, and so on. The prevention and control of HAI should be the number one priority among healthcare facility issues because of the disastrous results of HAI on the community, society, and country.

Key words : Healthcare Associated Infections (HAI), healthcare facilities (hospitals), architectural prevention and control, planning, design, system, and guidelines

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Address #701, 194, Jeoljaero(Eojin-dong), Sejong, Republic of Korea
Tel +82-44-417-9600 **Fax** +82-44-417-9608 **www.auri.re.kr**

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