한국환경보건학회지, 제46권 제5호(2020)
J Environ Health Sci. 2020; 46(5): 599-609

pISSN: 1738-4087 eISSN: 2233-8616
https://doi.org/10.5668/JEHS.2020.46.5.599

사례 보고 | Case Report

Environmental Investigation of a Long-term Care Hospital with Respect to COVID-19

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ABSTRACT

Objectives: Coronavirus disease 2019 (COVID-19) first emerged in December 2019 in Wuhan, China, and has rapidly become a global pandemic with over 26.4 million confirmed cases and approximately 871,000 fatalities worldwide as of this writing. In the Republic of Korea, disease clusters frequently occurred in long-term care hospitals where the majority of residents are elderly with underlying medical conditions. Despite the fact that public health authorities and local community health centers have put tremendous efforts into preventing the spread of disease, positive cases have continued to occur. Thus, the Korea Centers for Disease Control & Prevention rapid response team decided to conduct an environmental investigation of a long-term care hospital to identify whether environmental contamination has remained and contributed to the spread of COVID-19.

Methods: An environmental investigation was conducted at Hospital A. The characteristics of the facility and its HVAC system were assessed by checking the layout and interviewing the people in charge. A total of 64 surface samples were collected from areas of concern, including patient rooms, toilets, elevators, and nurses' station. These samples were tested by a regional health and environmental research institute using real-time reverse transcription polymerase chain reaction.

Results: All samples from Hospital A were confirmed to be negative. Through interviews with high-level personnel at the regional community health center, we found that extensive disinfection is frequently performed on potentially contaminated areas in Hospital A in accordance with government guidelines.

Conclusion: The environmental control measures implemented in Hospital A had been sufficient for mitigating the risk of further infection, suggesting that such measures may also be effective for other long-term health care facilities.

Key words: COVID-19, elderly patients, environmental investigation, long-term care hospital, RT-PCR

I. Introduction

Since the novel coronavirus infectious disease 2019 (COVID-19) first emerged in Wuhan, China in December 2019, it has rapidly become a global pandemic as of March 2020.[1,2] Over 26.4 million confirmed cases have been reported globally, and approximately 871,000 deaths have been confirmed in 213 countries.[1] This pandemic has created tremendous burden on medical infrastructure across many nations crippling their capacity to respond to infectious diseases.

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Received: 20 August 2020, Revised: 18 September 2020, Accepted: 23 September 2020

According to the most recent information on COVID-19 published by Korea Central Disease Control Headquarters, there have been approximately 21,177 confirmed cases and 334 deaths (fatality rate: 1.6%) in the Republic of Korea.[3] The cumulative number of confirmed cases in the age group over 70 years old is currently 2,447 cases, which account for 11.55% of the total number of confirmed cases. On the other hand, in terms of mortality rate, the cumulative number of deaths due to COVID-19 in the same age group is 269, which account for 80.53% of the total fatalities linked to COVID-19. Thus, it is apparent that the elderly have a higher mortality risk than any other age group.[3]

As COVID-19 has progressed in Korea, a number of new cases have been clustered in certain types of hospitals, such as long-term health care facilities, and these epidemiologic characteristics have become more evident, especially in regions with more confirmed cases. Approximately 300 confirmed cases, including 48 fatal cases, have been associated with long-term care hospitals in Daegu, one of the most affected cities in the Republic of Korea. Health outcomes have often declined because the majority of patients housed in long-term care facilities are elderly and suffer from underlying medical conditions, such as chronic lung disease, serious heart conditions, or cancer. These health issues make them more vulnerable to infectious diseases, including COVID-19. According to recent reports by London School of Economics (LSE), a number of European countries, including France, England, Italy and Belgium, have also struggled with significantly high fatality rates associated with nursing homes or long-term health care facilities. Among these countries, the fatalities linked to COVID-19 occurring at such facilities accounted for approximately 49-64% of total deaths.[4] This epidemiological characteristic of the disease has been a major contributing factor to increasing overall fatalities. It is critical to take preventive measures to protect the susceptible population, especially those who reside in the aforementioned types of health care facilities. Taking proactive action to protect residents helps reduce the overall fatality rate as well as mitigate the risk of further disease spread in the local community.

Once a confirmed case is identified in a long-term health care facility, the Korea Centers for Disease Control & Prevention (KCDC) and local health authorities rapidly respond to minimize the impact of disease occurrence by implementing active infection control measures. These preventive public health measures include isolation of the positive residents, transferring them to designated hospitals, tracing contacts, monitoring symptoms, facility-wide testing, environmental sanitation with disinfectants, and training health care providers for infection control.

Despite tremendous efforts, some long-term care hospitals are still struggling with high rates of COVID-19 infection. Therefore, it is critical to identify whether environmental contamination remains a contributing factor to high incidences of COVID-19 in these facilities. With this goal in mind, the KCDC conducted an extensive environmental investigation at a specific long-term care hospital with the highest prevalence of COVID-19 in the city of Daegu at the time of planning (Hospital A).

A total of 123 cases were confirmed since the index case was identified on March 16, 2020. In the following days, the facility-wide diagnostic tests were conducted on all hospital residents and staff, and 48 additional individuals were confirmed to be infected with COVID-19. Those who were identified as positive cases were transferred to several designated treatment hospitals in the city of Daegu. The staff and residents who may have had contact with the confirmed cases were closely monitored, and their body temperatures were taken twice a day. All of the rooms and spaces that the confirmed cases occupied were immediately sanitized with an effective disinfectant. Training for infection control was also provided to the staff including health care providers, by public health professionals.

Although numerous preventive measures have

been taken by both the KCDC and local public health departments, new cases of COVID-19 continue to occur. Thus, the investigation reported in this study was conducted to identify whether the environmental contamination by SARS-CoV-2, the virus that causes COVID-19, in Hospital A has been a contributing factor to continued disease transmission. If so, it could provide scientific grounds for understanding how environmental factors can also influence disease spread in hospitals and would be valuable for establishing more effective infection control measures.

II. Materials and Methods

First, the facility structure and its mechanical system, including heating, ventilation, air conditioning (HVAC) of the hospital, were assessed using available information, followed by interviews with personnel in charge during facility visit. Second, an environmental investigation was conducted with a focus on specific areas of the hospital, including patient rooms and toilets, which were most likely to be contaminated with SARS-CoV-2. The target areas were determined based on the epidemiological data from Hospital A. The patient rooms with the highest number of positive cases were chosen. Samples were also collected from other places in the hospital with epidemiological importance including the elevator and a nurse station. Afterwards, the collected samples were transferred to the regional research institute for analysis.

1. Facility structure and mechanical system

Hospital A is located in the western part of Daegu which is one of the most COVID-19 affected cities in Republic of Korea.[3] The building is seven stories tall, and all floors have been dedicated to hospital use. The admissions office and treatment rooms are located on the first floor. From the second to the sixth floor, there are patient rooms, toilets, and resting areas. The building is comprised of two units (A and B), and the elevator is located between them. Because the elevator is frequently used by both staff and the patients, it may have served as a potential source of infectious contaminants throughout the hospital.

It was planned to figure out whether the HVAC and it duct system of the building had been well established in terms of structure and functioned sufficiently to maintain air quality of the main areas including patient room, toilet. However, the layout for the HVAC system was not available at the time of the visit, so the team was not able to obtain detailed information regarding ventilation. A number of long-term care hospitals have maintained internal air quality through natural ventilation, such as regularly opening windows. Thus, it can be inferred that the ventilation in each floors of the facility was maintained in similar ways.

2. Environmental risk assessment in regards to SARS-CoV-2

An environmental risk assessment was planned to collect surface samples from a total 70 spots in the patient rooms, toilets, nurse station, and elevator. The specific rooms and toilets for the sampling were determined based on epidemiological data. At the time of sampling, a total of 123 confirmed cases of COVID-19 had occurred in the hospital, 6 of which were located in rooms #503, #602 each. Since 10 confirmed cases had occurred among the nurses and other health care providers, the nurse station located in the 5th floor was also included in the sampling.

For the environmental assessment, samples were collected from the elevator, nurse station, patient room #503 and its toilet, and patient room #602 and its toilet.

Specific spots for the sampling were chosen based on research articles related to the environmental assessment of SARS-CoV-2 in hospital setting.[5,6] Those studies were designed and conducted by the scientists of Singapore, Hong Kong to identify the

hazard associated with SARS-CoV-2 while treating the positive patients in hospitals. According to the research articles, environmental contamination of SARS-CoV-2 has been detected mainly on bed rails, bed tables, sinks, toilets, and other frequently contacted areas.[5,6] Thus, our samples were collected from specific spots in the rooms and toilets that, were likely to have been touched by COVID-19-positive patients.

In addition, to assess the potential contamination of the nurse station, samples were collected from the tables and computer keyboards, which are frequently used and touched by nurses and other staff. Through this assessment, it was determined that the contamination in the nurse station contributed to nosocomial transmission, especially among staff members. Given strong opinions that the elevator might have contributed to the disease spread among the patients who resided in rooms on different floors, several spots in the elevator were also sampled for analysis.

The environmental investigation, including sampling, was conducted with the consent of the hospital. The sampling was performed by the KCDC team composed of three personnel (two epidemiologists and one environmental health expert). It took 3 h, from 17:00 to 20:00 on April 5th, 2020, to complete the sampling.

Before entering the target areas, all team members were fully equipped with an N95 mask, goggles, coveralls, double gloves, and shoe covers. The safety of the team was ensured during sampling via complete PPE and a high level of competency in using PPE. During sampling, hand washing using an effective-disinfectant (70% ethanol) was frequently performed by all members to prevent cross-contamination in between samples and minimize the risk of potential exposure.

It was planned that seventy samples were collected from designated spots in the patient rooms, toilets, elevator, and nurse station. However, we noticed that certain spots (rail and table of #7 bed in room #503, TV remote controller in room #503, exhaust fan in toilet #503, exhaust fan in toilet #602, and a walker) did not exist. Six samples were not collected. Thus, only 64 samples were successfully collected from pre-designated spots in the target areas.

The sampling of surfaces was conducted to investigate potential contamination throughout the hospital. The swab tool used for sampling was Universal Transfer Medium (UTM), which is a sterile flocked collection device manufactured by Puritan Medical Products Company, LLC. Prior to sampling the surfaces, the swab was submerged in the medium to be moistened.

When sampling the walls and glass windows, we sectioned the areas by 1 m^2 (1 m×1 m) and swabbed the region in an S-shaped pattern. Surfaces like bed rails, sinks, and toilets that could not be sampled using same method were sampled by swabbing the entire surface repetitively.

After collection, the sample vials were labeled with numbers corresponding to the designated locations. They were packaged in a triple-layered biological substance container and transferred by the public health personnel of Daegu Metropolitan City Seo-gu Community Health Center for lab analysis. The samples were kept at a low temperature and surrounded by ice packs during transfer.

The laboratory analyses of the 64 samples collected from the areas of concern were completed by the Daegu Metropolitan City Health & Environment Research Institute. To detect the presence of SARS-CoV-2 in the samples, real-time reverse transcription polymerase chain reaction (Real-time RT-PCR) analysis was used. This analysis targets the E and RdRp genes of SARS-CoV-2. The analysis was performed using an Applied Biosystems 7500 Fast Real Time PCR Instrument (Thermo Fisher Scientific, USA) and the reagent used for the test was AgPath-ID^{TM} One-Step RT-PCR Reagent (Thermo Fisher Scientific, USA). The reverse transcription was performed at 50^{o}C for 30 minutes, followed by

Table 1. Sampling locations

A total of 64 samples were collected from the spots described below:
Room #503 (17 samples): 6 bed rails (bed #1-6; the number was given to each bed counterclockwise from the right), 6 bed tables (bed #1-6), 2 bed headboards (beds #2 and #6), 1 door handle (inside), 1 door handle (outside) and 1 light switch.
Toilet #503 (9 samples): 1 door handle (inside), 1 door handle (outside), 1 sink outer rim, 1 sink inner bowl, 1 sink handle, 1 toilet inner bowl, 1 toilet seat, 1 support handle, and 1 toilet handle.
Room #602 (19 samples): 7 bed rails (bed #1-7; the number was given to each bed counterclockwise from the right), 7 bed tables (bed #1-7), 2 bed headboards (beds #2 and #6), 1 door handle (inside), 1 door handle (outside), and 1 TV control panel.
Toilet #602 (9 samples): 1 door handle (inside), 1 door handle (outside), 1 sink outer rim, 1 sink inner bowl, 1 sink handle, 1 toilet inner bowl, 1 toilet seat, 1 support handle, and 1 toilet handle.
Elevator (4 samples): 2 elevator control panels (#1-2), 1 front side, and 1 back side (mirror).
Nurse station (4 samples): 2 outer desks (right and left sides), and 2 inner desks, including computer keyboards (right and left sides).
Inner corridor (2 samples): 1 door glass in front of patient room #503, and 1 door glass in front of patient room #602.

inactivation of reverse transcriptase at 95°C for 10 minutes. PCR amplification was performed with 40 cycles at 95°C for 15 seconds and 60°C for 1 minute.[7] The cycle threshold value (CTV) as well positive or negative results were determined by the Daegu Metropolitan City Health & Environment Research Institute. Based on the lab analyses, the amount of virus shedding on each sample area was measured and compared.

III. Results

All samples were confirmed to be negative. None of the samples collected from the areas of concern were detected to contain SARS-CoV-2.

Table 2. Test results in each sample

Number	Sampling location		Result
1	Patient room #503 (17 samples)	#1 bed rail (both sides)	Negative
2		#1 bed table	
3		#2 bed rail (both sides)	
4		#2 bed table	
5		#3 bed rail (both sides)	
6		#3 bed table	
7		#4 bed rail (both sides)	
8		#4 bed table	
9		#5 bed rail (both sides)	
10		#5 bed table	
11		#6 bed rail (both sides)	
12		#6 bed table	
15		Light switch	
16		Door handle (inside)	
17		Door handle (outside)	
19		#2 bed headboard and approximate wall	
20		#6 bed headboard and approximate wall	

Table 2. Continued

Number	Sampling location	Result
21	Door handle (outside)	
22	Door handle (inside)	
23	Sink outer rim	
24	Sink inner bowl	
25	Toilet support handle	Negative
26	Sink handle	
28	Toilet inner bowl	
29	Toilet seat	
30	Toilet handle	
31	#1 bed rail (both sides)	
32	#1 bed table	
33	#2 bed rail (both sides)	
34	#2 bed table	
35	#3 bed rail (both sides)	
36	#3 bed table	
37	#4 bed rail (both sides)	
38	#4 bed table	
39	#5 bed rail (both sides)	
40	#5 bed table	Negative
41	#6 bed rail (both sides)	
42	#6 bed table	
43	#7 bed rail (both sides)	
44	#7 bed table	
46	Door handle (inside)	
47	Door handle (outside)	
48	TV control panel	
49	#2 bed headboard and approximate wall	
50	#6 bed headboard and approximate wall	
51	Door handle (outside)	
52	Door handle (inside)	
53	Sink outer rim	
54	Sink inner bowl	
55	Toilet support handle	Negative
56	Sink handle	
58	Toilet inner bowl	
59	Toilet seat	
60	Toilet handle	
61	#1 control panel	
62	#2 control panel	Negative
63	Front side	
64	Back side, including mirror	
65	Outer desk(right from corridor)	
66	Outer desk(left from corridor)	Negative
67	Inner desk including computer keyboard (right from corridor)	
68	Inner desk including computer keyboard (left from corridor)	
69	Door glass in front of patient room #503	Negative
70	Door glass in front of patient room #602	

Number	Sampling location
24–30	Toilet #503 (9 samples)
31–50	Patient room #602 (19 samples)
51–60	Toilet #602 (9 samples)
61–64	Elevator (4 samples)
65–68	Nurse station (4 samples)
69–70	Inner corridor (2 samples)

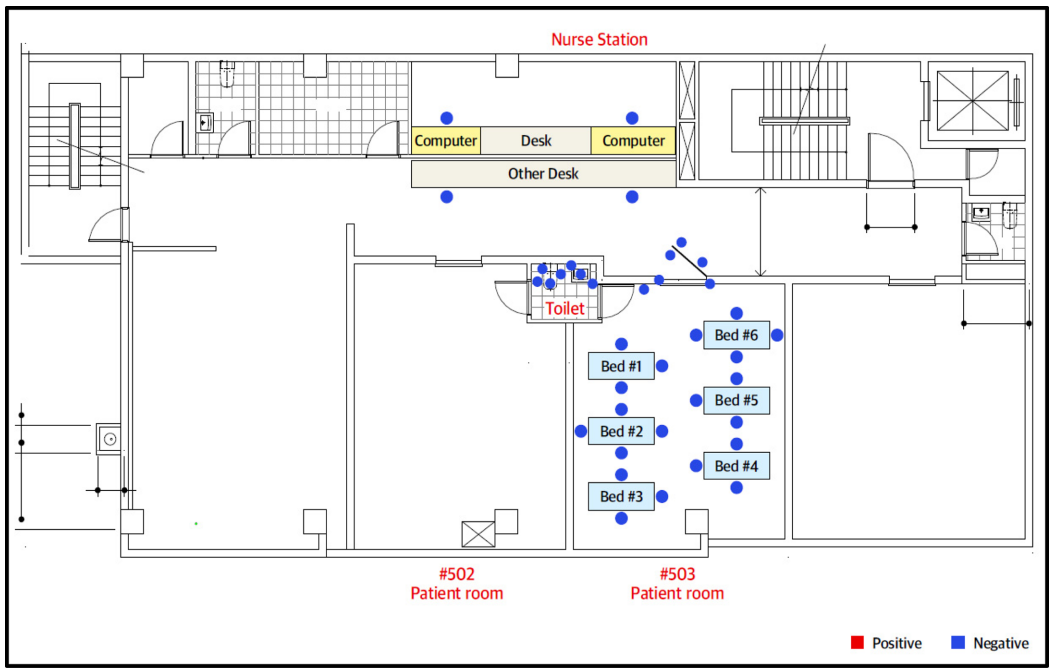

Fig. 1. Floor map of sampling spots marked with test results (patient room #503, toilet #503, nurse station, and inner corridor)

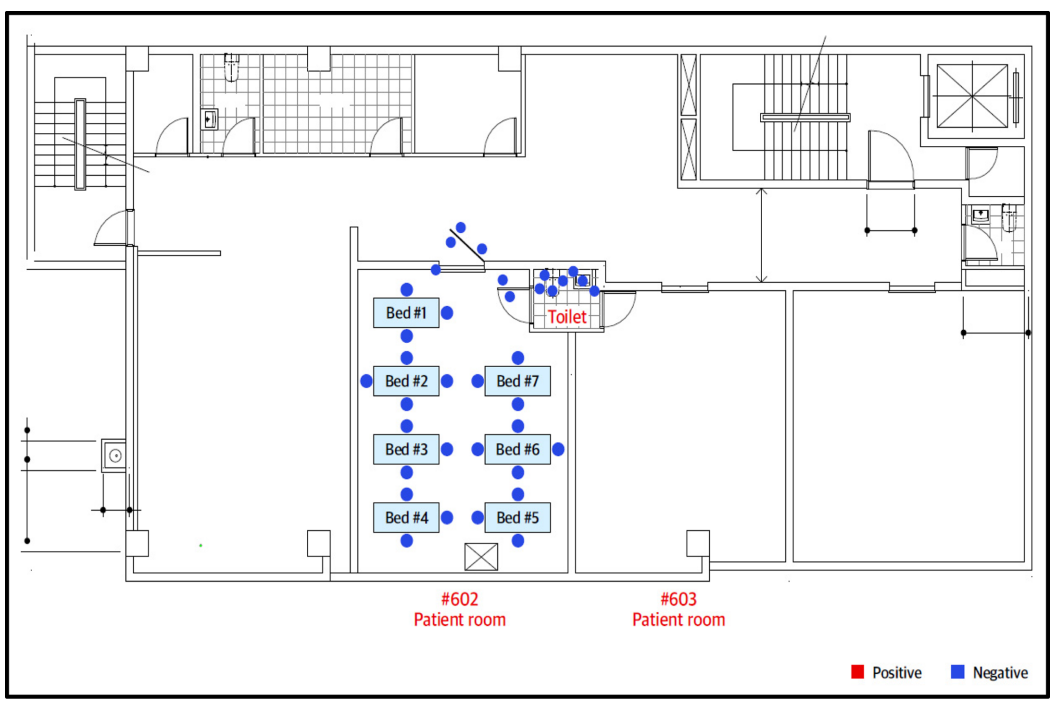

Fig. 2. Floor map of sampling spots marked with test results (patient room #602, toilet #602, and inner corridor)

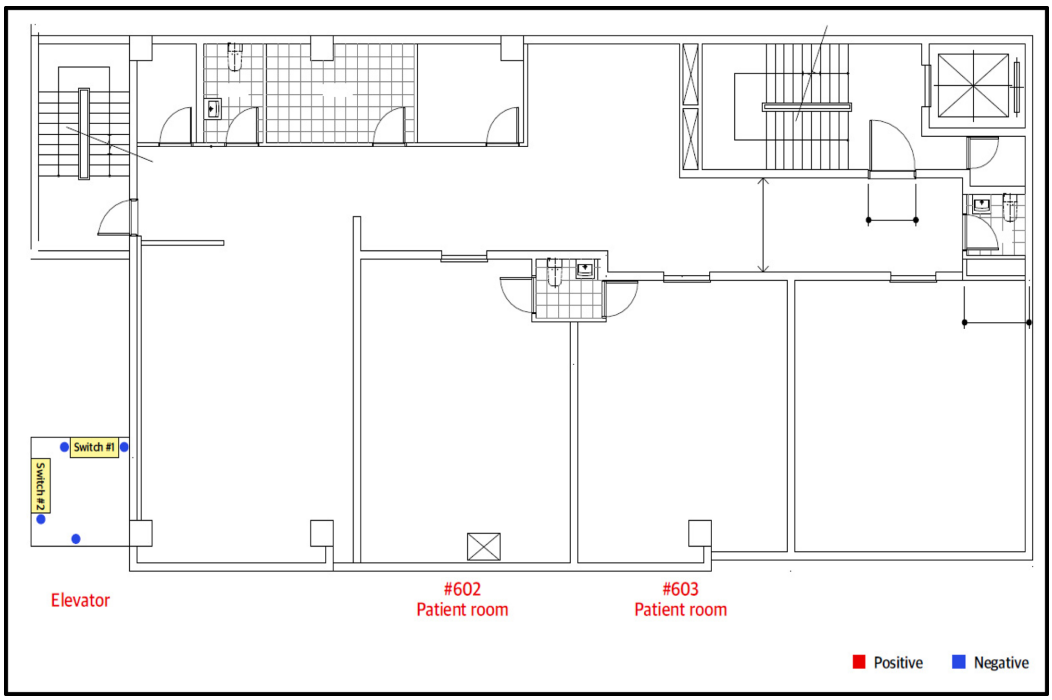

Fig. 3. Floor map of sampling spots marked with test results (elevator)

IV. Discussion

The HVAC layout of Hospital A was not available for the investigation, and the team was not able to ensure that the mechanical ventilation system in patient rooms and other areas functioned properly. Instead of operating mechanical ventilation, it was assumed that the internal air quality was maintained by natural ventilation processes, such as frequent window opening.

Through extensive environmental assessment, it was found that SARS-CoV-2 was not detected in the areas of concern, including patient rooms, toilets, nurse station, and elevator. Therefore, the potential environmental risk of SARS-CoV-2 contamination in the hospital is negligible, and implementation of disinfection and cleaning procedures with reference to governmental guidelines has been effective in minimizing environmental hazards.[8] It becomes more evident that the environmental control measures implemented for the hospital were effective when it is compared to the environmental studies conducted in other countries. According to those studies, the virus was detected extensively in the bed room, toilet and other objects that the COVID-19 patients used prior to the routine cleaning.[5,6] After the investigation, interviews with personnel in charge of environmental management at the Daegu Metropolitan City Seo-gu Community Health Center were conducted to determine how to control environmental risk regarding SARS-CoV-2. All of the potentially contaminated areas and objects that the COVID-19 patients had used and touched in the room, such as bed rails, bed tables, door handles, switches, and other frequently contacted areas, were routinely sanitized with designated disinfectants, including alcohol-based, sodium hypochlorite-based, and quaternary ammonium-based solutions. In addition to decontaminating patient rooms and their objects, the toilets and sinks that the confirmed patients had used were also

disinfected. The disinfecting solution was applied vigorously to potentially contaminated surfaces of the areas and objects using both spray and disinfecting wipes. The virus was not detected in any spot of the toilets or patient rooms. It is assumed that environmental sanitation was achieved through active control measures, including natural ventilation and disinfection. As stated in existing scientific research articles, virus shedding has been detected in samples of feces as well as saliva.[9,10] This implies that SARS-CoV-2 is also transmissible through the fecal route. If toilets are not properly disinfected and toilet hygiene is not strictly followed, they could serve as a source of disease transmission. Especially, for hospitals that have one restroom for every two patient rooms, it is more probable that contaminated toilets could serve as the fomite to transmit further infections to other residents who share the toilet. Thus, it is essential to maintain toilet cleanliness by performing periodic disinfection and making hand hygiene obligatory to prevent further disease transmission.

Certain objects, such as door handles, light switches, and TV remote controls are frequently touched by both patients and staff. These objects also have the potential to mediate the transmission of infection once contaminated. During the interviews, we found that all objects, including door handles in patient rooms, toilets, switches, and other frequently contacted areas, were vigorously disinfected with disinfectant-soaked wipes.

No SARS-CoV-2 particles were detected in the designated areas of the nurse station, including desks and computer keyboards. Since 10 confirmed cases occurred among nurses and other healthcare providers, the nurse station was considered to be potentially contaminated. However, it was found that there was no contamination of SARS-CoV-2 in the areas of the nurse station. Through the interviews, the team was informed that extensive decontamination of all surfaces and objects, including desks and, computers in the nurse station, had already been conducted by public health professionals.

Healthcare providers, including nurses, frequently use computers and various documents at nurse stations. If these staff members do not thoroughly wash their hands, it is expected that computers keyboards and other objects are likely to be contaminated with the virus and serve as the fomite for spreading the disease among healthcare workers sharing the same spaces. Thus, it is important to reiterate the importance of hand hygiene and regular disinfection of the objects at the nurse station to the benefit of both healthcare providers and patients.

No SARS-CoV-2 particles were detected in the elevator samples. All four samples collected from the two switch panels, front door, and back mirror inside the elevator were confirmed to be negative. The switch panels had been covered with vinyl sheets, and the sheet covers were regularly disinfected by hospital staff in charge. This measure seems to keep the panels clean and makes it easier to disinfect surfaces that are frequently used by numerous people in the hospital. As a result, it is assumed to be effective for prevention. Because none of the samples collected from the elevator were positive, it became evident that this elevator had not been acting as a contributing factor to disease spread between the patients on different floors.

Since this study has proven that there is no residual contamination of SARS-CoV-2 in the hospital environment it could be stated that the chances of COVID-19 transmission via environment route are considered to be negligible both among patient and employee groups. Besides, there is also one more issue that needs to be addressed. During the planning of this investigation, the elevator had been suspected as the major source which had contributed the disease spread among the people in different floors. However, the results have shown that SARS-CoV-2 has not been detected inside of elevator. Therefore, it is concluded that those cases in different floor were not been exposed to the virus

inside the elevator and the disease has not been transmitted by the use of elevator.

V. Conclusions

The investigation team was able to determine that environmental interventions, including extensive disinfection and, natural ventilation, were effective in controlling the spread of infection. Public health officers in charge of environmental management at the Daegu Metropolitan City Community Health Center have conducted extensive disinfection of the entire area of potential contamination with reference to the disinfection guidelines published by Korea Central Disease Control Headquarters. Through this investigation, it was proven that the measures taken for environmental infection control have been sufficient for the hospital. This finding implies that the environmental control measures applied to this hospital may be effective for other long-term health care facilities. It is critical and necessary to provide the comprehensive guidance which is proven to be effective for coping with COVID-19.[11,12] It encourages the public health and medical community to more strictly follow the given guideline and implement the environmental control measures more actively. This study was meaningful to prove that the guideline is sufficient and effective to control environmental hazard associated with COVID-19.

However, there are limitations to this environmental investigation. First, the results from the RT-PCR analysis only indicated the presence of the genetic material of the virus rather than the viability of the virus. Presence of the virus does not necessarily mean that it would cause infection in residents who were exposed because it is not known if the virus is viable.

Second, the sampling for the investigation was conducted five days after the last confirmed COVID-19 cases were identified in rooms #503 and, #602. It is possible that the virus may have undergone deactivation by the time of the investigation. However, it has been reported that coronavirus can survive for up to nine days in indoor settings.[13] Thus, as opposed to natural decay, the infection control measures implemented at the hospital, such as vigorous disinfection and natural ventilation, are effective and appear to have sufficiently reduced the environmental hazards caused by SARS-CoV-2.

Lastly, the number of environmental samples tested had to be limited to one sample for each spot of interest. Instead of collecting multiple samples from each spot, the team tried to maximize the credibility of the data by collecting multiple samples from the areas of highest incidence of confirmed cases, which were rooms #503, #602, and their respective toilets.

Acknowledgment

We would like to express our sincere thanks to the Daegu Metropolitan City Seo-gu Community Health Center and Daegu Metropolitan City Health & Environment Research Institute for their cooperation.

The opinions expressed by authors contributing to this journal do not necessarily reflect the opinions of the Korea Centers for Disease Control and Prevention or institution that the authors are affiliated.

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