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# Source Analysis and Effective Control of a COVID-19 Outbreak in a University Teaching Hospital during a Period of Increasing Community Prevalence of COVID-19



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**Address for Correspondence:**

**Kyung-Hwa Park, MD, PhD**  
Department of Infectious diseases, Chonnam National University Medical School, 42 Jebong-ro, Dong-gu, Gwangju 61469, Republic of Korea.  
E-mail: iammedkid@naver.com

\*Unhee Lee and Seong Eun Kim are equally contributed to this work.

\*Present address: Department of Laboratory Medicine, Jeonbuk National University, Jeonju, Republic of Korea

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**ORCID iDs**

Unhee Lee <https://orcid.org/0000-0003-2383-2961>  
Seong Eun Kim <https://orcid.org/0000-0003-0162-6155>  
Seung Yeob Lee <https://orcid.org/0000-0003-2851-1112>  
Hang Nam Wi <https://orcid.org/0000-0002-5942-0881>  
Okja Choi <https://orcid.org/0000-0003-3719-6791>  
Ji-Won Park <https://orcid.org/0000-0002-0060-2787>

Unhee Lee <sup>1\*</sup>, Seong Eun Kim <sup>2\*</sup>, Seung Yeob Lee <sup>3+</sup>, Hang Nam Wi <sup>1</sup>, Okja Choi <sup>1</sup>, Ji-Won Park <sup>1</sup>, Dahee Kim <sup>1</sup>, You Jung Kim <sup>1</sup>, Hwa Young Shin <sup>1</sup>, Mihee Kim <sup>1</sup>, Eun Ji Kim <sup>1</sup>, Seung-Ji Kang <sup>1</sup>, Sook-In Jung <sup>1,4</sup> and Kyung-Hwa Park <sup>1,4</sup>

<sup>1</sup>Department of Infection Control Unit, Chonnam National University Hospital, Gwangju, Korea

<sup>2</sup>Department of Infectious Diseases, Chonnam National University Hospital, Gwangju, Korea

<sup>3</sup>Department of Laboratory Medicine, Chonnam National University Hospital, Gwangju, Korea

<sup>4</sup>Department of Infectious Diseases, Chonnam National University Medical School, Gwangju, Korea

## ABSTRACT

**Background:** South Korea has been experiencing a third wave of coronavirus disease 2019 (COVID-19) since mid-November 2020. Our hospital in Gwangju metropolitan city experienced a healthcare-associated COVID-19 outbreak early in the third wave. The first confirmed COVID-19 patient was a symptomatic neurosurgery resident with high mobility throughout the hospital. We analyzed the transmission routes of nosocomial COVID-19 and discussed infection control strategies.

**Methods:** We retrospectively analyzed the severe acute respiratory syndrome coronavirus 2 reverse transcription-polymerase chain reaction (RT-PCR) testing results according to time point and evaluated transmission routes.

**Results:** Since COVID-19 was first confirmed in a healthcare worker (HCW) on 11/13/2020, we performed RT-PCR tests for all patients and caregivers and four complete enumeration surveys for all HCWs. We detected three clusters of nosocomial spread and several sporadic cases. The first cluster originated from the community outbreak spot, where an asymptomatic HCW visited, which led to a total of 22 cases. The second cluster, which included patient-to-patient transmission, originated from a COVID-19 positive caregiver before diagnosis and the third cluster involved a radiologist and a banker. We took measures to isolate Building 1 of the hospital for 17 days and controlled the outbreak during a period of increasing community COVID-19 prevalence. Universal screening of all inpatients upon admission and resident caregivers was made mandatory and hospital-related employees are now screened monthly.

**Conclusion:** Infection control strategies to prevent the nosocomial transmission of emerging infectious diseases must correspond with community disease prevalence. Our data reinforce the importance of multi-time point surveillance of asymptomatic HCWs and routine surveillance of patients and caregivers during an epidemic.

**Keywords:** SARS-CoV-2; Nosocomial Transmission; Outbreak; Infection Control

Dahee Kim <https://orcid.org/0000-0002-8985-8112>You Jung Kim <https://orcid.org/0000-0003-4766-9054>Hwa Young Shin <https://orcid.org/0000-0002-2401-3557>Mihee Kim <https://orcid.org/0000-0001-7781-8183>Eun Ji Kim <https://orcid.org/0000-0002-8848-4016>Seung-Ji Kang <https://orcid.org/0000-0002-3298-0520>Sook-In Jung <https://orcid.org/0000-0002-1577-678X>Kyung-Hwa Park <https://orcid.org/0000-0003-2836-6963>

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### Disclosure

The authors have no potential conflicts of interest to disclose.

### Author Contributions

Conceptualization: Park KH. Data curation: Lee U, Wi HN, Choi O, Park JW, Kim D, Kim YJ, Shin HY, Kim M, Kim EJ. Formal analysis: Kim SE. Investigation: Lee U, Wi HN, Choi O, Park JW, Kim D, Kim YJ, Shin HY, Kim M, Kim EJ. Methodology: Lee SY. Visualization: Kim SE. Writing - original draft: Park KH. Writing - review & editing: Kim SE, Kang SJ, Jung SI.

## INTRODUCTION

Since coronavirus disease 2019 (COVID-19) was first described in December 2019 in China, severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the virus responsible for COVID-19, has spread throughout the world. There have been numerous reports of COVID-19 in healthcare workers (HCWs) and hospitalized patients in several countries globally.<sup>1-3</sup> Although it is probable that hospital-acquired infections are also key factors in COVID-19 transmission, the contribution of nosocomial transmission to the spread of COVID-19 is currently unclear.

At present, South Korea is experiencing its third wave of COVID-19, which began mid-November 2020. Recently, we experienced a COVID-19 outbreak at Chonnam National University Hospital (CNUH) in Gwangju, South Korea, following the diagnosis of a HCW with COVID-19 on 11/13/2021. In this study, we report our experience in managing the in hospital COVID-19 outbreak. As a result of our study, we have changed our infection control strategies for preventing nosocomial transmission to correspond with community prevalence.

## METHODS

### Hospital overview

CNUH is a major acute teaching hospital with over 1,000 beds and a 24 h accident and emergency service, serving over 3.5 million people in the Chonnam province and Gwangju metropolitan city. CNUH is composed of seven buildings (buildings 1, 2, 3, 5, 6, 7 and 8) (**Supplementary Fig. 1A**). Building 1 was constructed in 1979 and building 8 was constructed in 2001. Buildings 1 and 8 each have twelve floors. Building 7 is next to building 8, and the two buildings are connected on floors 1, 2 and 7. Buildings 1 and 7 are linked on floor 2 by a sky bridge. The general ward of building 1 comprises two wings (A and B), a communal toilet, and a communal bathroom. In addition, there is one single-patient room, five two-patient rooms, and five six-patient rooms in each wing (**Supplementary Fig. 1B**). There are toilet facilities in each single or two-patient room in the ward.

### Hospital COVID-19 prevention measures before the healthcare-associated outbreak

All visitors and patients filled out a questionnaire regarding travel and contact history and underwent thermal scanning for fever before entry into the hospital premises was permitted. All patients with scheduled operations were only admitted following presentation of a negative SARS-CoV-2 reverse transcription-polymerase chain reaction (RT-PCR) test within 48 hours of admission.<sup>4</sup> Each outpatient was only allowed 1-2 accompanying person(s) when attending the specialist outpatient clinic. Each inpatient was restricted to only one attending caregiver throughout the period of hospitalization, except near the time of death; however, caregivers could be changed without restrictions. Patients with fever (> 37.5°C) or respiratory symptoms were transferred to the triage room in the emergency area or outpatient clinic for SARS-CoV-2 RT-PCR testing. Medical staff in the triage room wore personal protective equipment (PPE) including gowns, gloves, N95 respirator and face shields or goggles. Everyone in the hospital was encouraged to wear masks and follow hand hygiene practices. Our administrative office recommended to avoid large events and gatherings, but it was not mandatory.

### Test systems and contact tracing after the first confirmed COVID-19 HCW case in the hospital

The first confirmed COVID-19 case was a 30-year-old second-grade neurosurgery resident. On 11/13/2020, the patient visited the triage room presenting with cough and myalgia. The patient had no history of travel or close contact with confirmed COVID-19 cases. Following confirmation of COVID-19 infection on the evening of 13/11/2020, our infection control team announced the closure of the emergency room (ER) of the hospital; the ER and neurosurgical intensive care unit (NCU) were the main workplaces of the neurosurgery resident diagnosed with COVID-19. We then conducted contact tracing and tested HCWs, patients and caregivers in all areas served by neurosurgeons (ER, NCU, general neurosurgery wards [6A and 6B]) for COVID-19.

RT-PCR was performed using combined nasopharyngeal and oropharyngeal swabs in the CNUH laboratory, a diagnostic facility for COVID-19 authorized by the Korean Center for Disease Control and Prevention (KCDC). RNA was extracted using an automated nucleic acid extraction system (AdvanSure™ E3 System; LG Chem, Korea). Extracted RNA was amplified using a commercial kit (PowerChek™ 2019-nCoV Real-time PCR Kit; Kogenebiotech, Korea) and the envelope (*E*) and RNA-dependent RNA polymerase (*RdRP*) genes were detected (CFX96™ Real-time PCR detection system; Bio-Rad, USA). A positive RT-PCR result was defined as both *E* and *RdRP* genes had Ct values of 35 or less, whereas a Ct values over 40 was considered negative; a Ct values of 35–40 was considered indeterminate. In total, 439 respiratory samples from 344 HCWs, 47 patients and 48 caregivers were obtained between 11/13/2020 and 11/14/2020.

Close contacts of suspected/confirmed COVID-19 cases, as defined according to the World Health Organization guidelines,<sup>5</sup> were tested for COVID-19. Close contacts with negative test results were obliged to self-quarantine for 14 days following their most recent contact with a confirmed COVID-19 patient, then retested at the end of the quarantine period. In cases of contact but not close contact, self-quarantine was not enforced, but active and passive monitoring were implemented. During active monitoring, the local public health authority assumed responsibility to establish regular communication with exposed people to assess for symptoms. Passive monitoring required exposed people to self-monitor by performing regular temperature checks.

### Ethics statement

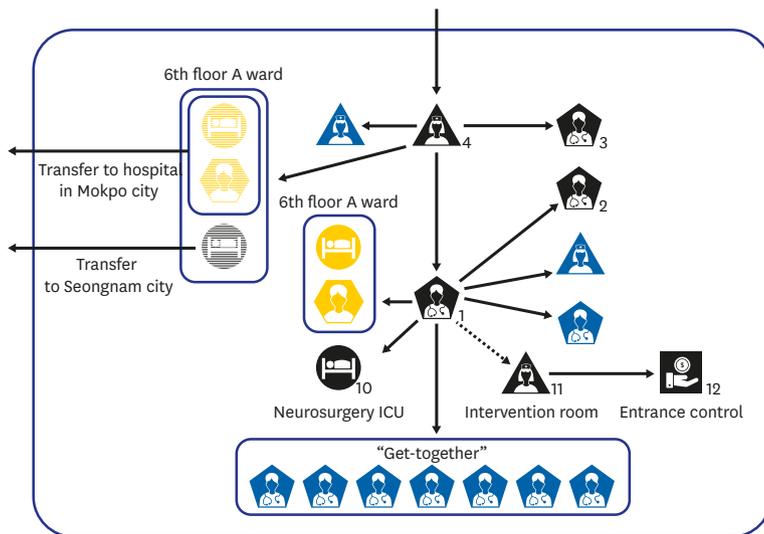
This study was approved by the Institutional Review Board of Chonnam National University Hospital (IRB No. CNUH-2021-186). Informed consent was waived because of the retrospective nature of the study.

## RESULTS

### Outbreak in the department of neurosurgery

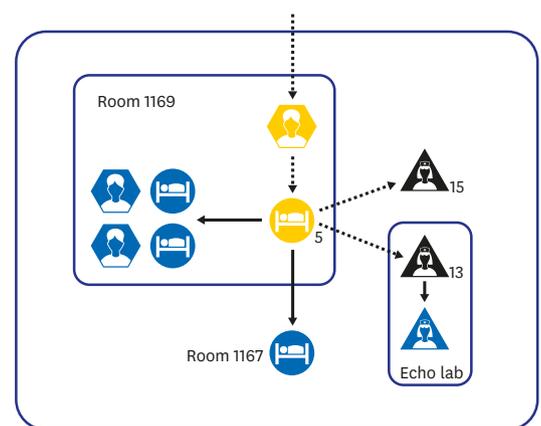
Following confirmation of COVID-19 in the second-grade neurosurgery resident, we traced contacts made with the COVID-19 case from 11/09/2020 to 11/13/2020; we found a symptomatic third-grade neurosurgery resident and discovered that 13 neurosurgeons had attended a get-together ('hoesik' in Korean) for 6 hours with the first COVID-19-confirmed HCW on 11/12/2020. **Fig. 1A** shows the estimated transmission routes of 22 cases of COVID-19 in the neurosurgery outbreak. Through contact tracing and testing, we diagnosed COVID-19 in two other neurosurgery residents (**Fig. 1A**, Case numbers 2 and 3) and a nurse (**Fig. 1A**, Case number 4) of ward 6A of building 1 on 11/14/2020. We quarantined all neurosurgery doctors and nurses,

**A. In-hospital transmission cluster 1, neurosurgical outbreak (n = 22)**

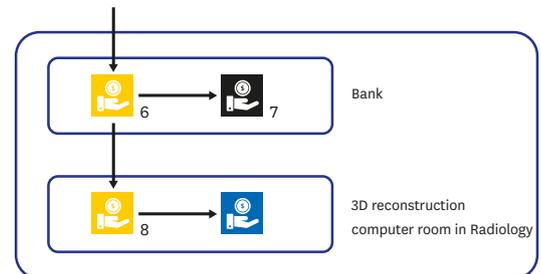


- A group of transmission
- Highly suspected path of transmission
- Possible path of transmission
- Nurse or nursing student
- Doctor
- Patient
- Caregiver
- Banker or Hospital employee (without direct care with patients)

**B. In-hospital transmission cluster 2, 11th floor ward (n = 10)**



**C. In-hospital transmission cluster 3 (n = 4)**



**D. Sporadic cases (n = 4)**



**Fig. 1.** Estimated transmission routes of COVID-19 cases who were diagnosed within CNUH or were epidemiologically associated with CNUH. **(A)** The in-hospital transmission during the neurosurgery (NS) department outbreak. Discharged patients and a caregiver from NS ward were transferred to other hospitals in Mokpo city and Seongnam city. **(B)** Intra-hospital transmission involving 10 COVID-19 patients. **(C)** Related COVID-19 cases in a private company (KJ bank). **(D)** Sporadic cases. The numbering of the COVID-19 case symbols represents the order in which the cases were diagnosed in the laboratory of CNUH during the complete enumeration survey. Blue coloring indicates COVID-19 cases that were diagnosed during the self-isolation period and yellow coloring indicates family members within a transmission group. Symbols with a grid pattern represent COVID-19 cases that caused community transmission after discharge. C.S.D = central supply department, COVID-19 = coronavirus disease 2019, CNUH = Chonnam National University Hospital.

healthcare assistants, and cleaners of NCU and neurosurgery wards (6A, 6B) from 11/14/2020 to 11/27/2020. The ER remained closed throughout this period because we were unable to respond to emergency neurosurgery calls due to the possibility of COVID-19 in HCWs. We recommended patients to be discharged from the hospital and quarantine at home for 14 days, and the remaining inpatients and caregivers were quarantined for 14 days within the hospital. We performed RT-PCR follow-up tests every 3 days for the remaining NCU patients, and semi-weekly RT-PCR follow-up tests for the remaining patients/caregivers in the general wards during the 14 days following last exposure. The patients and caregivers who were discharged from the neurosurgery areas between 11/09/2020 and 11/13/2020 were invited by call to undergo RT-PCR testing. From our surveillance, we found that three patients/caregivers discharged from ward 6A and two patients/caregivers discharged from ward 6B were infected with SARS-CoV-2. Of the follow-up RT-PCR tests, one patient in the NCU (**Fig. 1A**, Case number 10) was diagnosed with COVID-19 on 11/17/2020. Unexpectedly, a nurse based in the intervention room (Case number 11) who had performed several neurovascular interventions was diagnosed with symptomatic

COVID-19 on 11/18/2020. During the quarantine period of the neurosurgery-based HCWs, three symptomatic and seven asymptomatic HCWs were diagnosed with COVID-19.

Epidemiological evaluation of Gwangju city revealed that the neurosurgery outbreak originated from the community outbreak spot of the Gwangju city.

### First complete enumeration survey of all hospital employees and all patients/caregivers

COVID-19 was confirmed in a total of four HCWs (three neurosurgery residents and one nurse, Case numbers 1–4 of Fig. 1A) by 11/14/2020. Our rapid response team was gathered in the morning of 11/15/2020, and their roles were activated according to our hospital's public health crisis situations manual (Table 1). Following this, we expanded RT-PCR testing to all hospital employees, including outsourced agencies and all hospitalized patients and their caregivers, to find asymptomatic COVID-19 patients. The first complete enumeration test (CET) was conducted from 11/13/2020 to 11/17/2020, during which a total of 730 patients, 498 caregivers, and 3,346 hospital staffs, employees and business company employees had been subjected to COVID-19 testing by RT-PCR. Table 2 shows the number of SARS-CoV-2 RT-PCR tests performed according to the professions of HCWs.

**Table 1.** Role of rapid response team for public health crisis situations

Team name	Major roles
Command and Control Department (Team Manager: The Chief Medical Officer, Executive Secretary: Director of the Medical Administration Department)	<ul style="list-style-type: none"> <li>Establish and command medical guidelines for each medical situation</li> <li>Divide roles, command/control for each team</li> <li>Report specific, major status reports and give instructions</li> <li>Collect and control relevant information</li> <li>Cooperate with external institutions such as operation of isolation ward. (Cooperate/provide staffing support to other medical institutions with isolation ward)</li> <li>Make other major decisions</li> </ul>
Medical Team (Team Manager: Manager of Infection Control Department, Executive Secretary: Infection Control Team Manager)	<ul style="list-style-type: none"> <li>Report results after performing examination or treatment for confirmed (suspected) cases, with emerging infectious disease</li> <li>Execute treatment guidelines for each treatment situation/train related staffs</li> <li>Operate isolation facility or room</li> <li>Cooperate with government epidemiological investigation team</li> <li>Regular monitoring/reporting of isolated patients in the hospital</li> <li>Report patient treatment results to relevant institutions</li> <li>Make business contact with health administrative agencies and patient transfer agencies</li> </ul>
Medical Support Team (Team Manager: Chief Nursing Officer, Executive Secretary: Ward Nurse Section Chief)	<ul style="list-style-type: none"> <li>Secure treatment space</li> <li>Support patients with emerging infectious disease (include suspected cases)</li> <li>Classify patients</li> <li>Secure equipment in the emergency medical center</li> <li>Support protective equipment and supplies</li> <li>Organize medical status records</li> <li>Plan out work schedule for Emergency medical team</li> <li>Internal/External counsel/report via telephone</li> </ul>
Administration Support Team (Team Manager: Secretary General, Executive Secretary: General Affairs Team Chief)	<ul style="list-style-type: none"> <li>Monitor employees/visitors</li> <li>Control surrounding area of the isolation ward and transport patients</li> <li>Waste disposal</li> <li>Support meals</li> <li>Manage cleaning, infectious disease prevention and control</li> <li>Manage electrical control system and wireless communication</li> <li>Manage patient reception, billing, and number management</li> <li>Overall support for other administrative duties</li> </ul>
External Cooperation Team (Team Manager: Head of Planning and Coordination Office, Executive Secretary: Head of Budget Team, Head of External Cooperation Team)	<ul style="list-style-type: none"> <li>Establish/maintain a cooperative system with related external agencies (Additional budget, Secure supply support)</li> <li>Check the medical status of visiting patients</li> <li>Press release writing</li> <li>Provide related information to other internal/external members</li> </ul>

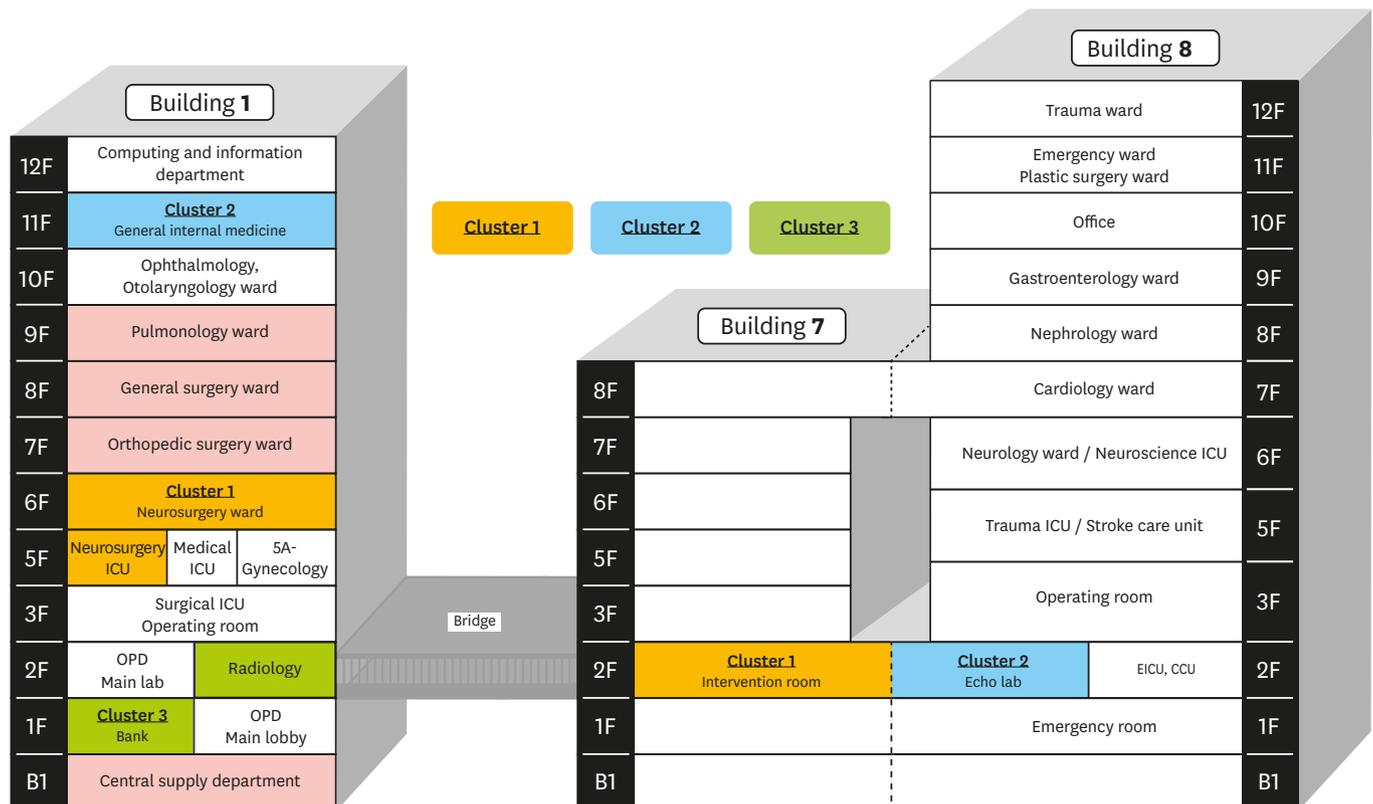
**Table 2.** The number of healthcare workers who underwent SARS-CoV-2 RT-PCR testing from 11/13/2020 to 12/04/2020 in Chonnam National University Hospital after the first confirmed case of COVID-19

Professions	1 <sup>st</sup> CET (Nov 13 to 17)	2 <sup>nd</sup> CET (Nov 18 to 23)	3 <sup>rd</sup> CET (Nov 24 to 28)	4 <sup>th</sup> CET (Nov 28 to Dec 4)
Doctors	709	472	471	468
Nurses	1,187	1,193	1,049	1,152
Medical support personnel	950	905	816	853
Employees	478	472	466	475
Business company (KJ bank)	22	26	28	24
Total	3,346	3,068	2,830	2,972

A person may undergo multiple SARS-CoV-2 RT-PCR tests in one CET cycle if COVID-19 symptoms are present.

SARS-CoV-2 = severe acute respiratory syndrome coronavirus 2, RT-PCR = reverse transcription-polymerase chain reaction, COVID-19 = coronavirus disease 2019, CET = complete enumeration test.

During the first CET, we found five additional asymptomatic COVID-19 cases, including a patient (Fig. 1B, Case number 5) on Floor 11 of building 1; two bankers who worked in Kwangju bank (Case numbers 6 and 7 of Fig. 1C) on floor 1; a radiologist (Case number 8, husband of Case number 6) on floor 2 of Building 1; and a caregiver on floor 9 of building 1 (Case number 9 of Fig. 1D). The overall COVID-19 positivity rate of the first CET ( $100 \times$  positive tests/total number of tests conducted,  $9/4,496$ ) was 0.2%. We were later informed by a community health center on 11/16/2020 about one asymptomatic COVID-19 case (caregiver of a patient from floor 7A who was discharged on 11/14/2020 after 3 days' admission), and one symptomatic COVID-19 case (patient from floor 8 discharged on 11/13/2020 after 4 days' admission). Fig. 2 shows a schematic diagram of COVID-19 occurrence sites in CNUH. The majority of COVID-19 cases were from within building 1, and the cases in building 8 were epidemiologically related to the COVID-19 cases of building 1.



**Fig. 2.** Floor plan of Chonnam National University Hospital and the sites of coronavirus disease 2019 occurrences. The areas of each cluster of intra-hospital transmission are colored similarly. Green areas represent the predicted sites of sporadic cases originating from outside the hospital. ICU = intensive care unit, EICU = emergency intensive care unit, CCU = coronary care unit, OPD = outpatient department.

### Outbreak resolutions

#### Quarantine of floors 5–11 of building 1

We did not find any epidemiological relationship between the neurosurgery outbreak and the seven COVID-19 cases discovered during the first CET. Therefore, we decided to quarantine building 1 on 11/17/2020 to prevent a larger healthcare-associated outbreak and to investigate potential epidemiological linkages. We assessed the COVID-19 risk for each ward, and classified the wards as high-risk (NCU, 6F, 7F, 8F, 9F, 11F) and low-risk (5A, 10F). For floors 5–11 of building 1, inpatients who had not had contact with confirmed COVID-19 patients were discharged or transferred to other hospitals, while inpatients and caregivers who had contact history with confirmed COVID-19 patients were quarantined in single rooms, cohort rooms or at home for 14 days after discharge. A total of 107 patients and 60 caregivers were isolated in the hospital. All employees in cohort wards used gowns, gloves, medical masks, and eye protection when providing care to patients in building 1. **Tables 3 and 4** show the cohort management guidelines of buildings 1 and 8, created by the CNUH infection control unit. Building 1 was closed to new admissions for 14 days. Outpatient clinics were also temporarily closed from 11/16/2020.

**Table 3.** Isolation (Building 1 Cohort) management guideline (1)

Building	EV NO.1	EV NO.2	EV NO.3	EV NO.8/ NO.9	EV NO.10	
Operating floors						
1	For patients in high-risk wards only	For patients in non-risk wards only	For CSD Only	For medical personnel only	For patient meals and medical waste transfer only (Use at designated time)	
	Excluding 10th floor	Floors 1, 2, 3, 5, 10				
8	EV NO.1	EV NO.2	EV NO.3	EV NO.6	EV NO.5	
	For medical personnel/patients and caregivers in non-risk wards			Contaminated laundry and medical waste transfer	For patients in high-risk wards only	EV NO.7
	CSD dirty articles transfer	CSD clean articles and patient meals transfer				
	All floor				Floors 1, 2, 5, 11	

**Table 4.** Isolation (Building 1 Cohort) management guideline (2)

Items	High-risk ward	Non-risk ward
Movement restrictions	Patient transfer: use EV No.1 (1 team only) Check that doors are locked on every floor/Do not use stairs	Patient transfer: use EV No.2 (1 team only)
Personal protective equipment	Wear four types of personal protective equipment - Main uniform, non-woven fabric gown, facial masks (KF94 level or - CPE plastic isolation gown, face mask (KF94 level), face higher), face protection (face shield or goggles), latex gloves - When entering the ward: four types of personal protective equipment should be worn - When leaving the ward: ① Remove gown, gloves, and face protection (excluding mask) and sanitize your hands before leaving the ward ② Replace contaminated mask and sanitize your hands after leaving the ward - Moving between floors: Personal protective equipment must be treated on the relevant floor and worn again on the entry floor - When applying isolation caution (contact with patients, caution against splashes etc.), additional protective equipment needs to be applied	
Secure rest space	- Clean zone: resting/eating area - Use of nurse room or designated patient room ① When entering clean zone: take off gown, gloves, face protection (excluding masks) ② Take off mask while eating or relaxing, replace your mask when finished ③ When exiting clean zone: wear four types of personal protective equipment (need to be placed in the clean zone)	
Patient placement	- Single/double room: one patient only (high risk patient priority – patients with symptoms etc.) - Multi-occupancy room: maximum four patients (Maintain the maximum distance between patients) - Distribute patients as far apart as possible if there is enough space in the hospital	
Patient and caregiver care	- Check proper wearing of mask occasionally. Do not enter another room. - One caregiver per patient. Safely record the list of guardians (department of management) - Re-entrance of the alternate caregiver or existing caregiver: Check the test results within 48 hours.	
Principles of treatment	- Treatment limited to in charge of patient - Minimize testing that requires a lot of movement/medical treatment (when absolutely necessary)	

(continued to the next page)

**Table 4.** (Continued) Isolation (Building 1 Cohort) management guideline (2)

Items	High-risk ward	Non-risk ward						
Discharged Patients	<ul style="list-style-type: none"> <li>- Patients and caregivers should wear polyvinyl gowns and gloves upon discharge</li> <li>- If previously un-reported discharge or only the caregiver needs to leave the hospital, be sure to contact the infection control office (management transfer to public health center)               <ul style="list-style-type: none"> <li>① Move patient to 1st floor with the transfer staff</li> <li>② Hand patient over to safety personnel</li> <li>③ Patient boards car or public health center vehicle waiting in front of the safe clinic</li> <li>④ Management transfer to public health center</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>① PCR test the day before discharge</li> <li>② Classify as active monitoring target when result is negative</li> <li>③ Provide active monitoring information</li> </ul>						
Patient transfer	<ul style="list-style-type: none"> <li>- Wear four types of personal protective equipment</li> <li>- Minimize contact during transfer, thorough hand hygiene after transfer</li> </ul>							
PCR F/U	<ul style="list-style-type: none"> <li>- COVID-19 PCR tests are periodically taken for patients and caregivers (Ward: 2 times a week/ICU: 3 times a week)</li> </ul>							
Examination	<ul style="list-style-type: none"> <li>- Minimize examination and contact the examination room in advance</li> <li>- Have the patient wear a gown and gloves</li> <li>- With transfer staff, avoid risks in surroundings while moving</li> <li>- Portable X-ray imaging: Wear four types of personal protective equipment</li> <li>- Machine moves outside after disinfection</li> </ul>							
Sample management	<ul style="list-style-type: none"> <li>- PCR sample: Triple packaging, delivery using icebox, transfer immediately</li> <li>- Other samples: Place sample in the sample zipper bag (marked as a COVID-19 suspected specimen), deliver it using a tray, disinfect the tray afterwards.</li> <li>- Carry out test after disinfecting the outer surface</li> <li>- The internal assistant delivers the sterilized specimen to the external assistant</li> <li>- External assistant: Wear a mask &amp; gloves when transporting samples, no entry into the ward</li> </ul>							
Cleaning & Disinfection	<table border="0"> <tr> <td>Patient only E/V</td> <td> <ul style="list-style-type: none"> <li>- Cleaned &amp; disinfected by cleaning crew</li> <li>- Wear four types of personal protective equipment</li> <li>- Sanitize hands each time gloves are changed</li> </ul> </td> </tr> <tr> <td>Ward</td> <td>Follow &lt;General Cleaning Guidelines&gt;, but use 40 times diluted bleach</td> </tr> <tr> <td>Bathroom</td> <td> <ul style="list-style-type: none"> <li>- Cleaning cycle (at least four times in the morning and afternoon)</li> <li>- If possible clean right after patient-use</li> </ul> </td> </tr> </table>	Patient only E/V	<ul style="list-style-type: none"> <li>- Cleaned &amp; disinfected by cleaning crew</li> <li>- Wear four types of personal protective equipment</li> <li>- Sanitize hands each time gloves are changed</li> </ul>	Ward	Follow <General Cleaning Guidelines>, but use 40 times diluted bleach	Bathroom	<ul style="list-style-type: none"> <li>- Cleaning cycle (at least four times in the morning and afternoon)</li> <li>- If possible clean right after patient-use</li> </ul>	
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Bathroom	<ul style="list-style-type: none"> <li>- Cleaning cycle (at least four times in the morning and afternoon)</li> <li>- If possible clean right after patient-use</li> </ul>							
Treatment of medical waste and contaminated laundry	<ul style="list-style-type: none"> <li>- External, carry out using a designated elevator</li> <li>- Dispose of all waste (including general waste) in quarantine medical waste container               <ul style="list-style-type: none"> <li>① In use, triple packaging is applied.</li> <li>② Keep the quarantine medical waste container closed at all times</li> <li>③ When carrying out quarantine medical waste, seal and disinfect it</li> <li>④ Carried out by people in charge (Wearing four types of personal protective equipment)</li> </ul> </li> </ul>							
Meal distribution	<ul style="list-style-type: none"> <li>- Patients and caregivers, resident workers (including cleaning staff): serve in the ward using disposable tableware</li> <li>- Leave your mask on except during meals, refrain from talking, keep distance</li> </ul>							
Ventilation	<ul style="list-style-type: none"> <li>- Open windows and emergency ramp doors once per duty to ventilate, but always keep ward entrance doors closed</li> </ul>							
Central supplies	<ul style="list-style-type: none"> <li>- Central supplies: Supply of goods to dedicated basket</li> <li>- Infusion fluid delivery: Delivered in a dedicated cart in front of E/V</li> </ul>							

#### *Surveillance of people with contact histories with confirmed COVID-19 patients*

The CNUH infection control team reviewed electronic medical charts, closed circuit television, and personal movements with the goal of identifying individuals who had had contact with confirmed COVID-19 patients; this was performed for each positive SARS-CoV-2 RT-PCR test. We predefined the range of exposure and patient close contacts. Although we attempted to trace contacts thoroughly, full tracing was not possible.

Of the cohort, 322 HCWs were quarantined, 279 HCWs were placed under active monitoring, and 29 HCWs were placed under passive monitoring (Table 5). Following incomplete contact tracing, emergency alert messages were sent to citizens through the Cell Broadcast System, encouraging people who had been in the CNUH area between 11/09/2020 and 11/17/2020 to visit screening centers voluntarily for testing.

#### *Five-day cycles of CET*

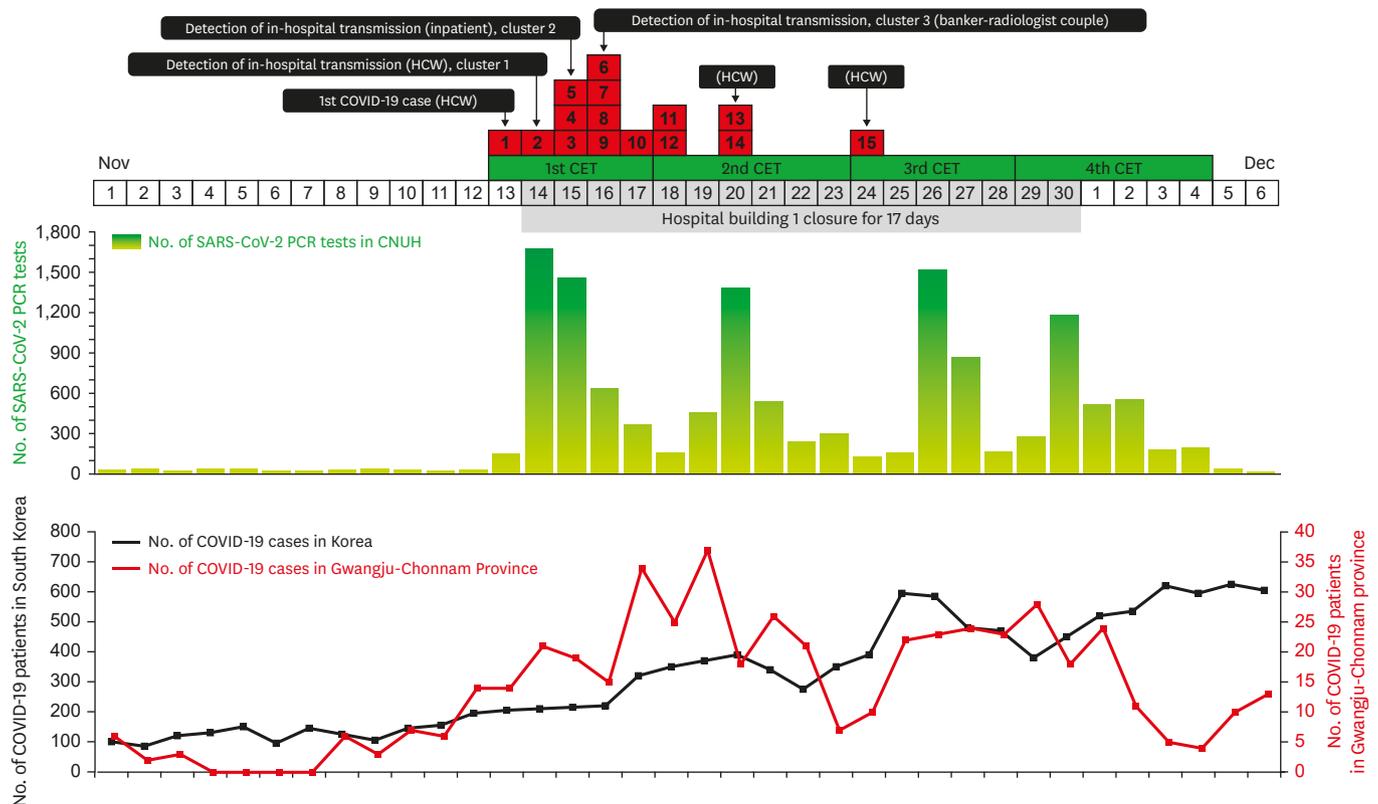
Following the detection of COVID-19 in CNUH, the community onset of COVID-19 patients increased simultaneously. We performed periodic testing (every 5 days) for the entire HCW

**Table 5.** Number of self-quarantine cases, active monitoring cases and confirmed cases from 11/13/2020 to 12/05/2020

Type of monitoring	No. of confirmed COVID-19 cases during stay in the hospital	No. in self-isolation	No. in active monitoring	No. in passive monitoring
Doctors	3	66 (8)	53	5
Nurses	5	179 (3)	160	0
Hospital-associated personnel	4	87 (1)	66	24
Inpatients	2	107 (3)	0	0
Caregivers	1	60 (2)	0	0
Total	15	499 (17)	279	29

The numbers in parentheses represents the number of people who were confirmed COVID-19 during self-isolation period. There were no confirmed cases during active or passive monitoring status. COVID-19 = coronavirus disease 2019.

population. Fig. 3 shows a timeline of healthcare-associated COVID-19 infections and the number of SARS-CoV-2 RT-PCR tests performed. During the second CET, we detected one symptomatic (Case number 13 in Fig. 3) and one asymptomatic (Case number 14 in Fig. 3) COVID-19 case, each without obvious epidemiological ties with previously confirmed COVID-19 cases in the hospital. During the third CET, one symptomatic HCW was diagnosed with COVID-19 (Case number 15 in Fig. 3); the HCW was a nurse who had worked on floor 11 until 11/13/2020. COVID-19 case numbers 13 and 15 were not under active or passive monitoring at the time of diagnosis.



**Fig. 3.** Timeline of the COVID-19 outbreak in CNUH. The red boxes indicate each COVID-19 case diagnosed in the CNUH laboratory. Layered red boxes represent the number of COVID-19 patients diagnosed per day. Numbers in the red boxes represent the temporal order of diagnoses in CNUH and correspond to the numbered cases in Fig. 1. Green graph (top) represents the number of SARS-CoV-2 PCR tests performed per day. Red and black graphs (bottom) represent the number of COVID-19 cases in South Korea and the surrounding community. CET = complete enumeration test, HCW = healthcare worker, COVID-19 = coronavirus disease 2019, CNUH = Chonnam National University Hospital, SARS-CoV-2 = severe acute respiratory syndrome coronavirus 2, PCR = polymerase chain reaction.

### Outbreak analysis

After performing four CET cycles in CNUH, and testing people outside of CNUH following calls or emergency message alerts, we discovered a total of 40 COVID-19 cases with suspicious links to CNUH, including the 22 cases detected during the neurosurgery outbreak. The second large cluster (cluster 2) of COVID-19 cases was linked to a patient on floor 11 (Fig. 1B, Case number 5). The initial SARS-CoV-2 RT-PCR test for Case number 5 was performed in the ER on 11/05/2020 and the result was negative; however, the same patient tested positive on 11/14/2020. Case number 5 had a 2D-echocardiograph on 11/12/2020. There were ten COVID-19 cases in cluster 2. Cluster 3 included a banker and a radiologist who were a husband-and-wife couple; the parents and children of the wife (banker) had tested positive for SARS-CoV-2 following RT-PCR testing. Case number 9 from floor 9 cared for her mother for 3 months, but the mother tested negative for SARS-CoV-2. In four cases of sporadic COVID-19 (Fig. 1D), there was no evidence of secondary transmission in the hospital.

During the quarantine period, the hospital quality improvement team ensured mask wearing compliance by all visitors and HCWs. Following the CNUH quarantine, our infection control policy was amended. Universal screening of all inpatients and resident caregivers was mandatory upon admission. A negative SARS-CoV-2 RT-PCR test within 48 h of admission was required. Whenever a caregiver changes, a negative SARS-CoV-2 RT-PCR test result was required.

Outpatient clinics re-opened on 11/18/2020 and the ER re-opened on 11/27/2020. On 12/01/2020, building 1 re-opened after 17 days' quarantine. Total patients admitted were 922 on 11/12/2020 before the first confirmed COVID-19 cases. The lowest number of admitted patients was 248 on 11/28/2020, and the total number of patients admitted on 12/07/2020 after the quarantine was 540. The official total of COVID-19 cases associated with the CNUH, including *n* order transmission, was 67.

### Change of infection control practices after outbreak

Universal screening of all inpatients and resident caregivers is now mandatory upon admission and on day 4 of hospitalization, and HCWs are tested monthly. For HCW and patients with potential exposure to patients with COVID-19, additional RT-PCR testing every 3 days for active monitoring and PCR every 5 days for passive monitoring are mandatory. Ventilation is an important factor in preventing the virus that causes COVID-19 from spreading. We identified areas that are not well ventilated and set split air conditioning units, fan coils or any system that runs with a recirculation mode not to recirculate. In cases where the recirculation of air is unavoidable, we increased outdoor air exchange by opening windows.

We recommended keeping windows in patient rooms open and opening emergency ramp doors once per duty, but always keeping the patient doors and the curtains between beds in the multi-occupancy room closed. An audit team including infection control team, quality improvement team, and nursing staff measured the performance rate of the guidelines (hand washing, mask, ventilation, etc.) regularly.

## DISCUSSION

Throughout the current COVID-19 pandemic, preventing nosocomial COVID-19 outbreaks has been a major challenge for hospitals. In this study, we found that three classes of COVID-19 cases posed the greatest risk as sources of transmission in healthcare settings:

SARS-CoV-2 positive HCWs who were not yet aware of their infection, SARS-CoV-2 positive caregivers before diagnosis and SARS-CoV-2 positive patients before diagnosis. Through epidemiologic evaluation, we found that during the neurosurgery COVID-19 outbreak (cluster 1), the initial source of COVID-19 was inflow from outside the hospital from a HCW, which consequently triggered intra- and inter-hospital COVID-19 spread. This highlights the important role of HCWs in the introduction of COVID-19 from the community into enclosed hospital settings. The number of asymptomatic cases of COVID-19 is high in young people.<sup>6</sup> Young people, including acting nurses and residents, comprise the majority of the hospital workforce, and are more likely to work in multiple places throughout hospitals as well as to be socially active. Younger patients may not be screened and diagnosed with COVID-19 due to their lack of symptoms. Our experience highlights the need for repeated mass screening of all HCWs to help reduce HCW-associated transmission in acute-care teaching hospitals, although there are debates regarding mass testing for asymptomatic HCWs to reduce nosocomial transmission.<sup>7-9</sup>

By implementing the CET survey, we found an additional two infection clusters and four sporadic cases. In epidemiological investigation, we predicted that case number 14 might have been the last spreader in hospital transmission. Therefore, the CET period was decided to end two weeks after case number 14 was confirmed positive (Dec 04, 2020). We set CET interval as every 5 days because we conduct PCR every 5 days for passive monitoring. The early detection of COVID-19 cases in the hospital was likely to have reduced community spread. We found evidence for intra-hospital transmission in cluster 2, and that the caregivers played an important role in nosocomial COVID-19 transmission. Identifying the source of infection for HCWs and caregivers is more difficult, as they migrate between the hospital and the community on a daily basis. Therefore, universal screening upon admission of all inpatients and resident caregivers may be an effective strategy to prevent outbreaks in tertiary care hospitals with high influxes of patients, especially when the prevalence of COVID-19 is increasing within the community. Our results suggest that a testing strategy should be adapted based on the prevalence of the disease within the population as predicted by epidemiological surveillance, with testing for symptomatic individuals at times of low prevalence, then implementing rapid expansion of testing to include asymptomatic HCWs during new infection wave.

The infection control policy for COVID-19, which includes the use of masks and frequent use of alcohol-based hand sanitizers, is currently being implemented in all South Korean hospitals. Combining facial masks and social distancing is effective at controlling COVID-19.<sup>10</sup> However, the extent of hand hygiene compliance among HCWs varies widely, ranging from 20% to 80%.<sup>10,11</sup> Mask wearing throughout the day in healthcare settings can be difficult. In CNUH, mask wearing compliance in patients/caregivers was not high (personal communication). A study of mask use in health care settings found that respiratory pathogens on the outer surface of used medical masks may result in self-contamination, and the risk increases with increasing time of mask use (> 6 h).<sup>12</sup> It is important for health authorities to provide clear guidelines for face mask wearing to increase compliance. Furthermore, it is necessary to implement hand hygiene and mask use improvement interventions targeting patients/caregivers, as well as HCWs.

During the quarantine of building 1, we generated management guidelines for ward cohorts including movement routes, patient room distribution principles, RT-PCR intervals, and patient care. During health crises such as epidemics, HCWs must work harder and for longer

periods of time, and often do so in a context where knowledge and understanding of the novel pathogen is still in its infancy. Unexpected outbreaks with nosocomial transmission bring fear and anxiety to HCWs, patients and caregivers. During the outbreak described in this study, it was important for HCWs to be supported, and to have clear management guidelines. Although our hospital already had manual about the public health crisis situations such as **Table 1**, in real practice, there were many miscommunications and difficulties. Actually, the infection control team was to act as a control tower and was burned out. By sharing our clinical experience, we hope that other hospitals facing COVID-19 outbreaks can enhance their preparedness and develop guidelines for caregivers, patients, and HCWs.

Our data reinforce the importance of multi-time point surveillance of asymptomatic HCWs, and of routine surveillance of patients and caregivers. Systems for the prevention of intra-hospital transmission should not be restricted to the hospital alone. Basic infection control policy (mask use, hand hygiene and social distancing) should also be implemented at the community level.

## SUPPLEMENTARY MATERIAL

### Supplementary Fig. 1

Map of Chonnam National University Hospital (CNUH) and layout of general ward in CNUH building 1.

[Click here to view](#)

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