



COVID-19 RESPONSE



Global Learnings Evidence Brief

Protecting Health Care Workers in South Korea During the COVID-19 Pandemic

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Table of Contents

I. Introduction

II. Methods

III. Health Care Worker Infections in South Korea

IV. Key Lessons

A. Centralized Triage

- Reorganization of Healthcare Facilities

- Risk Stratification and Bed Assignment

B. Hospital-level Triage

C. Equipping and Screening Health Care Workers

- Personal Protective Equipment (PPE)

- Limited Daily Work Hours

- Health Care Worker Screening

D. Containment of Community Spread

E. Adherence to the Fundamentals

V. Exploring Clusters of Health Care Worker Infections

VI. Discussion

VII. Challenges

VIII. Conclusion

VIII. Acknowledgements

IX. Appendix

- Appendix 1. Case Definition

- Appendix 2. Risk Stratification Examples

- Appendix 3. KCDC PPE Guideline

- Appendix 4. Seoul National University Hospital PPE Guideline

- Appendix 5. COVID-19 Infection Prevention and Management Checklist

X. References

I. Introduction

Healthcare workers (HCW) around the world have been on the frontline of the battle against Coronavirus Disease 2019 (COVID-19). In past epidemics of Severe Acute Respiratory Syndrome (SARS) and Middle East Respiratory Syndrome (MERS), many cases of secondary transmission occurred in hospitals. Given that hospitals are active battlegrounds for HCWs, protecting HCWs has multiple benefits as their safety is tied to the integrity of the medical system and wellbeing of the public. Safeguarding HCWs from COVID-19 allows health systems to:

1. Sustain the capacity necessary to care for a surge of patients (both COVID and non-COVID),
2. Prevent nosocomial spread to their patients and other staff members, and
3. Limit community spread through protection of HCW themselves and their family members.

Unfortunately, HCW infections have been a major problem in many countries (Table 1). Comparable, up-to-date data are sparse in the matter, but more than 3,000 HCWs have been infected in China and over 4,000 in Italy.¹⁻³ Meanwhile, the United States has been estimated by the Centers for Disease Control & Prevention (CDC) to have at least 9,282 HCW infections as of April 9th.⁴ This is likely a significant undercount as the State of Massachusetts alone had at least 2,200 infections on May 5th.⁵ The staggering numbers should be interpreted with caution given the inherent differences in HCWs per capita, differential access to testing, degree of community transmission, and epidemiological causes of the confirmed HCW cases. Nevertheless, HCW infection is an undeniable challenge that mandates timely deliberation given the anticipated longevity of the pandemic.

Table 1. Cases of COVID-19 among health care workers and the general population in Italy, Spain, United States, and South Korea

Country	Total Population in 2020	Report Date	Days since 100th case (Date of 100th Case)	Total No. of COVID-19 Cases ⁶	Cases per Million	No. of Tests per Million People	Total No. of HCW cases	% HCW of Total Cases	HCW Cases per 10,000 HCWs
Italy	60.5 million	3/20	25 (2/24)	41,035	678	3,419	4,268 ²	9.1%	72.4
Spain	46.8 million	4/21	49 (3/3)	194,515	4,156	22,222	35,295 ⁷	18.1%	788.0
U.S.	331.0 million	4/9	37 (3/3)	459,165	1,387	7,250	9,000+*	11%**	16.6
South Korea	51.3 million	4/3	44 (2/21)	10,062	196	8,641	241 ⁸	2.4%	4.9

Note. Total 2020 population numbers for all countries from 2019 Revision of World Population Prospects from the United Nations: <https://population.un.org/wpp/>. Counts of COVID-19 cases and tests reported from Our World in Data (3/2020-4/2020). HCW counts (doctors, nurses, midwives) obtained from the most recent year (2018 for Italy and South Korea, 2017 for Spain and U.S.) of the [Global Health Workforce Statistics database](#) of the World Health Organization Global Health Observatory data repository.

*Only 16% of all COVID-19 cases reported to CDC from Feb 2 to Apr 9 (49,370 out of 315,531) included data on one's occupational status in the medical field⁴

**Estimated by CDC based on reported cases⁴

South Korea has been recognized for its successes with mass testing and meticulous contact tracing, as well as efficiently flattening the curve of infections from its large outbreak in Daegu in less than a month (Figure 1). There has been less coverage for the way that the country redesigned its health system in order to respond effectively to emerging infectious disease outbreaks and avoid nosocomial infections that plagued the country during the 2015

MERS epidemic. In this evidence brief, we explore and identify the key health systems interventions and protocols that South Korea implemented in order to reduce the nosocomial spread of SARS-CoV-2, the virus causing COVID-19. Moreover, we investigate clusters of SARS-CoV-2 infections that did occur in health facility settings and assess the country’s response and adaptations to such incidents. Through this, we highlight the key lessons and details that other countries facing current and future waves of COVID-19 can utilize to improve their health system response, maintain care for all patients (COVID-19 and non-COVID-19), and protect health care workers.

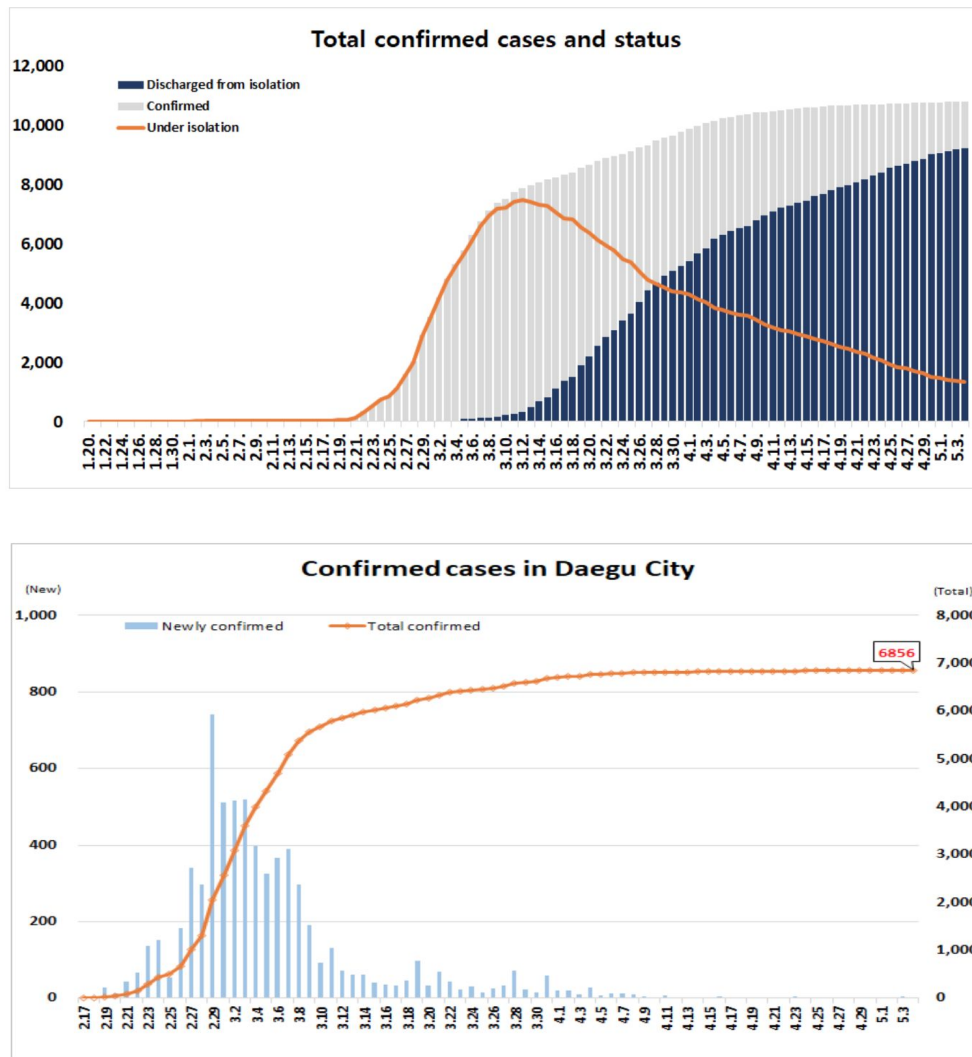


Figure 1. New and cumulative COVID-19 cases in South Korea (top) and Daegu (bottom) as of May 3, 2020. Reprinted from regular briefing by Korea Centers for Disease Control and Prevention, May 3, 2020⁹

II. Methods

Over a two-week rapid turnaround process, the team performed extensive semi-structured interviews via video conferencing and email with three frontline infectious disease specialists, a former director of Korea Centers for

Disease Control & Prevention (KCDC), and four physicians in Daegu, including a neurosurgeon, two infectious disease specialists involved in the central COVID response efforts, and a medical volunteer at an Infectious Disease Hospital. Interview questions were designed to understand the best practices to protect HCWs from COVID-19 in South Korea and catalogue the interviewees' assessment of Korea's successes, failures, and recommendations. Additionally, we conducted translations and reviews of official protocols from the KCDC and academic medical centers as well as other grey literature sources to identify common protective measures implemented in the hospitals and beyond to prevent HCW infections. Lastly, we sourced data about HCW infections from official KCDC and local government briefings, our interviewees, publicly available databases, and news media in order to compile country-level and subnational summaries and analyses.

III. Health Care Worker Infections in South Korea

On April 5th, KCDC released information on the status of HCW infections and their epidemiological etiology.⁹ Out of 10,062 confirmed cases, 241 (2.4%) were HCWs, the vast majority being nursing staff (190, 78.8%). 41.9% of the confirmed HCWs were due to community-based infections outside the hospital, 27.3% while providing general medical services, and 13.3% secondary to group infections in hospitals (Table 2). At least half of the reported HCW infections (121, 50.2%) arose from Daegu, including 14 doctors, 56 nursing staff, and 51 nursing aides.¹⁰ HCWs in South Korea were infected at a rate of 4.67 HCW cases per 10,000 HCWs compared to 4.47 non-HCW cases per 10,000 non-HCWs, a statistically non-significant difference. As of April 28th, seven HCWs (all nursing staff) caring for COVID-19 patients tested positive, and three HCWs while working in screening clinics. There were no known cluster outbreaks in isolation wards.¹¹

Table 2. Health Care Worker Infections and Source of Infection, April 3rd, 2020

Category		All HCWs	Doctor	Nursing Staff	Others
Total no. infected		241	25	190	26
Nosocomial infections	Treating COVID-19-positive patients	0	0	0*	0
	Working at COVID-19 screening clinics	3	1	2	0
	Providing general medical services	66	6	57	3
	Group infections in hospitals	32	4	23	5
Community-based infections		101	7	76	18
Unknown route of infection		26	5	21	0
Under investigation		13	2	11	0

Note. Adapted from a April 5th briefing about April 3rd data by the Central Disaster and Safety Countermeasure Headquarters on COVID-19.

*As of April 3rd, two nurses, who were treating COVID-19-positive patients, were suspected to be infected. They later received positive test results. As of April 28th seven nursing staff were deemed to have been infected during the care of COVID-19 positive patients.

IV. Key Lessons

Plaudits for Korea's COVID-19 response were hard to come by in February 2020. During the unexpected outbreak in Daegu, many patients passed away while waiting for hospitalization, the supply of masks ran low, and the government was criticized for its reluctance to institute stricter measures. Three months into the COVID-19 pandemic, the landscape surrounding Korea has dramatically shifted: 106 countries have sought out Korea's testing kits, its homegrown drive-through testing model has spread throughout the world, and growing international attention has been placed on its rigorous digital contact tracing measures.¹² Korea was equipped with some favorable preconditions, such as the close coordination between the KCDC and the Ministry of Health and Welfare, a national health insurance scheme, and rapid mobilization of their commercial laboratories. Nevertheless, there were some key overlooked features of its national strategy and health system that helped mitigate the spread of COVID-19, particularly within hospitals--even without imposing strict lockdowns or shelter-in-place orders, nor implementing a widespread cessation of non-COVID-19 health care.

Korea's national COVID-19 response was distinctly influenced by the 2015 MERS outbreak that infected 186 patients and cost 38 lives. The administration at the time was perceived to be elusive and dismissive, and the government was motivated to rethink its approach to infectious disease outbreaks and to prepare for the next national emergency. Such organizational reforms took place in the form of new laws, operational frameworks, and changes in the public mindset. Given that nearly half of the cases were secondary to nosocomial transmission, several layers of health system reorganizations were specifically set in motion, including expansion of negative pressure isolation units and stockpile purchases of personal protective equipment (PPE). Therefore, when the country faced another respiratory virus in 2020, Korea was ready to deploy its full arsenal. Its macro- and micro-level strategies not only safeguarded its communities but also the health system, and its low rate of HCW infections during the first several months of the pandemic suggest that its suite of interventions were effective.

From our interviews and reviews of protocols, the five major elements at the crux of Korea's strategy in protecting its HCWs were:

- **Centralized triaging:** efficient mobilization of finite resources across a region while providing the appropriate level of care in controlled settings
- **Hospital-level triaging:** prevention of cross-contamination within the hospital while maintaining the integrity and functionality of the health system
- **Equipping and screening HCWs:** application of stricter guidelines for PPE, screening, testing, and self-quarantine for HCWs
- **Limiting community spread:** concurrent administration of robust testing, supportive contact tracing and self-quarantine, consistent monitoring, and public guidelines for social distancing
- **Adhering to the fundamentals:** diligent compliance with basic public health principles

A. Centralized Triage

“ Stratification therefore is key. Once we allocate high-level isolation units for treating mild patients, severe or critically-ill patients will be isolated in less-equipped and less-protected units. This will subsequently leave health care workers at greater risk of infection as they manage severe or critically-ill patients while providing critical care or aerosol-generating procedures. ”

-Dr. HongBin Kim, Professor, Department of Internal Medicine, Seoul National University Bundang Hospital

Central triaging served two main functions to

1. Optimize the quality of patient care by securing medical resources (ICU, ventilator, ECMO, etc) for severe and critically ill patients, and
2. Efficiently concentrate, prioritize, and mobilize finite resources (e.g. PPEs, negative pressure rooms, HCWs, etc).

Reorganization of Healthcare Facilities

1. Screening

Local Designated COVID Screening Clinic

Upon developing signs and symptoms suspicious for COVID-19 (fever or respiratory symptoms), the general public was instructed to call the national COVID-19 hotline (1339) for a consultation and be referred to a local designated COVID screening clinic.¹³ Instead of directly presenting to a primary care clinic or a hospital emergency department, patients were initially evaluated at a local screening clinic, most frequently operated by regional public health centers. Additionally, even individuals without symptoms or epidemiological risk factors were still able to be evaluated and tested at the screening centers at their own expense. Every HCW at the screening clinic was equipped with Level D PPE ([Appendix 3](#)) with N95 respirators.

A total of 261 local COVID screening clinics were operated by public health centers, regional medical facilities overseen by the Ministry of Health and Welfare that provided a central point of coordination.¹³ Other types of screening clinics (e.g. drive-through and walk-through) were later implemented to accommodate a greater need for testing upon the surge of cases in February and March. The screening clinics were ultimately able to centralize each region's screening efforts, funneling potential infectious sources through a standardized channel. Individuals with COVID were isolated accordingly and prevented from unknowingly infecting others.

2. Treating Confirmed/ Suspected Patients

National Designated Isolation Units

National Designated Isolation Units (NDIU), established prior to the COVID-19 Outbreak, were built to provide appropriate clinical management for suspected and confirmed patients under isolation while protecting both the patient and HCWs. After the 2015 MERS outbreak, the Korean government increased the number of NDIUs in order to better prepare for future outbreaks, such as SARS, Avian Influenza, MERS, emerging infectious diseases, and biological agents. As of 2019, two types of NDIUs were established with a total of 535 beds across 29 hospitals nationwide (Table 3).

- a. High-level Isolation Units: Designed for infected patients within a negative pressure isolation facility, including an isolated patient room and bathroom. These units aided in preventing nosocomial spread with the use of built-in negative pressure facilities and fully separated decontamination spaces. They were typically reserved for critically-ill COVID-19 patients.
- b. General Isolation Units: Non-negative pressure isolation units reserved for treating patients requiring contact precautions. These units were constructed before 2015 as part of the governmental initiative to establish infectious disease-specific inpatient-level care.

Table 3. National Designated Isolation Units in Korea, 2019

	Number of single occupancy hospital rooms	Number of multi-occupancy hospital rooms (number of beds in multi-occupancy rooms)	Total number of rooms (total number of beds)
High-level isolation units	141	20 (57)	161 (198)
General isolation units	13	80 (324)	93 (337)

Note. Adapted from Protocol for National Designated Isolation Units by the Korea Centers for Disease Control and Prevention, November 2019¹⁴

Designated Hospitals

Individuals who tested positive at COVID-19 Screening Centers were routed to appropriate designated COVID-19 hospitals based on their severity of illness and availability of beds. At the time of the 2015 MERS outbreak, the Korean government designated certain hospitals (mainly public hospitals) to secure hospital beds and optimize resources for treating MERS patients. Upon recovering from the outbreak, such designated hospitals received reimbursement, and greater engagement of private hospitals was cultivated through incentivization policies. A discussion around establishing a concrete healthcare delivery system for emerging infectious diseases alongside a network of Infectious Disease Hospitals also occurred at that time. While the progress in integrating central and regional Infectious Disease Hospitals was slow, 69 hospitals were quickly designated and transformed into Infectious Disease Hospitals in response to the COVID-19 crisis. Existing non-COVID-19 inpatients were transferred to other institutions in order to accommodate COVID-19 patients exclusively in the entire hospital or dedicated wards.¹⁵ The government secured additional beds for patients with severe symptoms across 50 hospitals in addition to the 198 national designated high-level isolation units. Dedicated beds for COVID-19 were established at a total of 104 hospitals.¹⁶

Designated Emergency Medical Centers

The Korean government also designated a number of emergency medical centers at tertiary hospitals/large academic medical centers for critically-ill patients with COVID-19-like symptoms to support their timely treatment during the “golden hour.”

Community Treatment Centers

In order to simultaneously isolate and care for COVID-19 patients while also relieving hospitals of bed shortages, the Korean government procured government-run facilities and retreat centers owned by private corporations, and transformed them into temporary isolation wards. Clinically stable patients who did not warrant inpatient treatment were quarantined and monitored by HCWs regularly.

3. Securing Medical Care for Non-COVID Patients

COVID-19 Protection Hospitals

COVID-19 Protection Hospitals were established to ensure accessibility and safety of non-COVID-19 patients by spatially dividing patient care areas for respiratory versus non-respiratory patients. Type A hospitals provided outpatient services that separated respiratory and non-respiratory patients whereas Type B hospitals consisted of both outpatient and inpatient services for COVID and non-COVID patients. The National Central Disaster and Safety Countermeasures Headquarters received applications and designated 303 hospitals in South Korea as COVID-19 Protection Hospitals on March 7. All Protection Hospitals operated outpatient clinics for respiratory patients, 209 of which also managed screening clinics capable of specimen collection. 113 Protection Hospitals concurrently had inpatient rooms dedicated to respiratory patients as well. The designation status, however, was not mutually exclusive: a hospital could be selected as a both Designated COVID-19 and Protection Hospital. For instance, the National Medical Center (NMC), a national public hospital in Seoul funded by the Ministry of Health and Welfare to lead much of the central care coordination efforts, was designated as an Infectious Disease Hospital while also being a Type A Protection Hospital: an Infectious Disease Hospital given that it provided inpatient care specific for COVID-19 patients, and a Protection Hospital as it provided outpatient services to both COVID-19 and non-COVID-19 patients by maintaining strict spatial separation between the two patient cohorts.

Table 4. Health Care Facilities in South Korea for the Care of COVID-19 and Non-COVID-19 Patients.

	Aim	Types of Facility	Number of Facilities
Designated COVID-19 Hospitals	Inpatient care of COVID-19 patients	Tertiary hospitals, Community hospitals	104 hospitals, including 69 Infectious Disease Hospitals
Community Treatment Centers	Isolation and care for COVID-19 patients with mild severity of illness	Non-medical facilities	16 centers (March 15)
Designated Emergency Medical Centers	Emergency medical care of critically-ill patients with COVID-19 symptoms	Tertiary hospitals	n/a
COVID-19 Protection Hospitals	Continued care and protection of non-COVID-19 patients and HCWs from infection	Tertiary hospitals, Community hospitals	344 hospitals (April 13)

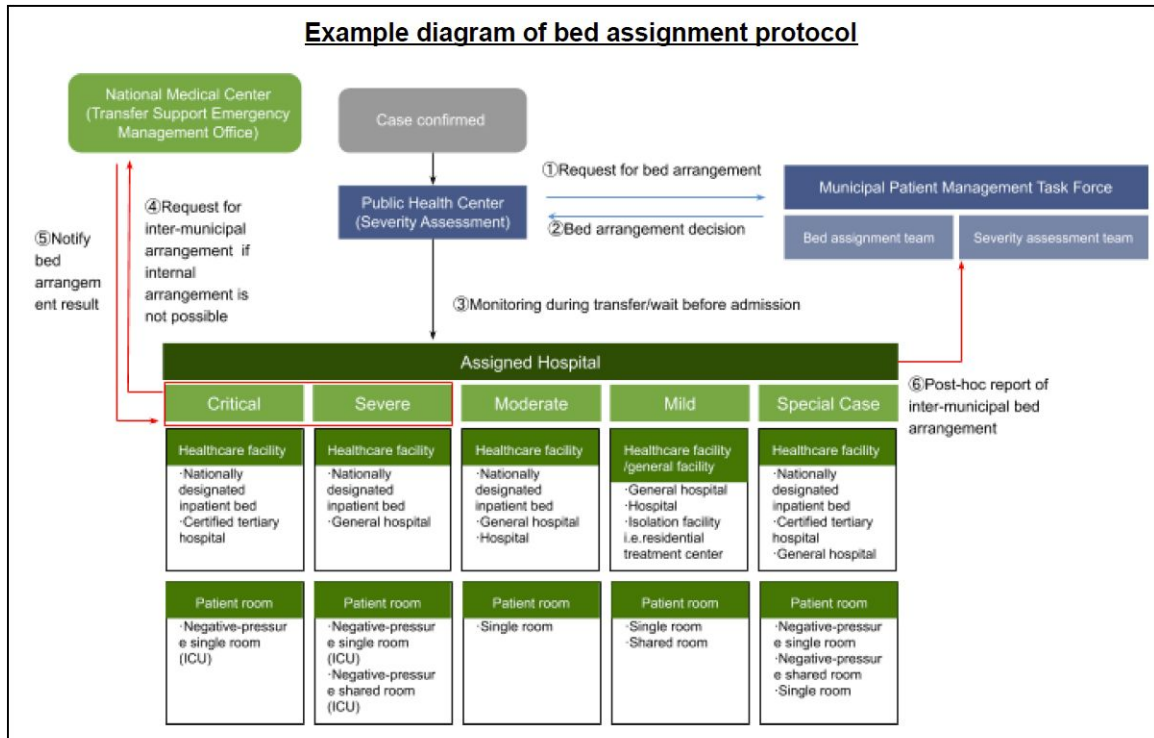
Note. Data for number of facilities from the Ministry of Health and Welfare, Republic of Korea (2020)

Risk Stratification and Bed Assignment

1. Central Coordination of Tiered Medical Care

Each designated facility within a given region was delegated with a specific level of clinical COVID-related care. The Patient Management Task Force (PMTF) at the city/province-level spearheaded bed assignments based on the severity of each patient. While mild patients were largely monitored at isolation facilities (e.g. Community Treatment Centers), moderate to critical patients were hospitalized and treated at general or tertiary care hospitals (an example of a severity-specific model of assignment to medical facilities can be found in Figure 2). When an escalation or step down of care was needed, the designated facility reported to the PMTF for an intra-municipal transfer to appropriate facilities. In cases of any bed shortage in a given city

or province, the Transfer Support Emergency Management Office at NMC orchestrated patient transfers between the two regions. A dynamic referral system allowed for a fluid hand-off between institutions.



* Special wards: Dialysis patients (dialysis ward), pregnant women (delivery room), transplant recipients (sterile unit)

Figure 2. KCDC Example Central Bed Assignment Protocol with Risk Stratification

Reprinted from Covid Playbook Appendix (v1.0), retrieved from https://www.covidtranslate.org/CovidPlaybook_Appendix_EN_v1.0.pdf, English translated by the Covid Translate Project. Original source from COVID Response Guidelines (For Local Governments) 7-3 Appendix by the Central Disease Control Headquarters and the Central Disaster Management Headquarters, Republic of Korea, April 2 2020.¹⁷

2. Patient Severity Classification

KCDC advised the use of a consistent patient severity classification protocol by each city, county, and district governments in instituting a system that would enable methodical assessment of confirmed patients and rapid identification of those with known risk factors, e.g. advanced age or chronic health conditions. Local governments were able to modify the selected protocol in accordance with their available assessment modalities and resources. Three example guidelines and one illustrative case of an original scoring system are presented in [Appendix 2](#).

3. Principles of Bed Assignment¹⁷

Confirmed patients

Negative-pressure single rooms should be used whenever possible to prevent circulation of air from a confirmed patient’s room throughout the hospital. If no negative pressure room is available, air circulation should be minimized from the confirmed patient’s room into the hospital building. If a single room is not available, the patient can be admitted to a shared room specific for confirmed cases on a ward that is

completely separate from regular patient wards or in an isolation facility, such as a community treatment center.

Detailed protocol¹⁷ :

1. Negative-pressure single room must be used, as a general rule
2. If (1) not available, use a negative-pressure shared room
3. If (2) not available, use a regular single room
4. If (3) not available, use a regular shared room
 - a) Note: 3-meter distance between patient beds not necessary
5. If (4) not available, use all rooms on an entire floor
6. Severely ill patients must be admitted to nationally-designated isolation beds in negative pressure single rooms
 - a) Distribute among negative pressure rooms in tertiary hospitals
7. Conditions for steps (3), (4), (5):
 - a) Movement: Separate patient movements completely between confirmed and regular patients; when a confirmed patient is admitted to a regular room, the entire patient ward should be dedicated to COVID-19 patients
 - b) Ventilation System Standards: Adjust the hospital ventilation system to use 100% of outside air, and do not re-circulate indoor air.

Suspected patients

A negative-pressure single room is recommended whenever possible; if no negative-pressure single room is available, use a regular single room that meets the ventilation system standards(as defined above in 7.b.).

Prioritize high-risk patients who require medical procedures when assigning negative-pressure beds.

B. Hospital-level Triage

“ The most important principle is to restrict the COVID patients’ access to the emergency department and the outpatient wing, and provide their care in a spatially separated, designated/ isolated setting. Once COVID patients come into contact with regular patients, the system is bound to collapse. At that time, there will not only be deaths from COVID, but also from the rest of our patients, especially those in need of immediate intervention, let’s say from stroke or MI... A dire situation in which the HCWs cannot do much either. ”

-Dr. Kyoung-Tae Kim, Associate Professor, Department of Neurosurgery, Kyungpook National University Hospital

Hospital-level triage served two main functions:

1. Construct complete spatial separation between COVID and non-COVID patients, and thereby lower the risk of in-house cross-contamination, and
2. Sustain the full functionality of the hospital to provide optimal medical care to those in need.

1. Main Entrance

Visitors were restricted, and visitor access was managed strictly at the entrance. Hospitals typically performed main entrance-level screening procedures to stop any suspected patients or visitors from entering the hospital and to appropriately guide those with symptoms and/or risk factors to the screening clinic outside the hospital or triage center at the emergency department. Especially at COVID-19 Protection Hospitals, visitors other than patients' caregivers were prohibited from entering hospital wards and emergency rooms. Only one caregiver per each patient was permitted to enter after a required screening process that included a short questionnaire.¹⁸

Examples from Kyungpook National University and Seoul National University Bundang Hospitals (SNUBH)

Upon presenting to the main entrance, patients and visitors were handed a brief questionnaire on (a) presence of fever and respiratory symptoms, and (b) epidemiological risk factors (contact with confirmed cases or international travels within 14 days). A day entrance pass was issued only when the body temperature was found to be below 37.5C using a non-contact thermometer. SNUBH also reduced the number of entrances to restrict the inflow into the hospital.

Restrictive entry could have potential drawbacks

Many private hospitals tried to protect themselves after experiencing financial damage, including fines by the government, during the 2015 MERS outbreak. For example, some hospitals denied care for patients from Daegu.¹⁹ Without clear boundaries to restrictions, there could be unintended consequences and discrimination.

2. Screening Clinic

COVID-19 screening clinics were temporarily set up outside the hospital, e.g. under a tent at a parking lot. While the hospital screening clinics were able to identify COVID-19 carriers, similar to the local designated screening clinics and drive-through/ walk-through testing sites, the primary objective of the hospital screening clinics was to identify and evaluate all patients with fever or respiratory symptoms. The expected outcome was two-fold: (1) prevention of unscreened entry into the hospital, and (2) prevention of contact between non-COVID outpatients and inpatients with COVID-19 suspected and confirmed patients.

A decision to pursue COVID testing was made after a thorough evaluation. Tested individuals were instructed to return home and self-quarantine while waiting for results, whereas others were given a day entrance pass if they were deemed to be at low risk of COVID-19. Per the KCDC guidelines, the clinics were equipped with a visitor waiting area, examination rooms, isolation room for suspected patients, specimen collection room, and PPE (surgical masks and N95 respirators (for patients and HCWs respectively), hand sanitizers, face shields, disposable gowns and gloves, shoe covers, and coveralls).²⁰ Installation of negative

pressure rooms was preferred when possible. SNUBH also equipped their screening clinics with a separate x-ray imaging room (blueprints depicted in Figure 3).

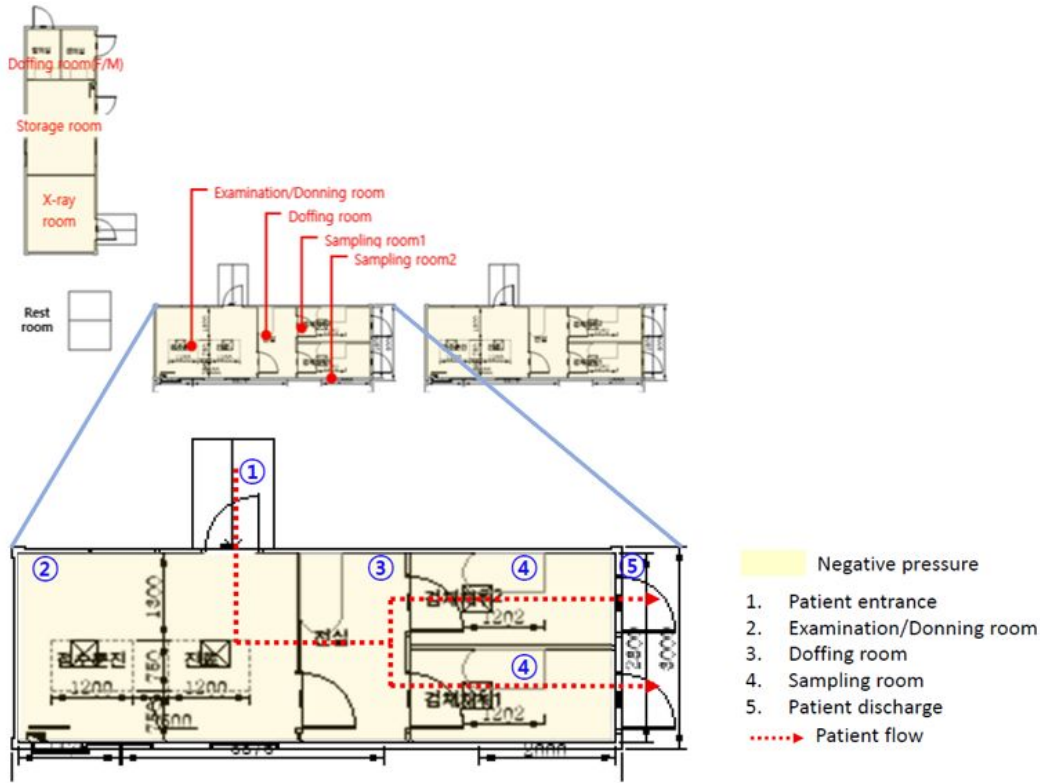


Figure 3. A COVID-19 screening clinic at Seoul National University Bundang Hospital (used with permission from SNUBH).

3. Emergency Department

Capacity for emergent medical care needed to be ensured even in the setting of a national epidemic, and therefore another layer of screening was established at the emergency department (ED) entrance. Those without risk factors were able to receive standard medical care, while individuals with symptoms and risk factors were transferred to a negative-pressure isolation room for additional triage. The objective of ED screening was to monitor all incoming hospital visitors around the clock without compromising the quality of emergent patient care and to prevent nosocomial spread within the ED.

4. Spatial Separation Between COVID and Non-COVID Patients

All designated hospitals adhered to a complete separation of care for COVID patients from the rest by using COVID-specific passageways (check-in desks, hallways, elevators, etc), wards, units, and buildings whenever possible. Tertiary care centers created temporary isolation wards with and without portable negative pressure devices, and were able to treat confirmed and suspected patients in detached clinical settings.

Case 1. SNUBH

SNUBH had nine national designated high-level isolation units. Every unit was a single-patient negative pressure room, and five units were also equipped for ICU-level care, including ventilator, continuous renal replacement therapy, and even extracorporeal membrane oxygenation. As the number of confirmed cases increased, SNUBH renovated one general ward to an isolation ward with eleven beds using portable

negative pressure devices. Additionally, SNUBH preemptively created an isolation ward to hospitalize suspected COVID-19 patients and patients under investigation (PUI).

Case 2. Keimyung University Daegu Dongsan Hospital (an Infectious Disease Hospital)

Since this hospital was exclusively dedicated to treating COVID-19 patients, it ran “cohort wards” for COVID-19 patients who did not require ICU-level care in a non-negative pressure setting. The hospital contained 20 ICU beds, including four negative pressure ICU units.

C. Equipping and Screening HCWs

Personal Protective Equipment (PPE)

“ Having learned difficult lessons from the 2015 MERS outbreak, Korea was aware that the safety of health care workers was vital to overcoming another epidemic. While it is true that Korea’s central PPE protocol was aggressive, potentially more so than needed, no one argued for a downgrade for PPEs in an urgent setting where the system could not afford to lose the medical workforce. ”

-Dr. Hong Bin Kim, Professor, Department of Internal Medicine, Seoul National University Bundang Hospital

KCDC put forth guidelines on protective equipment recommendations, stratified by care setting and relevant medical activity ([Appendix 3](#)). Some hospitals tabulated further by exposure risk (e.g. Seoul National University Hospital PPE guideline listed in [Appendix 4](#)), but there was a general consensus about using Level D protection with a N95 respirator when caring for symptomatic (fever or respiratory symptoms), suspected, and confirmed COVID-19 patients. Compared to other global guidelines, the KCDC recommended a higher level of protection for the care of suspected or confirmed COVID-19 patients by suggesting a N95 respiratory-equivalent as the baseline rather than surgical masks (Table 5). Other guidelines may have had to adapt their guidelines due to respirator shortages. Regardless, there appeared to be a difference in assessing the aerosol risk of SARS-CoV-2 with KCDC adopting a more conservative approach to COVID-19 by requiring more protection for lower risk situations. A greater level of protection with PAPR was encouraged when involved in aerosol-generating procedures (e.g. cardiopulmonary resuscitation, intubation, extubation, bronchoscopy, nebulizer therapy, sputum induction, etc).

Table 5. Comparison of National PPE Guidelines for Standard Suspected/ Confirmed COVID-19 Patient Care

	WHO ²¹ (Last updated 4.6.2020)	CDC ²² (Last updated 4.13.2020)	ECDC ²³ (Last updated 3.31.2020)	KCDC ¹⁷ (Last updated 4.2.2020)
Standard Suspected/ Confirmed Patient COVID-19 Care (In the absence of aerosol-generating procedures)	<ul style="list-style-type: none"> - Medical mask - Eye protection - Gown - Gloves 	<ul style="list-style-type: none"> - N95 respirator OR face mask - Eye protection - Isolation gown - Gloves 	<ul style="list-style-type: none"> - Surgical mask OR FFP2 respirator when available - Eye protection - Long-sleeved gown OR apron - Gloves 	<ul style="list-style-type: none"> - KF94* OR equivalent - Eye protection - Long-sleeved gown OR coveralls - Gloves x2

Note. KF94 are considered equivalent to FFP2 and N95 respirators. N95 respirators have been preferred in tertiary hospitals with robust infection control programs given their better air leakage profile.

A central guideline on conservation and reuse of PPE did not exist, but a couple common strategies were solicited as listed below.

1. Reuse of PPE

Although Korea was prepared with an established supply of PPE, hospitals did not have a surplus. This led to a shift in practice from one N95 respirator per patient encounter to, in some cases, one per day when treating confirmed COVID-19 patients. Unless the respirators (a) came in direct contact with the patient, (b) became visibly contaminated and wet, or (c) were non-functional, HCWs conserved N95 respirators without putting themselves and others at potential risk. Upon reusing a respirator, much attention was paid to doffing to ensure one did not touch either side. In addition, SNUBH allowed HCWs to reuse goggles, respirators, and coveralls unless visibly contaminated, and only switch gloves and aprons for each confirmed patient encounter. This overall approach appears to have been facilitated by the aforementioned patient stratification method, which led to a complete separation between COVID and non-COVID patients and compartmentalization of patients by their COVID-19 status (confirmed vs. suspected). HCWs were offered a care setting in which a consistent level of PPE use was possible while treating patients of similar exposure risk.

2. Patients wore their own masks

COVID-19 occurred in the setting of a culture of widespread, voluntary mask-wearing due to air pollution and seasonal yellow dust in South Korea. Masks could be easily purchased in convenience and drug stores and were found in many households. Therefore, when hospitals were no longer able to freely provide masks for their patients, it was not a big challenge for patients to present to the hospital wearing their own masks. One major drawback was that civilian purchase of masks caused an imbalance in distributing masks appropriately to the highest risk populations such as HCWs and immunocompromised patients. At the height of the epidemic, the central government intervened by (1) acquiring 80% of the Korean manufactured masks, (2) designating specific days for when people could purchase masks according to the final digit of their birth year²⁴, and (3) limiting individual purchase to two masks a week.²⁵ Overall, South Korea operated in an environment in which wearing masks was already normalized across the nation.

Limited Daily Work Hours

Prolonged duty hours (>10hours/ day), along with working at high-risk departments and performing suboptimal hand hygiene, were associated with increased risk of COVID-19 according to Ran *et al.*'s retrospective cohort study of 72 confirmed HCWs at a designated tertiary hospital in Wuhan.²⁶ The authors concluded that all staff members part of high-risk departments, including Pulmonary, Infectious Disease, ICU, and Surgery Departments, would be infected if they worked >15 hours per day. In congruence with such findings, the Korean government instituted supplementary measures to optimize HCWs' wellbeing and prevent burnout. For HCWs dispatched to domestic COVID hotspots, e.g. Daegu and Gyeongbuk area, their workweek was decreased to forty hours with overtime compensation, in addition to a two-week limit for public sector workers and one-month cap for those in private sectors.²⁷ The Korean Health and Medical Workers' Union also strongly defended the need for additional financial assistance, flexible work hours, and mental health support for HCWs during this time.²⁸ Sensible interventions on shift length and staff advocacy accompanied by optimal PPE support yielded additive effects in achieving greater HCW safety and protection.²⁹

Health Care Worker Screening

All HCWs were screened for fever, respiratory symptoms, and epidemiological risk factors (domestic travel to a COVID hotspot, international travel, or connection to a cluster outbreak) with a short questionnaire on a daily basis (or twice daily in some hospitals). The exact protocol was hospital-dependent, e.g. SNUBH screened its HCWs using a mobile application each morning, while Kyungpook University and Keimyung University Dongsan Hospitals screened its HCWs and measured their temperature (using non-contact thermometers) at hospital entrances. Despite the varying methods for screening HCWs, the implementation of stricter guidelines for monitoring, testing, and self-quarantine was consistent across medical systems.

1. Monitoring

All HCWs treating suspected/ confirmed COVID-19 patients were required to report their temperature and presence (or absence) of fever and respiratory symptoms twice daily. Depending on the hospital, HCWs were mandated to report to occupational health, human resources, or their divisional medical director.

2. Testing

All HCWs with clinical exposure of medium to high risk to confirmed patients, or those who became febrile or develop respiratory symptoms were tested (Refer to Table 6 for definitions of the three tiers of risk exposure). Fiscal burden was rarely imposed upon the HCWs as the Korean government provided test coverage to all symptomatic HCWs. Seoul National University Hospital even provided test coverage to asymptomatic HCWs while some hospitals conducted periodic screenings in COVID-19 wards.

3. Self-Quarantine

A preemptive 14-day-long self-quarantine was mandated for all HCWs returning from high-risk area/ international travels, and with medium- and high-risk exposure to suspected/ confirmed patients. While HCWs with international travel history were allowed to return to work on day 15 upon completing their mandated quarantine, a negative repeat test on day 13 was required for those exposed without proper PPE.

A visualized pathway of how KCDC guided management of exposed HCW is depicted in Figure 4. Criteria for HCW clinical exposure stratified by level of risk, recommended monitoring system, and subsequent work limitations are listed in Table 6.

KCDC HCW PATHWAY | SOUTH KOREA

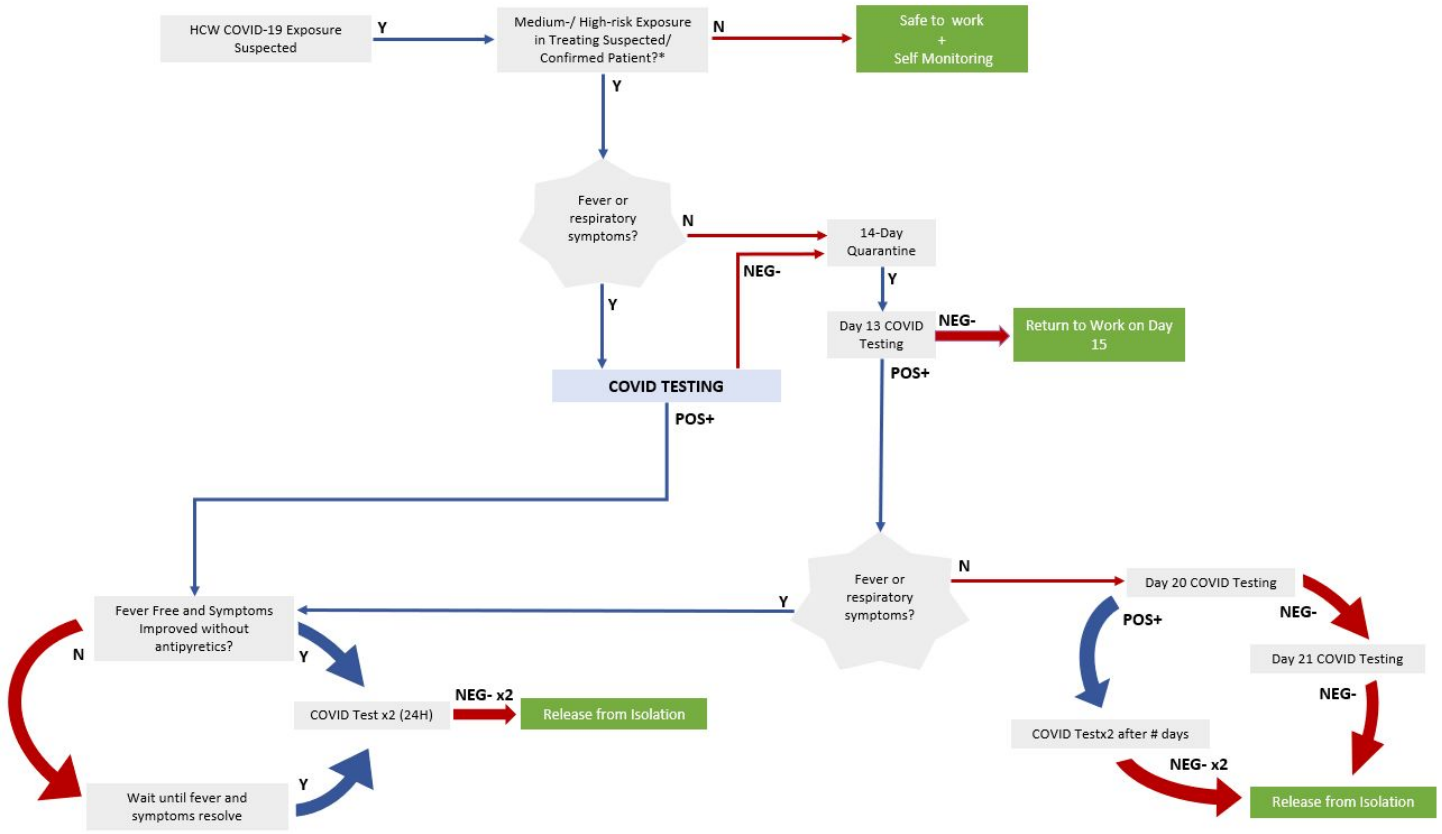


Figure 4. KCDC HCW Exposure Management Pathway

COVID testing is required for symptomatic HCWs with medium and high-risk exposure while treating suspected/ confirmed COVID patients (Please refer to Table 6 for exposure criteria). A 14-day quarantine is mandated for afebrile/asymptomatic HCWs with exposure of medium risk and above.

Table 6. Work Restrictions for Health Care Workers with Exposure to COVID-19 Patients and Suspected Cases

Epidemiological Risk Factors	Exposure Category	Recommended Monitoring (Up to 14 Days After Last Potential Exposure)	Work Restrictions for Asymptomatic HCW
① HCW performing aerosol-/ droplet-generating procedures (e.g. CPR, intubation, bronchoscopy, nebulizer therapy, sputum induction) with unprotected eyes, nose, and mouth OR otherwise present in the same space during such procedures	High	By the health facility/ agency	14-day suspension from work since the last contact date
② HCW performing aerosol-generating procedures without gown or gloves, OR otherwise present in the same place during such procedures	Medium	By the health facility/ agency	14-day suspension from work since the last contact date
③ HCW with unprotected eyes, nose, or mouth who comes into close contact with a patient wearing a mask *Note: Close Contact entails 1. Direct clinical patient contact; 2. Being within 2m radius from the confirmed patients for a considerable amount of time without proper PPE (involving hand contact or face-to-face conversation); 3. Direct contact with secretions or excreta	Medium	By the health facility/ agency	14-day suspension from work since the last contact date
④ HCW with unprotected eyes, nose, or mouth who comes into close contact with a patient NOT wearing a mask	Medium	By the health facility/ agency	14-day suspension from work since the last contact date
⑤ HCW without gloves, comes into direct contact with patient's secretions and excreta, and is NOT able to practice immediate hand hygiene Note: Classify as low risk if hands are washed immediately after contact	Medium	By the health facility/ agency	14-day suspension from work since the last contact date
⑥ HCW wearing a mask comes into close contact with patient wearing a mask	Low	Self-Monitoring	-
⑦ HCW wearing ALL recommended PPE (e.g. respirator, eye protection, gloves and gowns) and comes into close contact OR directly handles patient's secretions/ excreta	Low	Self-Monitoring	-
⑧ HCW NOT wearing recommended PPE, but engaging in simple interactions with a patient (e.g. entering a patient's room without direct clinical contact)	Low	Self-Monitoring	-
⑨ HCW with NEITHER direct clinical contact with patients NOR their secretions/ excreta, and NO entry to patients' rooms	Low	-	-

Note. Adapted from CDC Interim US Guidance for Risk Assessment and Public Health Management of Healthcare Personnel with Potential Exposure in a Healthcare Setting to Patients with Coronavirus Disease 2019 (COVID-19) <https://www.cdc.gov/coronavirus/2019-ncov/hcp/guidance-risk-assesment-hcp.html>¹⁷

D. Containment of Community Spread

“ It definitely helped that the Korean citizens voluntarily and diligently complied with social distancing to protect one another, albeit from panic. I presume that this collective effort has helped lower the community spread, minimize health care worker infections, and attenuate nosocomial spread within the hospital. ”



-Dr. Hong Bin Kim, Professor, Department of Internal Medicine, Seoul National Bundang Hospital

The extent of community spread is intimately tied to the integrity and functionality of the medical system. The greater the community spread, the more likely it is for nosocomial infections to occur as sheer numbers of cases may overwhelm or slip by existing systems. Therefore, a multi-pronged approach was undertaken to minimize the community spread as much as possible.

1. Testing Made Easy

The strategic mass testing by the Korean government was accompanied by innovative testing methods, such as walk-through (Table 6 and Figure 5, [link](#)) and drive-through (Figure 6, [link](#)) testing. Not only was the process expedited (maximum duration of 15 minutes), but, more importantly, it was also safe to everyone involved: the patient remained in his/her own car, limiting exposure to and from others, and the HCW collecting the specimen was fully equipped with Level D protection and a N95 respirator. Testing results were typically sent to the patient by the next day via text. Seventy-four drive-through sites were constructed across the country, and in Daegu specifically, 15,594 tests (16.7% of the city’s total) were performed at its 10 drive-through testing centers as of April 5th.³⁰ Easy testing allowed for early detection, ultimately leading to a greater degree of community protection. Meanwhile, innovations like the walk-through booths allowed HCWs to conserve PPE and avoid fatigue from wearing PPE for prolonged periods of time.

Table 7. Types of Walk-Through Testing for COVID-19

Types	① Negative pressure booth (Booth for patients)	② Positive pressure booth (Booth for medics)
Details	<p>Patients inside, Medics outside</p> 	<p>Patients outside, Medics inside</p> 
Note	Booths need to be sterilized after each use. Medics outside the booth must wear protective gears. Takes 10 mins for each sampling due to cleaning & sterilizing of the booth inside.	Only the gloves used outside the booth need to be cleaned & sterilized. Medics inside do not necessarily have to wear protective gears. Takes 1 min for each sampling.

Note. Reprinted from How Korea responded to a pandemic using ICT: Flattening the curve on COVID-19, by the Government of the Republic of Korea, April 15 2020³¹

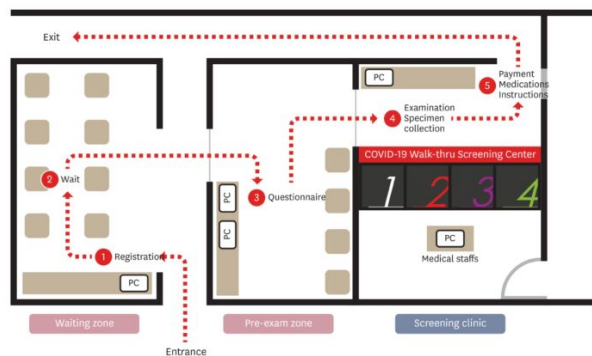


Figure 5. Flowchart of Walk-Through Testing Center³²

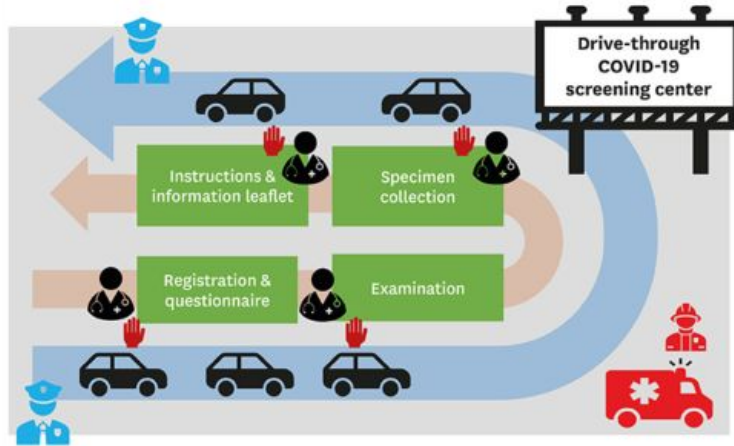


Figure 6. Illustration of a Drive-Through Testing Center³³

2. Contact Tracing and Self-Quarantine

Rigorous contact tracing was also pursued hand-in-hand with widespread, easy-to-access testing. Extensive epidemiological investigation evolved into a key player in limiting the community spread ever since the rate of confirmed cases gained significant momentum following the discovery of the patient #31 in Daegu in the middle of February. Contact tracing identified those with potential exposure through phone/ in-person interviews and using credit card purchase history and security camera footage whenever necessary. This ultimately allowed for prioritized testing, and individuals found positive were then quarantined at home, community treatment centers, or hospitals based on clinical severity. Early detection led to early isolation, which gradually decelerated the pace and extent of new infections.³⁴

Information gathered from contact tracing was also shared with citizens, based on the “[Infectious Disease Prevention and Control Act](#),” which legalized disclosure of relevant personal information after the 2015 MERS outbreak. Text alerts were sent to individuals who entered the geographical path of a confirmed case, and one could easily track the anonymized location and time of confirmed cases using a KCDC-sponsored mobile application called [Coronamap](#). Korean citizens were provided with the tools to visualize the viral epidemic, and in return took active ownership in mitigating the spread and physically distancing from others. They put public wellbeing above personal privacy and became integral stakeholders.³⁵

“The Korean government requested active participation from the Korean citizens, and the people took ownership of disease control and prevention, avoiding potential exposure and practicing physical distancing. Once the pandemic nears its end, we collectively will have to answer how much personal privacy we are willing to give up for public safety and wellbeing.”

Dr. Hong Sang Oh, Director, Department of Infection Control and Prevention, Korean Armed Forces Capital Hospital

3. Supportive Monitoring

Those under self-quarantine, whether due to close contact, international travels, or as a confirmed or suspected case, were closely monitored by their local public health centers. A public health officer would call twice daily to check for fever and respiratory symptoms, offer public health education, and re-triage when necessary. During the 14 days of self-quarantine, the government also delivered “comfort packages” that contained hygiene essentials, e.g. face mask and hand sanitizer, along with fresh produce and detailed garbage disposal instructions.³⁶ Lastly, harnessing its advanced Information Technology, the Ministry of the

Interior and Safety developed a smartphone application called “Self-Quarantine Safety Protection,” a mobile symptom-reporting tool also equipped with GPS tracking capability.³⁷ The use of novel technology added efficiency and flexibility to Korea’s response efforts.

4. Physical Distancing

Although there was no formal lockdown in South Korea and borders remained open, the start of the new academic year was postponed and large non-essential gatherings were discouraged. There was a nationwide voluntary cohesion around physical distancing, and dramatic decrease in human mobility was seen in mobile big-data analysis even (1) prior to the initial surge of cases with the diagnosis of patient #31 on February 18th and (2) in the absence of strict central enforcements (Figure 7). Citizens readily adhered to recommendations and guidelines, and businesses were able to stay open. As the former KCDC director simply put, “Distancing was a *choice*” in South Korea.

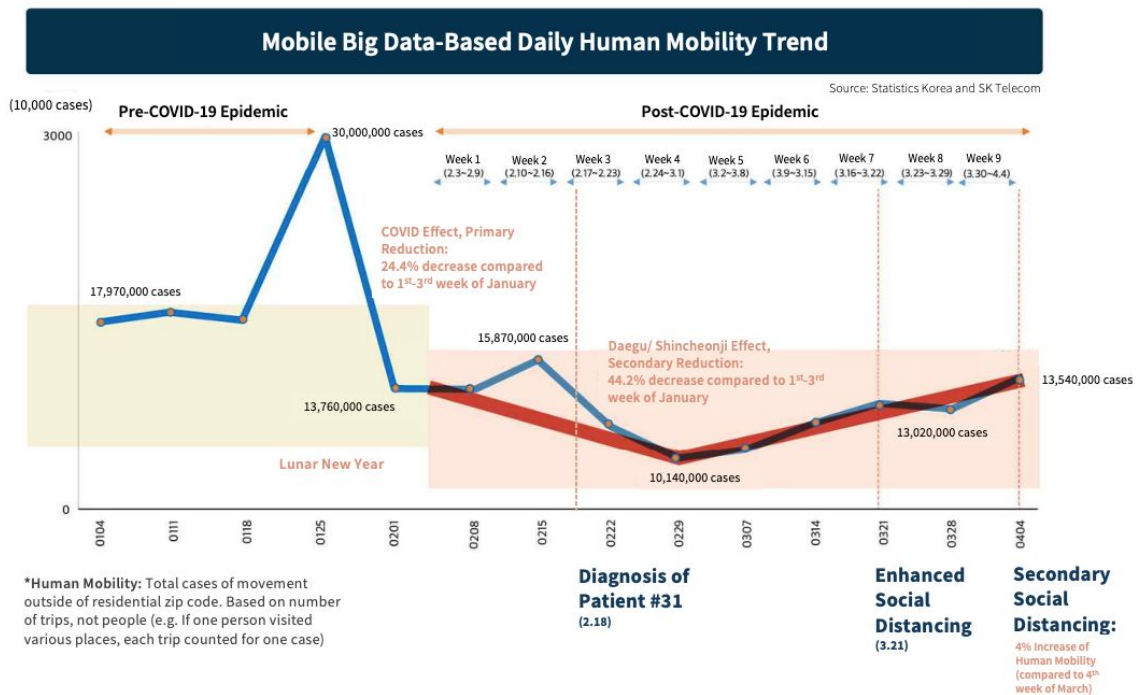


Figure 7. Human Mobility Trends from Mobile Phone Big Data Collection by SK Telecom.³⁸ Greatest reduction of 38.1% from baseline (1.9.2020-1.22.2020) activity by the 4th week of the epidemic (2.24.2020-3.1.2020) with increased mobility of 16.1% by the eighth week (3.23.2020-3.29.2020).

5. Transparent communication from central and regional leadership

KCDC press briefing was televised at 10am every day, and information on cumulative and new national COVID status, public health recommendation updates or policy changes were shared with the public. Three detailed daily reports were uploaded to the KCDC and Ministry of Health and Welfare websites: (a) Abridged National Epidemic Status (as of midnight), (b) Complete Daily Report on National Epidemic Status, (c) Complete Daily Report by the Central Disaster and Countermeasures Headquarters. All three documents were then translated to English by the afternoon the same day. A similar daily press conference was held at a regional level, allowing for easy access of up-to-date knowledge on Korea’s response strategy to COVID-19 and its outcomes.

E. Adherence to the Fundamentals

“ Infection control within the hospital can never be foolproof. The ultimate goal [therefore] lies in harm reduction. I have emphasized three main strategies to our hospital staff: (1) performing good hand hygiene, (2) wearing masks (and other PPE), and (3) cleaning surfaces ”

Dr. Hong Sang Oh, Director, Department of Infection Control and Prevention, Korean Armed Forces Capital Hospital

Albeit rudimentary compared to other larger scale safety measures, Korea’s rigorous dedication to each and every fundamental public health principles cannot be overlooked. All aspects of hygiene--hand washing before and after each patient encounter (scrub with soap and water for 40-60 seconds when in direct contact with patient excretions/ secreta/ other contaminants, and rub 20-30-seconds with alcohol-based hand sanitizer in other circumstances)³⁹; environmental cleaning (detailed protocols were available for cleaning materials, PPE requirements, location, procedural and doffing steps, and guidelines upon developing symptoms); and proper waste management--were implemented to prevent indirect transmission through fomites. A universal masking policy was implemented at hospitals in order to minimize pre-symptomatic or asymptomatic transmission among patients, visitors, HCWs, and the rest of the hospital staff. Physical distancing was also reinforced within the hospital; a 6-foot distance was maintained in lobbies, waiting rooms, and screening sites. Cafeterias were also reorganized, either with acrylic dividers between each seat or all tables facing one direction, to minimize possible exposure during close non-medical contact. These steps were followed diligently and simultaneously by everyone in the hospital, ultimately resulting in a synergistic effect on protecting HCWs and others.

V. Exploring Clusters of HCW Infections

Clusters of COVID-19 Infections in South Korea

Besides outbreaks related to the Shincheonji Church (Shincheonji), a religious group at the heart of the initial exponential spread of COVID-19 in Daegu, there have been a number of small clusters of COVID-19 cases in Korea. 51.4% and 18.1% of the total confirmed cases (including both HCWs and the general population) were connected to Shincheonji and small clusters, respectively, as of April 3rd. Many of the small clusters in fact arose from lower acuity healthcare facilities.

Group Infections in Hospitals

The first confirmed HCW was a nurse, who was also found to be an active member of Shincheonji.⁴⁰ A total of 101 HCW infections (41.9%) were community-based, including transmission related to Shincheonji (Table 1), and 32 other HCW infections (13.3%) were classified as group infections in hospitals. Nine hospital-related small clusters were identified based on the daily press briefings by KCDC and news articles (Table 7). Two-thirds of the clusters

were associated with long-term care or psychiatric hospitals (or a psychiatric ward at a general hospital). Others occurred in non-COVID-19-designated acute-care hospitals.

Table 8. Major Group Infections in Hospitals

Major Clusters*	City /Province	Hospital Characteristics			COVID-19 Infection Status		
		Type of Hospital	No. of General Beds	No. of doctors	First Reported Date	Total No. of Confirmed Cases# (Including Patients AND HCWs)	No. of HCW infections (doctors /nursing staff)
Cheongdo Daenam Hospital	Gyeong-buk	Hospital (psychiatry-focused)	125	11	2/19	120 ^b	At least 9 ^b (-/9)
Second Mi-Ju Hospital	Daegu	Hospital (psychiatry-focused)	60	6	3/26	170 ^a	8 ^a (0/8)
Hansarang Convalescent Hospital	Daegu	Long-term care hospital	199	4	3/16	123 ^a	12 ^a (1/11)
Daesil Convalescent Hospital	Daegu	Long-term care hospital	199	6	3/18	98 ^a	5 ^a (0/5)
KimSin Recuperation Hospital (+)	Daegu	Long-term care hospital	149	4	2/24	46 ^a	1 ^a (0/1)
Gyeongsan Seo Convalescent Hospital	Gyeong-buk	Long-term care hospital	192	6	3/19	58 ^b	At least 1 ^b (-/1)
Bundang Jesaeng Hospital (+)	Gyeonggi	General hospital	544	213	3/5	45 ^b (As of March 22)	25 ^b (3/22)
Uijeongbu St. Mary's Hospital	Gyeonggi	General hospital	654	301	3/29	72 ^b (57 nosocomial infection as of April 24)	5 ^b (2/3)
Daegu Fatima Hospital (+)	Daegu	General hospital	584	220	3/17	33 ^b (As of April 4)	At least 1 ^b (-/1)

* Described as 'other major clusters' in the press release of KCDC on April 3. Others are marked (+)

**In December, 2019 (Source: Health Insurance Review and Assessment Service, Korea)

a. data from the minutes of the City of Daegu, as of 6 pm April 3

b. data from press release by KCDC and news articles

Case Studies of Cluster Outbreaks in Hospitals

The First HCW Infection Cluster

The first hospital cluster outbreak occurred at the Cheongdo Daenam Hospital. The first case was reported on February 19, and 120 cases have been confirmed since. About 100 cases were patients on a closed psychiatric ward. The index case has remained undetermined, whether a patient on the psychiatric ward or a caregiver who traveled to China. Another hypothesis was related to the hospital's connection to Shincheonji. The entire hospital was subsequently isolated. Daenam Hospital was in fact the first to receive the order of cohort isolation by the central government. At least nine nurses were infected with COVID-19 in this hospital.⁴⁰

Long-Term Care and Psychiatric Hospitals in the City of Daegu

The City of Daegu has conducted mass COVID-19 testing for everyone in long-term care (LTC) hospitals since March 13. A total of 288 cases were confirmed in LTC hospitals as of April 3--267 cases (92.7%) of which were clustered in three hospitals (123 in Hansarang Convalescent Hospital, 98 in Daesil Convalescent Hospital, and 46 in KimSin Recuperation Hospital). Whenever a confirmed case was revealed, the patient was transferred to a designated COVID-19 hospital or community treatment center, and individuals with close contact were quarantined and monitored accordingly. Investigation was also pursued at Second Mi-Ju Hospital, a psychiatric hospital, as it was located in the same building as Daesil Convalescent Hospital. Out of 188 cases confirmed at psychiatric hospitals in Daegu, 170 (90.4%) occurred in Second Mi-Ju Hospital, and it also has been home to the largest cluster outbreak among all hospitals with group infections. All staff and patients in psychiatric hospitals in Daegu have been tested ever since. By April 3, 26 HCW infections (1 doctor, 13 nurses, and 12 nurse aides) were reported in these four hospital clusters. Since cases have recurred at LTC and psychiatric hospitals, those with confirmed cases have been reinvestigated regularly. Infectious disease experts have also been consulted to LTCs and psychiatric hospitals.

Group Infections at Acute Care Hospitals

At Bundang Jesaeng Hospital, a patient was confirmed on hospital day 4, after developing pneumonia-like symptoms following admission. Another patient was also confirmed on March 5, after visiting the ER of the same hospital without exhibiting respiratory symptoms at that time.⁴¹

As of March 22, a total of 45 confirmed cases were associated with this hospital, and more than half of their cases were HCWs (including at least 3 doctors, 12 nurses, and 10 nurse aides).⁴² Inpatients and hospital staff who had contact with the confirmed cases were isolated and investigated. The hospital closed its outpatient clinics and ED on March 6, and the transmission was postulated to have occurred while the patients' COVID-status was not yet confirmed.

The cluster at Uijeongbu St. Mary's Hospital was revealed while investigating the HCWs and patients on the 8th floor of the hospital. An epidemiologic investigation was conducted because a patient admitted to the 8th floor of the hospital from March 16 to 25 was confirmed with COVID-19 on March 29. The hospital has been closed since the cluster outbreak. Contact tracing and mass testing were completed, and KCDC reported the interim result of epidemiological investigation on April 24: Among 72 confirmed cases, 57 cases were associated with nosocomial infections, including 2 doctors and 3 nurses. A total of 22 asymptomatic cases were identified and confirmed through early detection. There was no known secondary transmission from asymptomatic cases.

VI. Discussion

The successes and shortcomings of South Korea in preventing HCW infections reveal key lessons that should be implemented, explored, and improved upon as health systems around the world face current and subsequent waves of the COVID-19 pandemic. Even as health systems survive the initial onslaught of COVID-19 cases, there will inevitably be flare-ups and possibly even larger second waves such as in the cases of Singapore and Japan. Therefore, the end of one wave signals an opportunity to rapidly iterate and improve health care delivery for the next surge.

Thus far, South Korea has avoided a surge of infections amongst health care workers caring for COVID-19-patients. This has not been the case in many regions around the world, particularly those overwhelmed with large community outbreaks such as New York City in the United States and the Lombardy region in Italy. Though most media reports extol South Korea's mass testing and contact tracing programs, our interviews and reviews of hospital protocols suggest that a multitude of initiatives taken at the national, regional, and hospital levels likely have made this outcome possible:

- A network of screening centers, equipped with sufficient capacity for rapid PCR testing and innovative testing methods (drive-through, walk-through), in order to capture and triage potential cases of COVID-19, protect HCWs, and facilitate easy testing
- Regional triage systems coupled with designated hospitals, emergency departments, and isolation units in order to spatially isolate COVID-19 both at the regional- and hospital-levels and prevent exposure of unprotected HCWs and non-COVID-19 patients to infection
- Government intervention to secure adequate supplies of PPE so that HCWs can utilize Level D PPE with N95 respirators for all suspected and confirmed cases of COVID-19
- Regular HCW screenings and a universal mask policy
- Restricted entry into hospitals and health care facilities and triaging of people with fever and respiratory symptoms to screening centers located outside of hospitals
- Maintaining facilities to provide continued care for non-COVID patients while still protecting staff and patients from infection
- Suppression of community spread through education about physical distancing and contact tracing initiatives
- Redesigning systems such as testing procedures to creatively preserve resources and personnel
- Practicing standard hygiene protocols and creating environments in which these actions are made more accessible or the default choice

Despite these successes, there were various outbreaks and challenges, particularly at long-term care facilities and psychiatric hospitals. Moreover, many nurses tested positive for COVID-19 compared to physicians. These issues highlight scenarios that require particular close attention:

- *Involvement in long, close patient contact:* While only ten physicians were found positive in the context of general medical care and hospital group infections, eighty nursing staff have been confirmed positive for COVID-19. Frequent patient contact and a longer duration of clinical care typically provided by nursing staff, compared to that of physicians, are likely contributors. Potential interventions include minimizing the number of necessary points of contact between the provider and patient as well as the number of personnel required to be in the patient room; ensuring adequate PPE and donning/doffing training and monitoring; and limiting lengths of shifts to avoid provider fatigue.
- *Facilities with suboptimal infection control measures:* Acute care and tertiary care hospitals are sufficiently staffed with infection control practitioners, yet such is rarely the case for LTC and psychiatric hospitals. Environmental control therefore is likely to be not as rigorous and consistent, resulting in a higher risk for prolonged unintended exposures. These institutions also lack in-house laboratories for COVID-19 testing, which makes appropriate and timely triage and diagnosis challenging. Additionally, LTC hospitals might be hesitant to quarantine personal support workers for every medium to high exposure as they tend to 8-10 patients at a time. Such reluctance is likely shared by personal support workers as well due to their fear of losing their jobs and dealing with the subsequent fiscal challenges as they typically are day laborers.

South Korea's response to these challenges has been to pursue mass testing, implement cohort isolation, and set up systems for remote infection control consultations. Additionally, the following interventions appear critical in tackling HCW cluster infections emerging in vulnerable care settings:

1. Accessible rapid and repeat testing for patients and HCWs in LTC and psychiatric hospitals⁴³
2. Improvement in infection prevention and control measures through proactive education and training, environmental maintenance, facility reorganization (e.g. "cohorting" suspected patients into single rooms), and expert consultation
3. A staff support system with high-priority PPE distribution, financial assistance, substitute workforces, nonpunitive sick leaves, and unemployment benefits, which together may facilitate better compliance with work restrictions when quarantine is needed⁴⁴

VII. Challenges

Incomplete Efforts Following the 2015 MERS Outbreak

As referred to in Section IV.A.Designated Hospitals, the designation of Infectious Disease Hospitals occurred urgently, only after when the COVID-19 epidemic started to unfold in Korea. Given the reactive nature of the response, this initiative resulted in involving many public community hospitals, which arguably were neither optimally equipped nor prepared--a byproduct of a partial post-MERS preparation.

Discussion on establishing a network of Infectious Disease Hospitals to strengthen the nation's infectious disease prevention and control strategy ensued soon after the 2015 MERS outbreak. Korea's ultimate recovery, however, was followed by a natural loss of momentum in such efforts, which manifested in a halt of financial and logistical support by the government. For instance, the NMC was selected as the Central Infectious Disease Hospital and Chosun University Hospital as the one for Honam region, yet other regions were left without any. In fact, developments at the NMC eventually stalled, and no new facilities were built for the Chosun University Hospital. The situation was similar for National Designated Isolation Units as well: budgets for construction, maintenance, and personnel have been insufficient.

The topic of Infectious Disease Hospitals is now being revisited, with additional hospital recruitment from the Central and Yeongnam regions . Nonetheless, a fully comprehensive national healthcare delivery system for emerging infectious diseases has yet to exist to date.

Unclear Impact and Unintended Consequences of Mass Testing

Korea's strategy of mass testing was not only notable in its supply and production capacity, but also its early anticipation for the nationwide need for testing. Only three weeks after the release of SARS-CoV-2 genetic sequence by China on January 12th, KogeneBiotech's diagnostic reagents were approved on February 4th, facilitated by the Ministry of Food and Drug Safety's Emergency Use Approval. Four other companies joined forces shortly after, and Korea's testing capabilities allowed for the country's abilities for case detection, contact tracing, quarantining, and monitoring.

Korea's "success" story of mass testing however warrants caution when interpreting its effect on disease control or adopting its testing strategy. As discussed in this brief, Korea deployed its strategy of social distancing, contact tracing, testing, isolation, and treatment in the setting of a public buy-in for universal mask wearing. The combination of these measures has been shown to be effective, but as an infectious disease expert in Seoul pointed out, the sole effect of mass testing cannot be parsed out without understanding the true scale of Korea's community spread with a "population-based, systematic serological survey."

Lastly, one unintended consequence of mass testing in Daegu, the site of a major outbreak amongst members of the Shincheonji church, was that there was an enormous influx of people seeking care at the city's hospitals. Hospitals were overwhelmed with incoming patients, and Daegu suffered bed shortages and patient deaths until the city adopted a robust triage system that offloaded mild cases to community treatment centers.⁴⁵ A systematic approach that addresses risk stratification and triage of confirmed patients should accompany any mass testing efforts.

VIII. Conclusion

Overall, the South Korean approach for protecting health care workers has been a multi-pronged strategy of centralized coordination, local adaptation of key protocols and principles, and a strong backbone of public health fundamentals (physical distancing, contact tracing, testing, isolation, and treatment). Adequate PPE was foundational but HCW infection control could not have been successful without a robust system of triage and coordination that increased health system capacity. Instead of adopting an “either-or” mentality, the country married constant preparation (even for future waves of infection) with response as well as containment with mitigation. Innovation came not only from breakthrough technologies such as their contact tracing smartphone apps but also from follow-through innovations in scaling triage systems, screening centers, and isolation units across the nation. Additionally, when facing resource constraints, health officials reconceptualized existing processes towards new models such as drive-through and walk-through testing that have spread to other countries around the world. When there have been shortcomings such as outbreaks in long-term care facilities, the health system has iterated and improved its processes. Lastly, leaders in South Korea adopted a stance of openness and sharing, evidenced by their detailed breakdown of health care worker infection rates and wide dissemination of their protocols and experiences.

As countries around the world prepare for initial or subsequent waves of infections, health systems’ ability to effectively and safely manage surges will be critical to both public health and economic stability. There is no single magic bullet, but countries also do not have to reinvent the wheel. By adapting and improving upon principles and processes from countries with positive outcomes like South Korea, the global community can not only withstand the COVID-19 pandemic but ultimately “crush the curve.”⁴⁶

IX. Acknowledgements

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X. Appendix

Appendix 1. Case Definition⁴⁷

1. Confirmed Case: An individual who are confirmed to be infected with a pathogen in accordance with testing criteria for diagnosis, regardless of clinical features
 - a. Diagnostic Test: COVID-19 genetic (PCR) testing, virus isolation
2. Suspected case: An individual who, after contact with a confirmed case during his/her symptomatic period, within 14 days of contact develops a fever (37.5C or higher) or respiratory symptoms (e.g. cough, shortness of breath)
3. Patient Under Investigation (PUI):
 - a. An individual who is suspected of COVID-19 or of pneumonia of unknown etiology, according physicians clinical judgement
 - b. An individual who develops fever (37.5C or higher) or respiratory symptoms (e.g. cough, shortness of breath) within 14 days of visiting a country with regional spread of COVID-19, such as China (including Hong Kong and Macau)
 - i. Refer to the WHO website for detailed status of local transmission
 - c. An individual with an epidemiological connection to a domestic cluster outbreak of COVID-19, who develops fever (37.5C or higher) or respiratory symptoms (e.g. cough, shortness of breath) within 14 days.

Cases subject to reporting

○ (Confirmed)	Someone confirmed as infected in accordance with laboratory criteria, regardless of clinical condition	
○ (Suspected)	Someone who has had contact with a confirmed case within the last 14 days	+ Develops a fever (37.5°C or higher) or respiratory symptoms (e.g., coughing, shortness of breath, etc.)
○ (PUI*)	Someone who has visited a country with regional COVID-19 transmission (e.g., China including Hong Kong and Macau) within the last 14 days	
○ (PUI*)	Someone with an epidemiological association to a domestic cluster outbreak of COVID-19 in the last 14 days	
○ (PUI*)	Someone who is suspected to have COVID-19, such as pneumonia of an unknown etiology, according to a doctor's opinion	

Appendix 2. Risk Stratification Examples¹⁷

Example 1: the Korean Medical Association Protocol for Severity Classification

Patients were classified into one of the four levels: Asymptomatic, mild, moderate, or severe. Required clinical assessments entailed: age, smoking history, underlying health conditions, shortness of breath and other symptoms (headache, cough, sore throat, phlegm, fatigue, myalgia, shortness of breath), mental status, body temperature with the history of antipyretics use, radiological signs of pneumonia, and oxygen saturation.

Special considerations:

- If a patient were from a long-term nursing or care facility, patient severity was escalated by one level.
- If 48 hours were to have passed since the improvement of symptoms included in the criteria below, the severity class was de-escalated by one level.⁹

Classification	Criteria
Asymptomatic	Meets all conditions below: ① Alert mental status ② Under 50 years of age ③ No underlying health conditions ④ Body temperature lower than 37.5 °C without antipyretics ⑤ Non-smoker
Mild	Alert mental status and one or more conditions below: ① Under 50 years of age ② No underlying health conditions ③ Body temperature 38 °C or lower with antipyretics ④ One or more symptoms* other than shortness of breath ⑤ Smoker
Moderate	Alert mental status and one or more conditions below: ① Body temperature 38 °C or higher with antipyretics ② Shortness of breath or radiological signs of pneumonia
Severe	① Altered mental status ② Severe shortness of breath ③ Oxygen saturation ≤90% ④ Radiological findings of severe bilateral pneumonia or ≥50% pneumonia

Example 2: Modified Early Warning Score (MEWS)

In 1999, a modified version of the Early Warning Scores was proposed with the purpose of facilitating prompt communication among HCWs when clinical deterioration becomes apparent.⁴⁸ Patients were classified into one of the four levels with MEWS: Mild, moderate, severe, and critical. Required clinical variables entailed: vital signs (pulse, systolic blood pressure, respiratory rate, and body temperature) and mental status. Scores for each variable ranged from 0 to 3, and patients were classified into one of the four levels upon the total score of the five variables.

Variable	3	2	1	0	1	2	3
Pulse (/minute)		≤40	41-50	51-100	101-110	111-130	≥131
Systolic blood pressure (mmHg)	≤70	71-80	81-100	101-199		≥200	
Respiratory rate (/minute)		≤8		9-14	15-20	21-29	≥30
Body temperature (°C)		≤35.0	35.1-36.0	36.1-37.4	≥37.5		
Mental status				Normal	Responds to voice	Responds to pain	Unresponsive

Score	Risk level	Monitoring frequency	Management
0-4	Mild (low risk)	6-12 hours	Symptomatic treatment and symptom monitoring
5-6	Moderate (moderate risk)	1-2 hours	Symptomatic treatment and symptom monitoring
≥7	Severe (high risk)	Continuous	Mechanical ventilation etc. necessary
≥7	Critical (high risk)	Continuous	<ul style="list-style-type: none"> • CRRT, ECMO necessary • Patients with end-stage conditions, such as irreversible brain damage, multi-organ failure, end-stage chronic hepatic or pulmonary diseases, or metastatic cancer

Example 3: British National Early Warning Score (NEWS)

Required clinical variables entailed: oxygen saturation, need for supplemental oxygen, heart rate, systolic blood pressure, respiratory rate, body temperature, and mental status. Scores for each variable ranged from zero to 3, and a summative score of >5 was considered moderate, while >7 severe.

Special consideration: Patients in high-risk groups were considered severe, and should be assigned to inpatient beds accordingly. High-risk groups were defined as:

- Age: 65 or older
- Chronic underlying health conditions: Diabetes mellitus; chronic renal, hepatic, pulmonary, and/or cardiovascular diseases; patients with hematologic malignancy; any cancer patients undergoing chemotherapy; patients on immunosuppressants; patients with HIV/AIDS
- Special situations: Patients with morbid obesity, pregnancy, end-stage-renal-disease undergoing dialysis, and/or organ transplant history
- Inpatients: Patients with oxygen saturation below 90% on room air requiring initial supplemental oxygen therapy

Variable	3	2	1	0	1	2	3
Oxygen saturation (%)	≤91	92-93	94-95	≥96			
Need for supplemental oxygen	Yes	Yes	No	No			
Heart rate (/minute)	≤40		41-50	51-90	91-110	111-130	≥131
Systolic blood pressure (mmHg)	≤90	91-100	101-110	111 - 219			≥220
Respiratory rate (/minute)	≤8		9-11	12 - 20		21-24	≥25
Body temperature (°C)	≤35.0		35.1-36.0	36.1-38.0	38.1-39.0	≥39.1	
Mental status				Normal			Abnormal

An Example of Modified Patient Severity Classification: Daegu Brief Severity Scoring System for COVID-19

As the NEWS and MEWS classification systems were originally intended for stratifying hospitalized inpatients, Daegu developed its own patient severity classification system better fit for triaging at-home patients awaiting admission and more specific for COVID-19 patients. With the Brief Severity Scoring System, patients were quickly classified into one of the four levels with a phone call-based survey: Asymptomatic to mild, moderate, severe, and critical. Required clinical variables entailed body temperature, duration of fever, respiratory symptoms, shortness of breath and its duration, and respiratory rate. Not only did Daegu's telephone-based scoring system alleviate the city's hospital-bed shortage, but also resulted in a decline of patients, including avoidable deaths, waiting for hospitalization or facility isolation.⁴⁵

Severity class	Criteria
Asymptomatic to mild	No symptoms or common cold-like symptoms
Moderate	Body temperature 37.5°C and cough
Severe	Suspected severe pneumonia (Body temperature over 38°C lasting over 3 days, respiratory symptoms)
Critical	Suspected critical pneumonia (shortness of breath for over 1 day, respiratory rate of 30/min or over)

Appendix 3. KCDC PPE Guideline

Care Setting	Activity	Respiratory Protection			Full Body Protection			Eye Protection	Note
		Surgical Mask	KF94	PAPR	Disposable Gloves	Disposable Gown	Full Body Suit (with foot covers)	Goggles (or Face Shield)	
Non-patient care	No patient contact	✓							
Non-respiratory Regular Patient care	Standard Patient Care	✓							Standard precautions or transmission-based precautions
	No patient contact	✓							
Screening Clinic	Patient Evaluation		✓		✓		✓	✓	
	Registration/ Check-in Desk		✓		✓	✓			
High-risk Patient Care 1. Hospital Screening Clinic 2. Outpatient Pulm Clinic 3. Quarantined Patient Room	Confirmed Patient Care		✓		✓ x2		✓	✓	
	Suspected Patient Care		✓		✓ x2		✓	✓	
	Standard Patient Care		✓		✓	✓		✓	
Specimen	Collection			✓	✓		✓	✓	
	Handling		✓	✓	✓		✓	✓	
	Transport (Intact and Covered)				✓				
Medical Waste	Wrapping/ Handling		✓		✓		✓	✓	
	Transport	✓			✓	✓			
Environmental Control	Patient Room Cleaning/ Disinfection		✓		✓		✓	✓	
	Ambulance Disinfection		✓		✓		✓	✓	
Transport	Ambulance Driver		✓		✓				If driver's seat not closed off or risk of contact is high with suspected/ confirmed pt
	Screening Personnel, Public Health Officer, Paramedic		✓		✓		✓	✓	
Clinical Procedure	Aerosol-generating Procedure			✓	✓		✓	✓	
	Radiologic Evaluation (e.g. X-ray)			✓	✓		✓	✓	

Appendix 4. Seoul National University Hospital PPE Guideline

Care Setting	Activity	Personnel	Respiratory Protection				Full Body Protection			Eye Protection	Note	
			Surgical Mask	KF94	N95	PAPR	Disposable Gloves	Disposable Gown	Full Body Suit (with foot covers)	Goggles (or Face Shield)		
Outpatient Exam Room	All Standard Patient Care	Patient	✓									
		HCW	✓									
Inpatient Ward	Regular, Non-Respiratory Patient Care	Patient									Follow standard precautions	
		HCW	✓									
	Suspected Patient Care	Patient	✓								*N95 respirators recommended for aerosol-generating procedures	
		HCW	✓		*			**		**	**If other bodily fluid exposure anticipated, wear disposable gown and face shield	
- COVID-19 Screening Clinic - Outpatient Respiratory Clinic - Pre-emptive Isolation Unit - ED Isolation Room	High Risk (Aerosol-Generating Procedures)	HCW			✓	*	✓	✓		✓	*PAPR can be applied when long-time exposure (>20min) is anticipated.	
	Moderate Risk (>1-2min-long procedures, <1min-long close contact, transport of mask-wearing patient)	HCW		✓			✓	*		*	*If other bodily fluid exposure anticipated, wear disposable gown and face shield	
	Low Risk (<2 min simple patient evaluation)	Patient	✓									
		HCW	✓				*					*Wear gloves upon clinical physical contact (e.g. during physical exam)
Emergency Room	All Standard Emergent Patient Care	Patient	✓									
		HCW	✓									
Transport of Specimen (Intact and Covered)		HCW					✓					

Appendix 5. COVID-19 Infection Prevention and Management Checklist⁴⁹

*For institution's self-inspection purposes

	Content	YES	NO (Anticipated Completion Date)
1	In the case of suspected, confirmed, or transferral of COVID-19 patients, do medical institutions of each region have an infection prevention and management program in place?	<input checked="" type="checkbox"/>	(M) / (D) / (Y)
2	Is the severity classification system for patients with acute respiratory diseases appropriately applied in medical institutions ?	<input checked="" type="checkbox"/>	(M) / (D) / (Y)
3	Are standard and droplet precautions optimally followed when managing suspected or identified patients with high-risk pathogens?	<input checked="" type="checkbox"/>	(M) / (D) / (Y)
4	Are aerosol precautions complied in situations where aerosols are generated?	<input checked="" type="checkbox"/>	(M) / (D) / (Y)
5	Is there a system set in place for hospitalization and transfer based on the clinical status of patients with COVID-19?	<input checked="" type="checkbox"/>	(M) / (D) / (Y)
6	Are there quarantine facilities for inpatient treatment of patients with COVID-19?	<input checked="" type="checkbox"/>	(M) / (D) / (Y)
7	Are there visitor restrictions? Are visitors required to wear adequate PPEs to see COVID-19 patients?	<input checked="" type="checkbox"/>	(M) / (D) / (Y)
8	Are HCWs provided with PPEs? Are guidelines set in place for proper use of PPEs?	<input checked="" type="checkbox"/>	(M) / (D) / (Y)
9	Are there appropriate internal guidelines for environmental control such as surface cleaning and disinfection?	<input checked="" type="checkbox"/>	(M) / (D) / (Y)
10	Are there processing standards for COVID-19-contaminated medical waste?	<input checked="" type="checkbox"/>	(M) / (D) / (Y)
11	Can the Infection Control team determine follow-up management and decide when to issue return to work orders for COVID-exposed HCWs? Is there a protocol set in place for identifying and prescribing quarantine to HCWs with exposed contact with COVID-19 patients?	<input checked="" type="checkbox"/>	(M) / (D) / (Y)
12	Is a strategy set in place for managing patients exposed to COVID-19 confirmed patients?	<input checked="" type="checkbox"/>	(M) / (D) / (Y)

<Source: National Capacities Review Tool for a Novel Coronavirus (nCoV) 10 Jan 2020, WHO/2019-nCoV/Readiness/v2020.1>

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