

ARTICLE

How South Korea Responded to the Covid-19 Outbreak in Daegu

June-Ho Kim, MD, MPH, Julia Ah-Reum An, MD, MPH, Pok-kee Min, MD, PhD, Asaf Bitton, MD, MPH, Atul A. Gawande, MD, MPH

Vol. 1 No. 4 | June 17, 2020

DOI: 10.1056/CAT.20.0159

The city of Daegu, South Korea, had the first large outbreak of Covid-19 outside of China. Despite facing similar challenges as other large cities — shortages of personal protective equipment, inpatient beds, and health care workers — the rate of Covid-19 infections among health care workers in Daegu remained lower than the rates experienced by its counterparts. Health system leaders and public health officials in Daegu mobilized a regional reorganization of the health system along with several hospital-level interventions that concentrated resources and equipment, relieved shortages, and ultimately protected health care workers and patients.

This article originally appeared as an early release on June 3, 2020, ahead of publication in NEJM Catalyst Innovations in Care Delivery issue 4 (July–August).

Soon after February 18, 2020, when health officials in Daegu discovered the first case of Covid-19 in the city of more than 2.4 million in southeast South Korea, the situation escalated rapidly. More than 2,000 confirmed Covid-19 cases were reported by February 29, and over 5,000 by March 7. For the medical system of the city of Daegu, one of the earliest consequences of the surge in Covid-19 cases was a shortage of hospital beds, supplies, and health care workers.

In 2015, South Korea had the largest Middle East Respiratory Syndrome (MERS) outbreak outside of the Middle East. At least 186 patients were infected with the virus and 38 people died. Many of these cases were determined to have come from nosocomial infections with an index case believed to have visited four different medical facilities before being diagnosed with MERS.^{1,2} As a result of significant in-hospital transmissions, several safeguards were put into place to prevent the same issue in future outbreaks, including an increased number of negative-pressure isolation rooms and stocking up on personal protective equipment (PPE).

Table 1. Covid-19 Infection Rates of Health Care Workers and the General Population in Daegu, South Korea*

	All health care workers	Doctors	Nurses	Nurse aides	General population
No. of confirmed Covid-19 infections	121	14	56	51	6,620
Population by segment**	27,388	5,908	11,557	9,923	2,433,568 [#]
Infection rate per 1,000	4.42	2.37	4.85	5.14	2.72

*As of March 24, 2020. **During the fourth quarter of 2019 (does not include additional personnel recruited from other regions during the Covid-19 outbreak). [#]In March 2020. Though overall rates of health care worker infections were lower than other major global outbreaks, Covid-19 infection rates among health care workers in Daegu were especially high among nurses and nurse aides, who staffed long-term care facilities and engaged in more frequent and closer patient contact, at nearly twice the rate as physicians and the general public in March 2020. Sources: Central Disaster and Safety Countermeasures Headquarters, Korean Statistical Information Service.

Nevertheless, as the SARS-CoV-2 virus spread rapidly in Daegu, 51 of 54 available negative-pressure isolation beds within the city were occupied only 4 days after the first confirmed case of Covid-19. By the end of February, more than 1,300 patients were waiting for hospital beds, and by early March, there were over 2,000 patients waiting.³⁻⁵ Health officials were concerned about a growing crisis, with reports early on of three patients who died at home while waiting for hospitalization.

Meanwhile, the city had a concurrent shortage of health care workers; there was significant concern about staff burnout, employees quitting, and health care professionals resting on the floor due to lack of space.⁶ Early on, at Kyungpook National University Hospital in Daegu, four of the seven doctors in the emergency department became sick. Meanwhile, epidemiology investigators who usually would track one confirmed case each were having to investigate three to four patients at once. Change was necessary to avoid a surge of health care worker infections and further pressure on the health care system.

A Pivot Toward Reducing Health Care Worker Infections in Daegu

Despite these early setbacks, as of March 24 — more than a month after the start of the Daegu epidemic — a total of 121 health care workers were infected with Covid-19 in Daegu (a city of more than 2.4 million people), including 14 doctors, 56 nurses, and 51 nurse aides.⁷ This represented 1.8% of the total 6,620 confirmed cases in Daegu at that time, which stood in contrast to other global hot spots, such as Italy, where 4,824 health care workers (9% of total cases) were infected by March 22.⁸

Compared to an infection rate of 2.7 per 1,000 people in the general population, health care workers were infected at a higher rate of 4.4 per 1,000 people (Table 1). However, there were notable differences by type of occupation: Doctors were infected at a lower rate of 2.4 per 1,000, while the rate for nurses and nurse aides was closer to 5 per 1,000. Health officials noted that nurses, compared to physicians, tend to staff facilities like nursing homes, where there were cluster outbreaks, and that they also have frequent, close interactions with patients.

At least 34 cases of the 121 cases were likely community-acquired, as they were determined to be members of the Shincheonji church where the primary cluster of community outbreaks occurred. Twenty-six cases of health care worker infections that did appear to be nosocomial in origin, involving clusters of infection at health care facilities, occurred at four long-term care facilities or psychiatric hospitals rather than acute care hospitals (Table 2).

Table 2. Clusters of Covid-19 Infections in Health Care Facilities in Daegu, South Korea*

Cluster outbreaks	Type of facility	First reported date	Total no. of confirmed cases	No. of health care worker infections (doctors/nurses/nurse aides)
Facility A	Psychiatric	March 26	196	8 (0/4/4)
Facility B	Long-term care	March 16	128	12 (1/5/6)
Facility C	Long-term care	March 18	98	5 (0/3/2)
Facility D	Long-term care	February 24	46	1 (0/1/0)

*As of May 5, 2020. Cases of nosocomial spread to health care workers were found in cluster outbreaks at four long-term care and psychiatric facilities. One physician tested positive for Covid-19 while 13 nurses and 12 nurse aides were infected as of May 5, 2020. Source: Daegu Medical Association.

Conversely, for health care workers caring for confirmed Covid-19-positive patients, there were zero nosocomial infections as of April 3. By May 1, there were two nurses and one nursing aide in Daegu who tested positive after caring for Covid-19 patients.⁹ Overall, the only reported health care worker death was one physician who died of the disease after contracting the virus from a patient at his private outpatient clinic in Gyeongsan, about 10 miles away.¹⁰

Despite immense pressures on its health care system, how was Daegu able to avoid an epidemic of health care worker infections and deaths? Health officials rapidly adopted a comprehensive package of interventions that relieved shortages, concentrated resources, isolated cases, and protected health care workers (Figure 1).

FIGURE 1

Key Steps to Protect Health Care Workers During the Daegu Outbreak

Regional Reorganization of the Health System

- Regional risk stratification & triage system
- Rapid expansion of beds for isolation with use of portable negative pressure machines
- Recruitment of health care workers for both public health and medical responses

Hospital-Level Interventions

- Hospital entrance and emergency department triage with Covid-19 screening clinics
- Universal mask policy and comprehensive use of PPE
- Screening and exposure management of hospital staff

Specific Measures in Response to Challenges

- Universal testing and contact tracing of people in long-term care and psychiatric hospitals
- Triage and cohort isolation of major clusters of outbreaks in facilities
- External consultation systems for facilities without infection control capabilities

Note: All testing was done by real-time polymerase chain reaction (RT-PCR) tests. PPE = personal protective equipment. Source: The authors

NEJM Catalyst (catalyst.nejm.org) © Massachusetts Medical Society

Table 3. Daegu's Covid-19 Brief Severity Scoring System

Severity class	Criteria	Triage
Asymptomatic to mild	No symptoms or common cold-like symptoms	Community treatment centers
Moderate	Body temperature 37.5°C and cough	Community hospitals
Severe	Suspected severe pneumonia (body temperature over 38°C lasting more than 3 days, respiratory symptoms)	Tertiary hospitals
Critical	Suspected critical pneumonia (shortness of breath for more than 1 day, respiratory rate of 30 breaths/minute or more)	Tertiary hospitals / ICU care

Severity class was determined by physician volunteers who interviewed patients by phone. The severity class and subsequent triage destination could be modified by factors such as age, comorbidities, end-of-life status, and dwelling in a long-term care facility. Source: Daegu Medical Association.

Regional Reorganization of the Health System

Rather than having individual hospitals operate on their own, given the growing crisis, the city of Daegu and the national government mobilized resources and protocols to reorganize and coordinate the response to the Covid-19 outbreak.

Regional Risk Stratification and Triage System

Prior to the outbreak, there was no system for risk stratification of patients infected with an emerging infectious disease, and only hospitals were allowed to isolate patients. However, as cases surged in late February, the Daegu Medical Association developed and implemented a four-category risk-stratification system, the Covid-19 Brief Severity Scoring System, based on similar scores such as the National Early Warning Score and the Modified Early Warning Score.¹¹

The four categories were: asymptomatic to mild, moderate, severe, and critical (Table 3). Symptoms were assessed by telephone interviews, and patients were isolated at designated facilities according to their severity of illness.

Asymptomatic and mildly symptomatic patients were admitted at community treatment centers — often dormitories for training institutions of South Korean companies transformed into centers used for monitoring patients without utilizing acute care resources.⁴ Meanwhile, patients with a higher severity of illness were hospitalized at community or tertiary hospitals.

“

Despite immense pressures on its health care system, how was Daegu able to avoid an epidemic of health care worker infections and deaths? Health officials rapidly adopted a comprehensive package of interventions that relieved shortages, concentrated resources, isolated cases, and protected health care workers.”

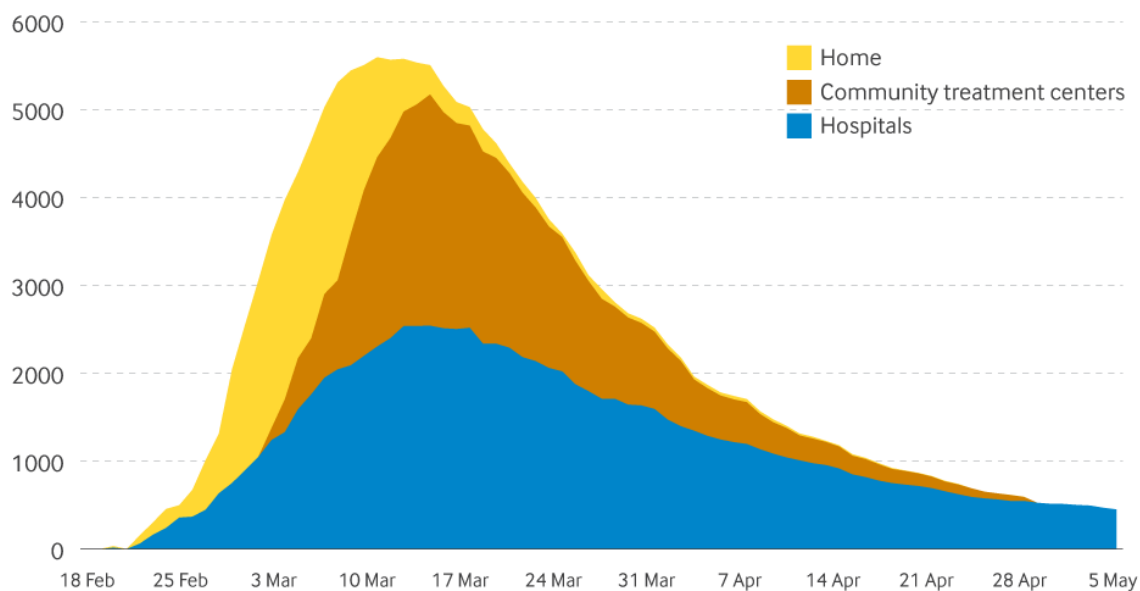
A referral system among each level of medical care allowed for patients with worsening clinical status to be efficiently transferred for a higher level of care, such as ICU-level care at tertiary hospitals. For asymptomatic to mild cases, by March 26, only 81 cases of 3,033 (2.67%) were transferred to the hospital, usually due to an acute exacerbation of their medical condition.

By implementing this system, the number of patients isolated at home declined rapidly without any reported deaths at home (Figure 2). As such, Daegu health officials reserved hospital resources for only those who absolutely needed them while identifying and isolating as many cases of Covid-19 as possible, thereby preventing community spread by household contacts. Limiting community transmission protected health care workers from becoming infected outside of the hospital as well as decreased the influx of potential cases into the hospital.

FIGURE 2

Cumulative Number of Covid-19 Patients in Home, Community Treatment Center, and Hospital Isolation in Daegu, South Korea (February to May 2020)

Health officials opened the first community treatment center on March 2, 2020, to relieve hospital bed shortages and provide places for monitoring and isolation. They also expanded the number of available beds for Covid-19 treatment to accommodate the surge.



Source: Daegu Medical Association

NEJM Catalyst (catalyst.nejm.org) © Massachusetts Medical Society

Meanwhile, by stratifying patients by risk, the appropriate health care personnel, protocols, and PPE could be allocated to specific care settings to offer maximal protection from nosocomial infections and optimize care for the patient.

Rapid Expansion of Beds for Isolation with Use of Portable Negative-Pressure Machines

In response to the bed shortage, health officials created 303 negative-pressure beds at the Armed Forces Daegu Hospital along with an additional 100 negative-pressure isolation rooms across the

city. Portable negative-pressure devices were used to convert existing rooms into ones that could prevent nosocomial spread to health care workers and other hospitalized patients.¹²

“*Daegu health officials reserved hospital resources for only those who absolutely needed them while identifying and isolating as many cases of Covid-19 as possible, thereby preventing community spread by household contacts.*”

Meanwhile, the city began designating 10 hospitals for the care of Covid-19 patients on February 21. Existing inpatients at these institutions were transferred to other hospitals, and a subset of these facilities was dedicated entirely to the treatment of Covid-19. Daegu Medical Center, a regional district public hospital, and Keimyung University Daegu Dongsan Hospital continued to exclusively manage patients with Covid-19. Meanwhile, hospitals like COMWEL Daegu Hospital were initially Covid-19-only hospitals that began accepting non-Covid-19 patients as the caseload decreased. Other hospitals maintained care for patients without Covid-19.

By March 30, the government secured 1,828 beds in Daegu at 11 hospitals (including the Armed Forces Daegu Hospital) for the treatment of Covid-19. Beyond Daegu, officials identified available beds in other nearby cities and provinces where they could transfer patients from Daegu who required hospital-level care; 1,296 beds at 24 hospitals were reserved in these other regions.

Additionally, the first community treatment center opened on March 2, with many following soon after, including dormitories for training institutes of private companies such as Samsung and LG. Fifteen community treatment centers admitted 3,033 people from March 3 to March 26, 2020. The centers were monitored by health professionals, and patients reported their symptoms regularly by a smartphone application or by phone. The facilities were equipped with pulse oximeters, X-ray machines, and real-time reverse transcription polymerase chain reaction (RT-PCR) tests for SARS-CoV-2 along with basic medications such as antipyretics.¹³

This rapid regional expansion of bed capacity enabled health officials to maximize their risk-stratification strategy. Moreover, it allowed them to concentrate cases of Covid-19 into hospitals that had the isolation units, infection control protocols, equipment, and personnel established to tackle the disease.

Recruitment of Health Care Workers for Both Public Health and Medical Responses

Given the acute need for health care workers, officials recruited people from other regions and provided early appointment of new workers. In total, about 2,392 additional health care workers were recruited. They were allocated to Covid-19 screening clinics, designated infectious disease hospitals, and community treatment centers. Additionally, 327 physicians volunteered without pay for various roles in the public health response, with 30 volunteering for the centralized Covid-19 response team and 260 volunteering for phone triage centers.

“ *In mid-February, emergency measures were implemented, which doubled the daily production of masks in South Korea to an average of 10 million by March.*”

At the same time, shift lengths were closely monitored to minimize health care worker fatigue that could cause errors in basic infection control, such as hand hygiene and PPE donning and doffing. Workweeks were limited to 40 hours per week, with compensation for overtime beyond that. There was a 2-week limit on shifts for public-sector workers and a 1-month limit for those in the private sector.

These additional workers proved critical for not only the clinical response, but also the population-level public health response. Moreover, the increased staffing capacity prevented individual health care workers from having to overextend themselves and risk conditions that might place them at a higher risk of infection.

As the outbreak in Daegu was brought under control, about four providers from other regions remained at the beginning of May while most health care workers returned home. Many physician volunteers involved in the public health response remained alongside the Daegu health care workforce in case of a second wave of SARS-CoV-2 infections.

Centralized Acquisition and Distribution of PPE

As with many cities around the world during the Covid-19 pandemic, Daegu faced a shortage of PPE — a critical issue that was escalated to the national government.¹⁴ Initially, the government implemented measures such as limiting export of masks and penalizing hoarding among retailers, but those interventions appeared insufficient. In mid-February, emergency measures were implemented, which doubled the daily production of masks in South Korea to an average of 10 million by March.¹⁵ The South Korean government stepped in during early March to purchase 80% of the mask supply from Korean manufacturers, fully ban exports, set a price limit on mask sales, and limit the weekly amount of masks sold through retailers. Moreover, the government prioritized the distribution of masks to medical facilities. Through this suite of interventions, shortages were relieved and no formal hospital policies around the reuse of PPE were implemented.

Hospital-Level Interventions

Hospital Entrance and Emergency Department Triage with Covid-19 Screening Clinics

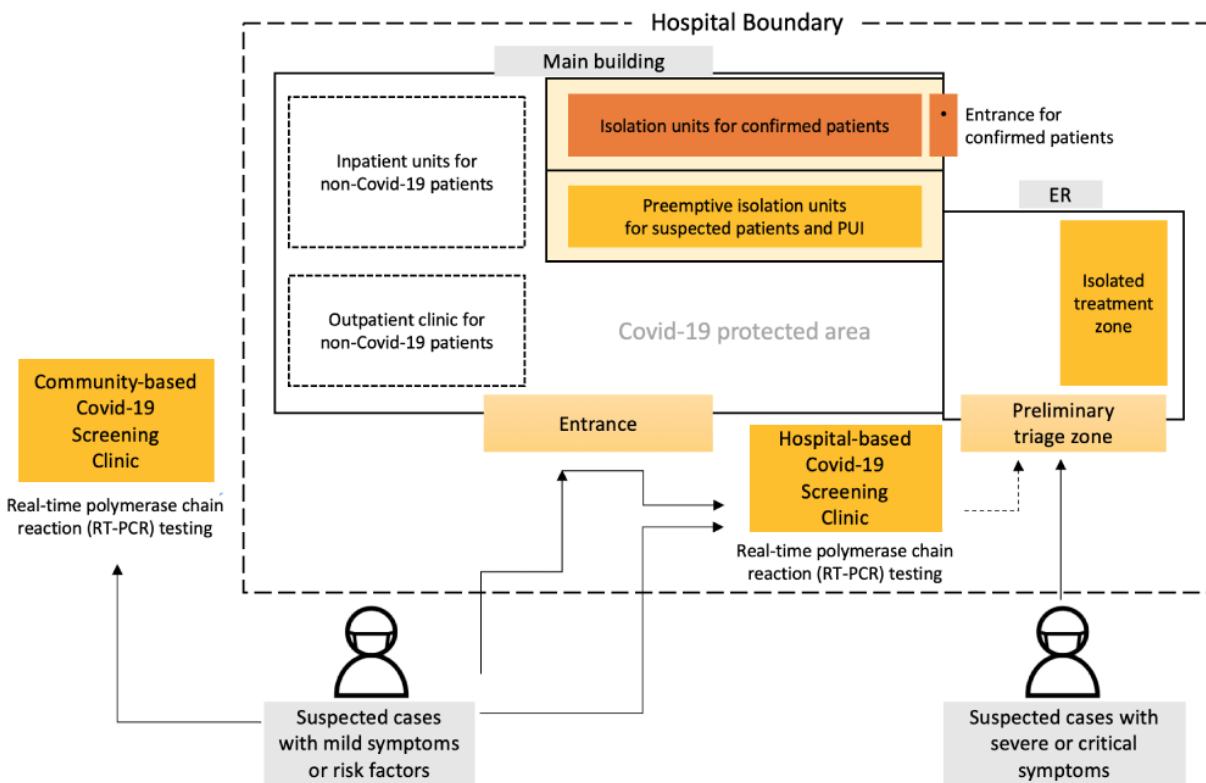
Across Daegu, hospitals implemented strict screening procedures at their entrances. For example, at Kyungpook National University Hospital, all visitors and patients walking through the entrance had their temperatures checked and answered a short questionnaire about respiratory symptoms and travel history. People who were cleared received a day pass for entry. Otherwise, they were triaged to a Covid-19 screening clinic outside of the main hospital building for further testing and evaluation.

Beyond designated Covid-19 centers, in Daegu, emergency medical centers at five tertiary hospitals were designated for treating critically ill patients with Covid-19 symptoms.¹⁶ To prevent cross-contamination between people with and without Covid-19, patients were first classified at a preliminary triage zone, depending on their severity and infection status. Emergency patients in serious condition with confirmed or suspected Covid-19 were provided with emergency treatment in a separate isolated treatment zone (Figure 3).

FIGURE 3

Schematic for Hospital-level Triage and Separation of Covid-19 and Non-Covid-19 Patients in South Korea

Hospital wards, emergency rooms (ER), and screening clinics in South Korea were organized to screen, triage, and separate suspected and confirmed cases of Covid-19 in order to avoid nosocomial infections and cross-contamination.



Note: PUI = persons under investigation

Source: The authors

NEJM Catalyst (catalyst.nejm.org) © Massachusetts Medical Society

By emphasizing screening, testing, and triage at hospital entrances, unscreened entry of individuals with Covid-19 could be minimized. Accurate sorting of individuals allowed a limited supply of PPE to be utilized at key areas of the hospital such as the screening clinics and isolation units in the

emergency department and hospital wards. This form of spatial separation protected health care workers as well as other patients without Covid-19.

Universal Mask Policy and Comprehensive Use of PPE

Hospitals in Daegu required a universal mask policy during and after the outbreak, as there was deemed to be a low risk for infection as long as both the health care worker and the patient wore masks during close encounters. Additionally, with a culture of pervasive mask-wearing in South Korea due to air pollution, many people already wore masks into hospital buildings.

“ *Shift lengths were closely monitored to minimize health care worker fatigue that could cause errors in basic infection control, such as hand hygiene and PPE donning and doffing.* ”

Following national recommendations from the Korea Centers for Disease Control and Prevention (KCDC), hospitals also adopted a policy of aggressive use of PPE. Staff used surgical masks only in the cases of non-Covid-19 patient care or times of no patient contact. N95 respirators along with eye protection, shoe covers, and coveralls were used at screening clinics and for the care of all suspected or confirmed Covid-19 patients. N95 respirators were recommended even for handling of specimens and medical waste, disinfection of spaces used by Covid-19 patients, radiologic evaluations, and transport of patients via ambulance. Meanwhile, at Keimyung University Daegu Dongsan Hospital, one of the designated infectious disease hospitals in Daegu, all hospital staff in the ICU wore powered air-purifying respirators (PAPRs) and hospital staff in general wards dedicated to Covid-19 patients wore N95 respirators.

Such widespread and comprehensive use of PPE was made possible by the triaging, cohorting, and isolation mechanisms at the regional and hospital level. Rather than compromising and justifying a weaker form of protection due to shortages, the KCDC and hospitals in Daegu were able to ensure that health care workers interacting with any potential case of Covid-19 had the assurance of proven protection for providers.

Screening and Quarantine of Hospital Staff

The KCDC recommended twice-a-day screening by symptom checks for fevers and respiratory prodromes of hospital staff working with Covid-19 patients. Additionally, each hospital adapted screening protocols for its hospital employees. For example, upon entering the hospital, all hospital staff (both medical and nonmedical) at Kyungpook National University Hospital were screened for fever and respiratory symptoms along with a review of their international travel history. Anybody who reported symptoms was tested for Covid-19, with results provided within hours, and could work only if they tested negative. Moreover, if there was a potential cluster outbreak on a ward, all staff working on the ward were tested regardless of symptoms. For health care professionals completing their rotation at a Covid-19 facility, they were all tested for Covid-19 regardless of their

symptoms. Only those who tested negative would be able to work at other clinical sites. All tests were done by nasopharyngeal and oropharyngeal swabs and analyzed by RT-PCR.

Health care workers were asked to self-quarantine if they had close contact with a Covid-19 patient without proper PPE, if they had traveled internationally, or if they were part of a specific religious group known to have a high incidence of infection. On the 13th day of quarantine after exposure, health care workers were tested and could return to work only on day 15 after testing negative.

Specific Measures in Response to Challenges

Despite many successes in Daegu, there were several clusters of health care worker infections, which suggests opportunities for further improvement. These clusters of outbreaks primarily occurred in long-term care and psychiatric hospitals, so a strategy of universal testing, cohort isolation, and infection control consultations was adopted.

Health officials in Daegu conducted universal Covid-19 tests by RT-PCR for everyone in those facilities. Through mass testing, they identified 476 total Covid-19 cases in long-term care and psychiatric hospitals as of April 3. Of those, 437 cases (91.8%) were clustered in four hospitals, with an additional 31 cases identified by May 5 (Table 2). Thirty-six health care workers were confirmed to be Covid-19-positive, with 26 infections (one doctor, 13 nurses, and 12 nurse aides) from the four hospital clusters as of May 5. The availability of universal testing and contact tracing capabilities enabled health officials to home in on clusters of nosocomial spread. Notably, only one physician among these outbreaks was infected while 25 nurses and nurse aides tested positive, reflecting differences in staffing and proximity of patient contact at these various facilities.

Confirmed Covid-19 patients were transferred to a designated Covid-19 hospital or a community treatment center. Additionally, close contacts were quarantined and monitored. Facilities with outbreaks were reinvestigated regularly, and large clusters prompted cohort isolation of infected patients. Similar to acute care facilities, testing and cohort isolation enabled the spatial separation necessary to prevent nosocomial spread.

Since these facilities were notably vulnerable to nosocomial infections and understaffed from an infection control perspective, health officials implemented external consultation services with infection control experts for further advice and oversight. These measures did not necessarily require facilities to hire in-house personnel, but rather consult external sources to ensure that proper protocols and best practices in infection control were followed.

Conclusions and Lessons Learned

There are limitations associated with Covid-19-related data, so it may be difficult to compare one city to another, one country to another. For example, testing policies and volumes have varied among and within countries over time. Variation also exists regarding the underlying health demographics of a given population, actions regarding quarantining and business closures, and population monitoring and contact tracing.

“ *As the city of Daegu has brought the initial outbreak and shortages under control, the possibility of a second wave of infections is a major concern. Daegu health officials are preparing for such a scenario with the assumption that it is already underway.*”

Though South Korea faced the Covid-19 pandemic with several advantages — including a national health insurance system, a higher volume of testing, a higher hospital bed capacity per capita, and preparation from the 2015 MERS epidemic — it still faced an unexpected outbreak that placed immense pressure on the health system in Daegu. Nevertheless, through a series of health system and hospital-level interventions, the city was able to rapidly address its shortages while minimizing nosocomial health care worker infections.

Though some of its components such as health care worker screenings and universal mask policies have been implemented at some U.S. hospitals, we offer a holistic series of interventions to prevent health care worker infections. Comprehensive measures are necessary particularly in the face of surges and shortages. The Daegu health system applied some key principles and actions that could potentially be replicated in other cities and regions around the world. These are:

- Consolidate hospital systems and resources during the crisis and implement rigorous risk stratification and triage protocols to separate Covid-19–confirmed or suspected patients from non-Covid-19 patients, concentrate resources, and alleviate shortages.
- Monitor patients at every level of acuity and infection status to prevent asymptomatic or mild cases from infecting close contacts, clinically deteriorating, or siphoning away acute care resources from severe or critical cases.
- Implement universal masking policies, aggressive use of PPE, and regular health care worker screenings to minimize nosocomial transmissions.
- Secure dormitories and residential facilities for Covid-19 patients who need minimal medical care.
- Allow for continued care of non-Covid-19 patients by isolation and triage mechanisms.
- Increase health care worker capacity not only for acute hospital care, but also for public health and community interventions.
- Conduct universal testing and intensive screening and management of high-risk facilities (nursing homes, long-term care facilities) with systems for cohort isolation, infection control consultations, and transfer to Covid-19–designated hospitals.

Through these measures, Daegu achieved a lower level of health care worker infections and deaths, bent the curve of new cases and deaths from Covid-19 among the general population, and maintained suppression to help allow South Korea to plan for reopening of businesses and schools

while preparing for future waves of the pandemic. As Gary Pisano and colleagues wrote in a recent *Harvard Business Review* article on Italy's response to the Covid-19 pandemic, "While the public discussion of the policies followed in [countries like South Korea] often focuses on single elements of their models (such as extensive testing), what truly characterizes their effective responses is the multitude of actions that were taken at once."¹⁷

In Daegu, after the number of confirmed cases exceeded 6,000 on March 15, the total has remained under 7,000. Since March 12, the daily number of confirmed cases did not exceed 100 cases as health officials continued intensive contact tracing and mass testing. On April 9, there were zero new cases of Covid-19 in Daegu. Meanwhile, the national death rate in early May had been about 1 per day, bringing the total number of Covid-19 deaths to 260 as of May 14, which represents a national Covid-19 fatality rate of 5.05 per million population over the course of the pandemic.¹⁸

Given the decreasing cases and testing needs, the city of Daegu closed six of 10 drive-through screening clinics. Community treatment centers have also been closed as the number of discharges exceeded the number of admissions for more than 10 consecutive days. Six community treatment centers remain open to respond to a potential second wave.

As the city of Daegu has brought the initial outbreak and shortages under control, the possibility of a second wave of infections is a major concern. Daegu health officials are preparing for such a scenario with the assumption that it is already underway. Indeed, a cluster of new cases in the capital city of Seoul in early May is attributed to a single club patron, demonstrating that continued vigilance is absolutely necessary.¹⁹ To prepare, officials are securing critical resources in case of a surge of patients in the next wave while maintaining several designated infectious disease hospitals and community treatment centers.

June-Ho Kim, MD, MPH

Fellow in General Internal Medicine and Primary Care, Brigham and Women's Hospital Fellow, Primary Health Care, Ariadne Labs, Boston, Massachusetts, USA

Julia Ah-Reum An, MD, MPH

Affiliate Physician, Ariadne Labs, Boston, Massachusetts, USA

Pok-kee Min, MD, PhD

Head of Covid-19 Response, Daegu Medical Association, Daegu, South Korea

Asaf Bitton, MD, MPH

Executive Director, Ariadne Labs, Boston, Massachusetts, USA

Atul A. Gawande, MD, MPH

Chairman, Ariadne Labs, Boston, Massachusetts, USA

Acknowledgments

First and foremost, we thank the many health care workers and volunteers in Daegu, South Korea who worked tirelessly to respond to Covid-19 and save lives. We thank the Ariadne Labs Covid-19 Global Learnings team (SeungJu Jackie Oh, Ruby Kwak, Kendra Kim, Louise Knabe, Kit Nichols) and numerous South Korean physicians and health officials, including Drs. Ho Young Chung and Kyoung-Tae Kim from Kyungpook National University Hospital and Dr. Heanji Kim, a medical volunteer at Keimyung University Daegu Dongsan Hospital in Daegu, who contributed data, insights, research, and review of protocols for this article. Special thanks to Jiwon Min for critical translation support and feedback on the manuscript. This work was supported by grants from the Patrick J. McGovern Foundation and the Morris-Singer Foundation.

Disclosures: June-Ho Kim, Julia An, and Pok-kee Min have nothing to disclose. Asaf Bitton reports grants from the Bill and Melinda Gates Foundation and the Patrick J. McGovern Foundation. Atul Gawande is the Chairman of Haven, the health care venture founded by Amazon, Berkshire Hathaway, and JPMorgan Chase.

References

1. Kim KH, Tandil TE, Choi JW, Moon JM, Kim MS. Middle East respiratory syndrome coronavirus (MERS-CoV) outbreak in South Korea, 2015: epidemiology, characteristics and public health implications. *J Hosp Infect.* 2017;95(6):207-13
2. Cho SY, Kang J-M, Ha YE. MERS-CoV outbreak following a single patient exposure in an emergency room in South Korea: an epidemiological outbreak study. *Lancet.* 2016;388(6):994-1001
3. Kim J-S. 1304 Confirmed Patients Who Couldn't Even Go to the Hospital. *Jungang Daily.* February 29, 2020. Accessed May 11, 2020. <https://news.joins.com/article/23718609>.
4. Yoon D. How South Korea Solved Its Acute Hospital-Bed Shortage. *The Wall Street Journal.* Dow Jones & Company. March 22, 2020. Accessed May 11, 2020. <https://www.wsj.com/articles/how-south-korea-solved-its-acute-hospital-bed-shortage-11584874801>.
5. Reuters. Thousands Wait for Hospital Beds in South Korea as Coronavirus Cases Surge. *The Japan Times.* March 4, 2020. Accessed May 11, 2020. <https://www.japantimes.co.jp/news/2020/03/04/asia-pacific/thousands-wait-hospital-beds-south-korea-coronavirus-cases-surge/#.Xrmk9sB7k2y>.
6. Yoon D, Martin TW. Not Enough Doctors in Daegu: As Virus Cases Rise, South Korea's Response Is Criticized. *The Wall Street Journal.* Dow Jones & Company. February 24, 2020. Accessed May 11, 2020. <https://www.wsj.com/articles/not-enough-doctors-in-daegu-as-virus-cases-rise-south-koreas-response-is-criticized-11582547600>.
7. Kim K-B. Daegu Medical Staff: 121 People with Corona-19 Infection, 1 Serious Condition, 1 Severe. *The Kyunghyang Shinmun.* Kyunghyang Media. March 28, 2020. Accessed May 11, 2020. http://news.khan.co.kr/kh_news/khan_art_view.html?art_id=202003281428001.

8. Anelli F, Leoni G, Monaco R. Italian doctors call for protecting healthcare workers and boosting community surveillance during covid-19 outbreak. *BMJ*.
9. Park M-S. No Additional Infection in Hospital Despite Confirmed Infected Medical Staff Taking Care of Corona-19 Patients. *DailyMedi*. Daily Medi Co. May 1, 2020. Accessed May 12, 2020. <https://www.dailymedi.com/detail.php?number=855667>.
10. Kim Y-M. 1st COVID-19 Death of Doctor Reported in Korea. *Korea Biomedical Review*. April 3, 2020. Accessed May 11, 2020. <http://www.koreabiomed.com/news/articleView.html?idxno=7912>.
11. Kim SW, Lee KS, Kim K, Lee JJ, Kim JY. Daegu Medical Association. A brief telephone severity scoring system and therapeutic living centers solved acute hospital-bed shortage during the COVID-19 outbreak in Daegu, Korea. *J Korean Med Sci*.
12. Lee JK, Jeong HW. Rapid expansion of temporary, reliable airborne-infection isolation rooms with negative air machines for critical COVID-19 patients. *Am J Infect Control* 2020;50:196-6553:30269-8 [Online ahead of print] <https://www.ncbi.nlm.nih.gov/pubmed/32371066>.
13. Her M. Repurposing and reshaping of hospitals during the COVID-19 outbreak in South Korea. *One Health* 2020;10:100137 [Online ahead of print] <https://www.ncbi.nlm.nih.gov/pubmed/32373705>.
14. Choi H-S. Moon Apologizes for Mask Shortage. *The Korea Herald*. Herald Corporation. March 3, 2020. Accessed May 13, 2020. <http://www.koreaherald.com/view.php?ud=20200303000718>.
15. Jung M-K. South Korean Government Takes Full Control of Face Mask Supply, Bans Exports. *The Korea Herald*. Herald Corporation. March 5, 2020. Accessed May 13, 2020. <http://www.koreaherald.com/view.php?ud=20200305000730>.
16. Park. 14 Hospitals in Yeongnam Area Designated as Corona-19 Serious Emergency Medical Centers. *DailyMedi*. Daily Medi Co. March 17, 2020. Accessed May 12, 2020. <http://www.dailymedi.com/detail.php?number=854081>.
17. Pisano GP, Sadun R, Zanini M. Lessons from Italy's Response to Coronavirus. *Harvard Business Review*. Harvard Business Publishing. March 27, 2020. Accessed April 13, 2020. <https://hbr.org/2020/03/lessons-from-italys-response-to-coronavirus>.
18. Roser M, Ritchie H, Ortiz-Ospina E, Hasell J. Total Confirmed COVID-19 Deaths. *Coronavirus (COVID-19) Deaths*. Our World in Data. Updated daily. Accessed May 13, 2020. <https://ourworldindata.org/Covid-deaths>.
19. Gong SE. South Korea Delays Reopening Schools as Coronavirus Cases Resurge: Coronavirus Live Updates : NPR. *National Public Radio*. May 12, 2020. Accessed May 13, 2020. <https://www.npr.org/sections/coronavirus-live-updates/2020/05/12/854407305/south-korea-delays-reopening-schools-as-coronavirus-cases-resurge>.