

Original Article



OPEN ACCESS

Received: Dec 4, 2020

Accepted: Feb 17, 2021

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Response to the COVID-19 Outbreak in The Emergency Department Designed for Emerging Infectious Diseases in Korea

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ABSTRACT

Background: According to the recent coronavirus disease 2019 (COVID-19) pandemic experience, many emergency departments experience difficulties in responding to emerging infectious diseases and this has led to a public health crisis. Our emergency department (ED) is designed to respond to mass outbreaks of infection. Three major preparations were taken to respond to infectious disease; first, to improve the emergency department facilities; second, to create programs to respond to each phase of an epidemic of COVID-19; lastly, to implement education and training to promote the safety of medical staff. We would like to share the actual responses and statistics of patients visiting emergency department during COVID-19 periods of pandemic.

Materials and Methods: This research was conducted through a retrospective chart analysis provided by a public medical center with 502 beds since the first report of a COVID-19 confirmed case on January 19, 2020 to June 15, 2020 in Seoul, the capital of Korea. Our emergency department was designed based on Korean Regional Emergency Center Facility Standards, and modified throughout each phases of COVID-19 outbreak. Patients suspected to be infectious are screened in the triage, separating them from general patients, and then receive isolation treatment in isolated wards.

Results: A total of 4,352 patients visited the ED. 3,202 screenings were conducted with 5 confirmed cases. Another 1,150 patients were treated with general emergent symptoms. There were no problems such as closure of the emergency department or isolation of medical staff while managing COVID-19 confirmed patients.

Conclusion: Improving emergency department facilities, create an operational program to respond to each phase of COVID-19 outbreak and implement educational programs enabled large number of screening tests and hospitalization for COVID-19 suspected patients while maintaining general medical services. Research in emergency department designs and operational programs should increase to combine research data with better ideas to respond not only during regular periods but also during periods of pandemic.

Keywords: COVID-19 pandemic; Infectious disease; Emergency department; Triage

Conflict of Interest

No conflicts of interest.

Author Contributions

Conceptualization: TP. Data curation: SIC.
 Formal analysis: WC. Investigation: JIK.
 Methodology: SIC, WY. Software: WC.
 Validation: SWM. Visualization: JIK. Writing -
 original draft: SIC. Writing - review & editing:
 TP, KL, YK.

INTRODUCTION

The recent discovery of new strains of infectious diseases and their transmission have caused widespread prevalence. Severe acute respiratory syndrome (SARS), first reported in Guangdong Province, China, in 2002, resulted in more than 8,000 confirmed cases in 26 countries in 2003 [1, 2]. In addition, Middle East respiratory syndrome (MERS), first reported in Saudi Arabia in 2012, remains prevalent with 2,553 confirmed cases and 876 deaths worldwide [3].

Korea had its first confirmed MERS case in May 2015, and it had the most confirmed cases outside Saudi Arabia, with 186 confirmed cases and 36 deaths within two months [4, 5]. A total of 89 of the confirmed cases, 47.9% of the total number of cases, occurred in emergency centers [6]. Such experiences not only showed the importance of quarantine measures at the national level but also containment in medical facilities, especially where patients, caregivers, and medical staff move. At the time, measures had been taken to operate temporary screening stations and manage paths of travel, but those proved to be less effective, and hospitals and emergency centers, whichever a confirmed case was reported, closed and medical staff were quarantined [7]. Such measures, like closing down hospitals that reported confirmed cases, impact the community because of the suspension of medical services, including general patient care, and resulted in death due to the inability to receive proper medical care in time [8].

Our hospital has remodeled the emergency department based on the Korea Centers for Disease Control and Prevention (KCDC) guidelines and the Korean Regional Emergency Center Facility Standards under the ‘Emergency Medical Service Act’ revised after the MERS outbreak in 2015, and programs to respond to emerging infectious diseases have been initiated. In addition to that, we reconstructed our ED facilities to respond to nonepidemic, sporadic and pandemic phases of COVID-19 according to COVID-19 infection control guidelines. There were no massive outbreak of COVID-19 in Korea at the beginning of the research period, but a large number of confirmed cases occurred in other cities in mid-February related to religious gatherings and the massive infection was identified in clubs in Seoul in early May. This research aims to present statistics on patients based on the periodic progression of COVID-19. This study compares data of COVID-19 screening patients with general patients and presents the number of patients in correspondence with periodic events in ED designed to respond to mass outbreaks of infection.

MATERIALS AND METHODS

1. Research design, duration, and population

This research was conducted through a retrospective chart analysis provided by a public medical center with 502 beds since the first report of a COVID-19 confirmed case on January 19, 2020 to June 15, 2020 in Seoul, the capital of Korea. During the research period, patients who showed fever of 37.5°C or higher, respiratory symptoms, or had epidemiological concerns (having visited nations or areas of prevalence or workplaces, groups or establishments with a confirmed case), received COVID-19 real time reverse transcription polymerase chain reaction (RT-PCR) test. Patients who had other symptoms were treated for general emergent symptom.

2. Introduction to the institution where research was conducted

The Ministry of Health and Welfare has designated this institution as a central medical institution dedicated to infectious disease, serving as a control center for responding to emerging infectious diseases. The emergency center has also been designated a central medical center for providing emergency care related to local emergency patients and conduct projects related to domestic and international disaster response, trauma, and toxicology.

At this time of the emerging epidemic, our hospital has developed intensive care and treatment guidelines for confirmed patients, supported local medical institutions, and managed epidemic-related medical institutions nationwide. By preparing for emergency situations such as national epidemics and disasters and by expanding medical service infrastructure, our hospital mainly plays a role on the safety and health of the people, especially on the treatment of the severely ill.

3. Facility of the institution where research was conducted

Our emergency center was remodeled from October 23 to December 11, 2015 based on the guidelines required by KCDC and Korean Regional Emergency Center Facility Standards under the 'Emergency Medical Service Act' revised after the MERS outbreak on December 15, 2015 in accordance with the institution's conditions [6, 9].

Designed based on Korean Regional Emergency Center Facility Standards, patients suspected to be infectious are screened in the triage, separating them from general patients, and then receive isolation treatment in isolated wards. Two negative pressure isolation rooms (NPIRs) with anterooms and three general isolation areas have been installed with separate bathrooms. Different units are designed according to the severity of illness. Mildly ill patients are separated by curtains. Moderate to severely ill patients are physically separated by glass walls to keep them away from other vulnerable patients. Additionally, air conditioning facilities are separated, and an air distribution control system was installed to enable air circulation 6 to 12 times per hour (Fig. 1).

4. Changes in the emergency department response

1) Non-epidemic phase (- JAN/27/2020)

During this period, KCDC raised its alert level from 1 (blue) to 2 (yellow) on January 20, 2020 and World Health Organization (WHO) did not announce any crisis alert.

Even under ordinary circumstances, a triage nurse wore protective equipment (a disposable gown, gloves, an N95 mask, and a face shield) and checked the patient's travel history first, with travel history to China added to the questionnaire after the unidentified respiratory disease became prevalent in Wuhan, China, and maintained an ordinary response manual. Even after a patient was assigned to a ward, if infectious disease was suspected, alarm code would broadcast, movement was controlled, personal protective equipment was recommended, and the patient was moved to NPIR (Fig. 2A).

2) Sporadic Phase (JAN/28/2020 - FEB/02/2020)

During this period, KCDC raised its alert level to 2 (orange) on January 27.

Since the first domestic confirmed case, pretriage space was constructed outside the ED where if infection was suspected, the patient would be treated in NPIR instead of the general emergency ward. If infection was not suspected, the patient would be treated in the general

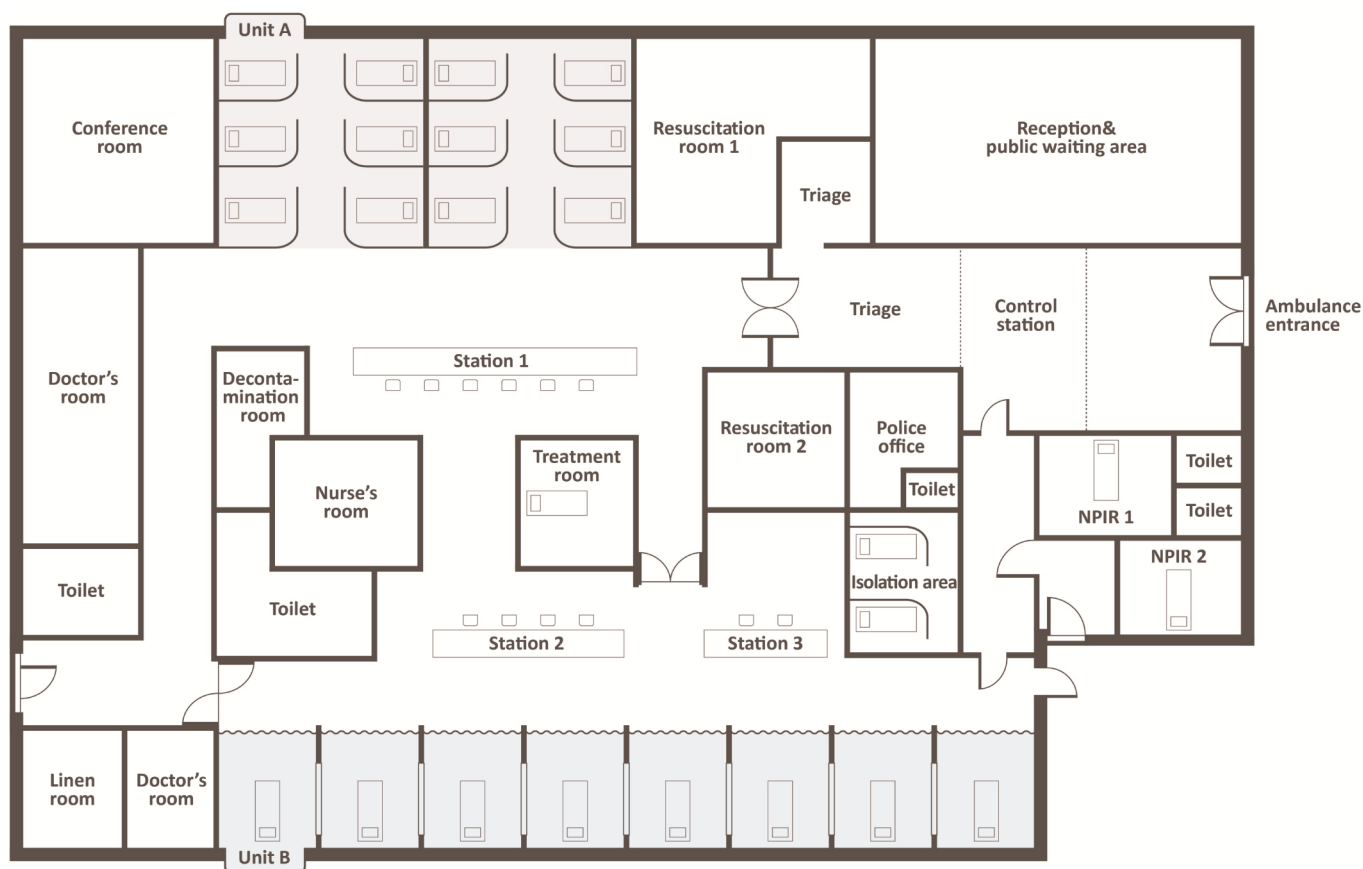


Figure 1. Floor plan of our emergency center, which has been remodeled based on the guidelines required by the KCDC and Korean Regional Emergency Center Facility Standards. KCDC, Korea Centers for Disease Control and Prevention; NPIR, negative pressure isolation room.

emergency ward. In the course of pretriage, the medical staff equipped Level D to prevent medical staff infection, rotating every one or two hours. After the patient entered the NPIR in ED, another medical staff equipped Level D for sample collection and examination. PCR testing of COVID-19 was not available in our hospital at this period; thus, the samples were sent to Central Disease Control Headquarters, and patients were treated in NPIR until being notified with the result. Later, patients were released according to their test results, where they were admitted to NPIR or discharged (Fig. 2B).

3) Pandemic Phase I (FEB/03/2020 - APR/24/2020)

During this time, WHO declared public health emergency of international concern on January 30, followed by declaration of a pandemic on March 11th. In addition, KCDC raised its alert level to its highest level, 3 (Red) on February 23.

We have made a preemptive transition to respond to the pandemic phase in line with the increased rate in confirmed cases. The treatment zone for moderate to severely ill patients was changed to the infected zone for screening COVID-19 and admitting suspected patients, and a portable chest computed tomography (CT) for screening was installed outside. Suspected patients were admitted to the infected zone directly from outside pretriage, underwent chest X-ray after examination, and if highly suspected, a chest CT was performed in the outside portable CT. Moreover, aerosol/droplet infectable samples were collected

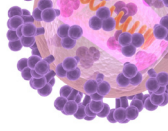


Figure 2. Floor plan according to the response level with a moving line of patient and medical staff. At the nonepidemic phase (A), the patient was moved to isolation beds at triage or from general treatment areas if infectious disease was suspected. At the sporadic phase (B), pretriage space was constructed outside the ED where if infection was suspected, the patient would be admitted directly to NPIR instead of the general emergency ward. If infection was not suspected, the patient would be treated in the general emergency ward. At the pandemic phase I (C), the treatment zone for moderate to severely ill patients was changed to the infected zone for screening COVID-19 and admitting suspected patients, and portable chest CT for screening was installed outside. At pandemic phase II (D), a walk-through booth was installed outside the ED, where collection of nasopharyngeal swabs from both symptomatic and asymptomatic patients was carried out. At pandemic ED, emergency department; NPIR, negative pressure isolation room; COVID-19, coronavirus disease 2019; CT, computed tomogram.

in NPIR in the ED. If the patient appeared asymptomatic after examination and collection of samples, the patient was advised to return home using personal transportation under quarantine measures. Patients epidemiologically concerned or suspected after chest radiography would be admitted and treated in outside-ED NPIR until notification of a negative result, at which point the patient was transferred to another hospital or treated as an outpatient for follow-up (Fig. 2C).

4) *Pandemic Phase II; Pandemic phase I + Walk through booth (APR/25/2020-)*

A new concept of large-scale screening inspection was introduced followed by the installation of a walk-through booth outside the ED [10]. The collection of nasopharyngeal swabs from both symptomatic and asymptomatic patients was carried out in the booth, whereas sputum expectoration was carried out in a NPIR in the ED due to droplet infection risk. If a chest X-ray was needed, the patient was admitted to the infected zone for examination. This allowed asymptomatic patients and patients without lower respiratory tract symptoms to receive examination and medicine without entering the ED (Fig. 2D).

5. Infectious disease response program in the ED

1) *Linking of immigration information with the hospital's electronic medical record system*
 Since 2015 in Korea, the KCDC has provided immigration data for both Koreans and foreign nationals participating in short-stays to the national health insurance system and has distributed related programs to medical institutions. Each individual medical institution has linked this information to its Electric Medical Record (EMR) system. This allows institutions to check patients' travel histories to countries with infectious disease outbreaks immediately upon reception.

2) *Infectious disease alarm within the ED*

The ED runs three infectious disease alarms: code A (air, airborne and droplet caution), code B (blood, and other body fluids), and code C (contact, feculent and skin contact caution). Once the medical staff first identified such alarms, movement within the ED was restricted, personal protection equipment was worn, the patient was assigned to an isolated area, and those who came into contact were identified. However, the usefulness of this alarm system is confined to pre-pandemic period of COVID-19.

3) *Weekly briefings on infectious disease trends and gathering information on prevalent areas*

All medical staff in the ED were required to be present at a weekly meeting where the briefings conducted by KCDC on both domestic and foreign infectious disease trends were presented and familiarize themselves with these trends [11]. In addition to checking patients' immigration data provided by KCDC upon reception, staff checked real-time infectious disease trends in the countries patients visited through web searches to prevent foreign inflow of infectious disease [11].

4) *Vaccination for staff in the ED*

Staff were vaccinated with preventable diseases such as hepatitis A, B, MMR (measles, mumps, rubella), and influenza through the infection control department.

5) *Wearing personal protective equipment and disinfection*

Staff in charge of triage wore personal protective equipment on a regular basis (Faceshield, a mask, a disposable gown and gloves). They practiced wearing protective equipment for

levels C and D repeatedly throughout the educational program in hospital settings annually. As the COVID-19 virus is transmitted mainly through respiratory droplets and close physical contact, all of the healthcare workers sanitize hands using alcohol, change disposable gown and gloves between each patient.

Environmental surfaces where suspected COVID-19 patients are being cared for, was properly cleaned and disinfected using diluted 5% sodium hypochlorite and ventilated whenever each patient was discharged. Also, whole contamination zone (unit B) was cleansed at least twice daily to prevent further transmission or cross-infection [12].

6. Statistical analysis

The quantitative variables are presented as the means with standard deviations (SD), and categorical variables are presented as numbers and percentages. The data were analyzed using SPSS software (IBM SPSS statistics for Windows, version 26.0, IBM Corp, Armonk, NY, USA).

7. Ethics statement

The present study protocol was reviewed and approved by the Institutional Review Board of National Medical Center (approval No. NMC-2007-032). Informed consent was exempted by the Institutional Review Board.

RESULTS

1. Screening and general emergency patient treatment analysis

During the research, a total of 4,352 patients visited the ED. A total of 3,202 (73.6%) completed screening and fever evaluation. 22 were screened in sporadic phase and 3180 were screened during pandemic phases. Another 1,150 (26.4%) were treated in the ED for other general symptoms unrelated to COVID-19 symptoms. Screened patients showed coughing as the most common symptom (13.5%). Seventy (2.2%) of the screened patients came in close contact with another confirmed patient. Five hundred (15.6%) of the screened patients underwent chest X-rays, and another 102 (3.2%) underwent chest CT scans. Sixty-nine (2.2%) of the patients were admitted to NPIRs due to the high probability of COVID-19 infection. A total of 5 (0.2%) screened patients resulted in a confirmed case of COVID-19 (**Table 1**). 115 (27.4%) of the general patients had Korean Triage and Acuity Scale (KTAS) levels 1 to 3 (**Table 2**).

2. Statistics on the number of patients treated by the epidemic period

Changes in the pattern of statistics on the number of patients treated by the epidemic period are presented in **Figure 3**. Few patients went under screening measures early on, but the number increased when a large number of confirmed cases occurred in other cities in mid-February related to religious gatherings. Moreover, the numbers surged when massive infection was identified in clubs in Seoul in early May.

3. Results about ED safety

During the research, 5 confirmed cases were identified. All of the confirmed cases were identified in pandemic periods of COVID-19. Patient 1 had travel history of Israel within 14 days and close contact with other confirmed patients. Patient 2 was re-confirmed case of COVID-19. Patient 3 was related to massive infection identified in clubs in Seoul in early May. Patient 4 had no symptom but had suspected contact history with other COVID-19 confirmed patient. Patient 5 had high fever (39.5°C) with radiologically suspected COVID-19

Table 1. Characteristics of patients undergoing 2019–Novel Coronavirus RT-PCR

Characteristics	COVID-19 RT-PCR N = 3,202 (73.6%)
Baseline characteristics	
Age (Mean ± SD)	38.0 ± 15.06
Sex	
Male	2,148 (67.1%)
Female	1,054 (32.9%)
Nationality	
Korea	3,060 (95.6%)
China	70 (2.2%)
Asia	50 (1.5%)
Europe	10 (0.3%)
North America	9 (0.2%)
Other	3 (0.1%)
Symptom and sign	
Body Temperature, °C (Mean ± SD)	36.9 ± 0.65
<37.5	2,714 (84.8%)
37.5 - 38.5	397 (12.4%)
≥38.6	91 (2.8%)
Respiratory symptom	
Cough	725 (23.1%)
Sputum	435 (13.5%)
Rhinorrhoea	303 (9.5%)
Sore throat	259 (8.6%)
Dyspnea	261 (8.2%)
Anosmia or dysgeusia	55 (1.7%)
2	(0.1%)
Epidemiologic factors	
Travel history (within 14 days)	
None	3,029 (94.6%)
China	57 (1.8%)
South East Asia	45 (1.4%)
North America	22 (0.7%)
Europe	15 (0.5%)
Japan	14 (0.4%)
Middle East Asia	9 (0.3%)
Hong Kong/Macau	8 (0.1%)
South America	2 (0.1%)
Contact history with confirmed case	70 (2.2%)
Screening test	
Specimen of COVID-19 RT-PCR	
Sample collection period	
Sporadic phase	22 (0.7%)
Pandemic phase I	899 (28.1%)
Pandemic phase II	2,281 (71.2%)
Sample collection area	
Nasopharynx	3,202 (100%)
Sputum	1,002 (31.3%)
Radiologic test	
Chest X-ray	500 (15.6%)
Chest CT	102 (3.2%)
Disposition	
Admission to NPIR	
Sporadic phase	69 (2.2%)
Pandemic phase I	1 (0.0%)
Pandemic phase II	47 (1.5%)
21	(0.7%)
Confirmed COVID-19	
Sporadic phase	5 (0.2%)
Pandemic phase I	0 (0.0%)
Pandemic phase II	2 (0.1%)
3	(0.1%)

COVID-19, coronavirus disease 2019; RT-PCR, reverse transcription polymerase chain reaction; SD, standard deviation; CT, computed tomography; NPIR, negative pressure isolation room.

Table 2. Characteristics of patients not suspected of having COVID-19 with general emergency medicine management

Characteristics	Not suspected COVID-19 N = 1,150 (%)
Age (Mean ± SD)	48.72 ± 20.20
Sex	
Male	611 (53.1%)
Female	539 (46.9%)
Nationality	
Korea	1,055 (91.7%)
China	54 (4.7%)
Other Asia	28 (2.4%)
Europe	5 (0.4%)
North America	3 (0.3%)
Other	5 (0.4%)
Body Temperature, °C (Mean ± SD)	36.7 ± 0.71
KTAS	
KTAS level 1	10 (0.9%)
KTAS level 2	45 (3.9%)
KTAS level 3	260 (22.6%)
KTAS level 4	622 (54.1%)
KTAS level 5	213 (18.5%)
Admission	146 (12.7%)

COVID-19, coronavirus disease 2019; SD, standard deviation; KTAS, Korean triage and acuity scale.

and admitted outside-ED NPIR before PCR results came. None of the cases led to closure of the ED or suspension of emergency services. Moreover, none of the cases led to infection or quarantine of medical staff or other patients.

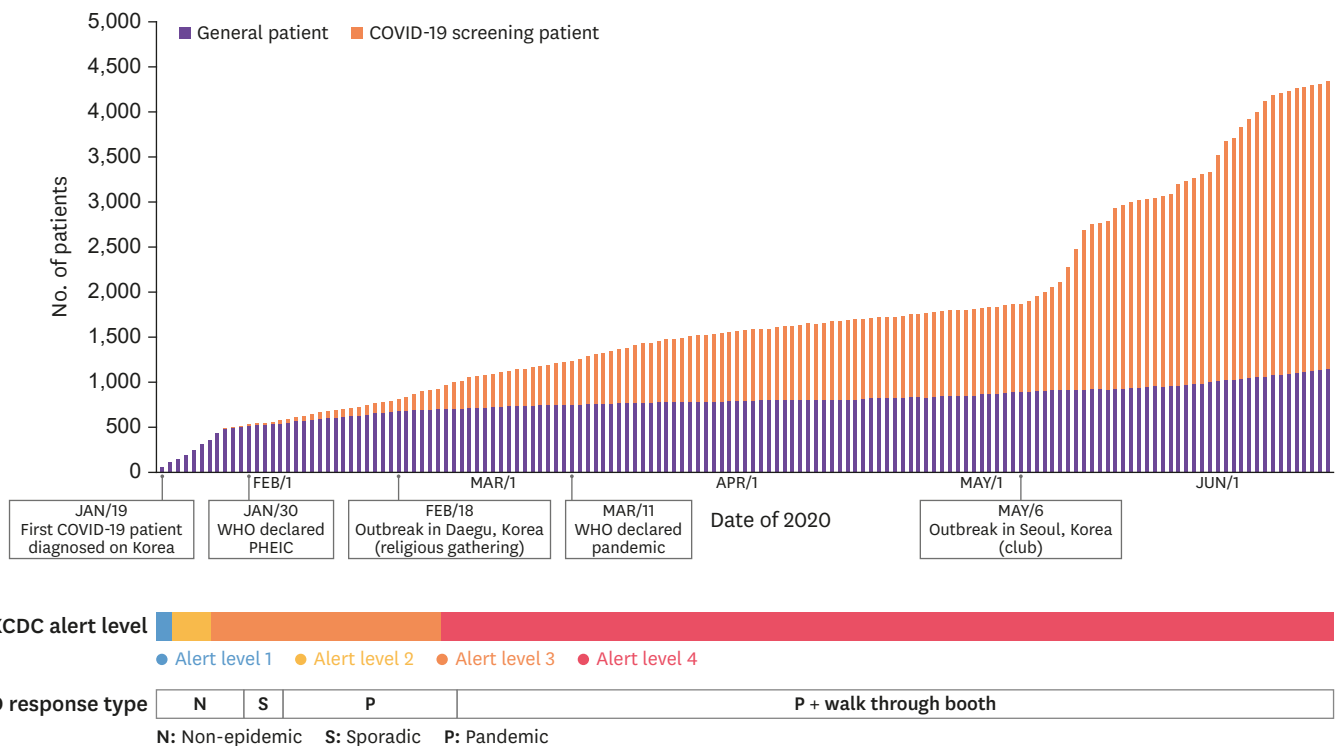


Figure 3. Changes in the pattern of the statistics on the number of patients treated in the epidemic period. COVID-19, coronavirus disease 2019; WHO, World Health Organization; PHEIC, public health emergency of international concern; KCDC, Korea Centers for Disease Control and Prevention; ED, emergency department.

DISCUSSION

Our research aims to show an emergency department in response to the COVID-19 outbreak throughout the world. These responses were prepared before the massive outbreak, and this report aims to share such experiences.

Three major preparations were taken to respond to infectious diseases: the first preparation was to improve the emergency department facilities; the second was to create an operational program to respond to each phase of an epidemic and run it regularly; the last preparation was to implement education and training to promote the safety of medical staff in response to the epidemics and review and improve on parts that needed support.

Since the designs of emergency departments in the past have not taken transmission into account, we experienced failure of the emergency departments, which should be the frontline to quarantine measures, leading to national quarantine failures a few years ago. Unfortunately, we did not have many studies to advise the responses of the emergency department against infectious diseases. Therefore, our design has evolved through processing existing research, KCDC advice, and real-time operational simulation.

The second strategy in responding to the spread of the epidemic was the differentiation of the operation pattern according to the phase. This strategy came as a result of many emergency departments still closing after reporting a confirmed case in the particular facility [8]. Such closures of emergency centers and suspension of services have been reported to increase mortality by approximately 5 - 15%. To resolve this issue, we established outside pretriage at the appropriate epidemic phase and divided the emergency department into clean and contamination zones. Accordingly, we have reorganized the movements of patients and medical staff. In contrast with some other screening stations only collecting upper respiratory tract swabs, we have held on to the possibility of the screened patient carrying other diseases and made other diagnoses possible as well. For this purpose, symptomatic patients were provided with independent space for examination and blood tests and moved to emergency department NPIR to collect lower respiratory tract samples. If necessary, patients also underwent chest X-ray and chest CT scans. In fact, one of the confirmed patients had suspected COVID-19 radiological patterns, thus he admitted to outside-ED NPIR before PCR results came. Such measures enabled the suspected patients to be admitted without remaining in the emergency department for a long period of time.

This operational system has several advantages, first preventing infection inside the emergency department. Patient movement restriction and personal protection equipment worn by medical staff prevent infection even if the patient is infected. No confirmed cases were reported to have infected or quarantined the medical staff who examined the patient. Another advantage is the safe quarantine of screened patients. Patients with severe symptoms received appropriate examinations and were admitted if necessary while waiting for the results, which prevented the highly suspected screened patients from returning to their communities. Last, this allowed for the continuation of examination and treatment of general emergency patients even on a limited basis. In fact, according to our data, during the COVID-19 pandemic, patients of similar KTAS levels, based on the classification of the degree of symptoms of general emergency patients, visited the institution compared with those who visited before the period of research, and 146 of them were admitted.

In this study, there were some limitations. First, the reason for the low number of confirmed cases was largely due to our city not experiencing a mass outbreak of COVID-19 at the study period. Also, the primary screening of COVID-19 PCR is carried out in a public health center, not in the hospitals. The quarantine system in Korea operates in ways that once a person is confirmed, he/she goes under the management of health authorities, which designates an epidemiologist who identifies all who came in contact with the confirmed patient within two days from the day the confirmed shows symptoms, screens them in a public health center, and quarantines them. This protocol makes it difficult for frontline health institutes to encounter patients who came in close contact with the confirmed. Therefore, the usefulness of our system during a large outbreak has not been confirmed yet. Since massive outbreak of COVID-19 is still ongoing, additional research during pandemic period is required.

Second, as a public hospital, the designation as a dedicated epidemic institution in the public health crisis made it possible to assign more workforce and resources to the current epidemic, which made immediate role change in modules possible. Moreover, the fact that many university hospitals were located nearby made the distribution of general severe patients possible and made the model feasible. Frankly, it would be impossible for all emergency departments to operate in this form; however, if infectious disease response base institutions in charge of screening and treating infectious disease divide their roles with other hospitals and select and apply our model, they could operate their emergency department in a much safer environment.

In conclusion, this research introduces responses to the different phases of COVID-19 outbreak in the emergency department designed for emerging infectious diseases. Currently, COVID-19 is a pandemic situation worldwide, and a large scale pandemic may occur in Korea in the future. Thus emergency department designs and operational programs should increase to combine research data with better ideas to respond during periods of pandemic in the future.

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