American Journal of Emergency Medicine 45 (2021) 483–489

Contents lists available at ScienceDirect

American Journal of Emergency Medicine

journal homepage: www.elsevier.com/locate/ajem

Effectiveness of negative pressure isolation stretcher and rooms for SARS-CoV-2 nosocomial infection control and maintenance of South Korean emergency department capacity

Sang-Chul Kim, M.D [a,1,*], So Yeon Kong, PhD [b,1], Gwan-Jin Park, M.D [a], Ji-Han Lee, M.D [a], Joon-Kee Lee, M.D [c,d], Mou-Seop Lee, M.D [e], Heon Seok Han, M.D [c]

[a] Department of Emergency Medicine, Chungbuk National University Hospital, 776, 1st Sunhwan-ro, Seowon-gu, Cheongju-si, Chungcheongbuk-do 28646, South Korea
[b] Strategic Research, Laerdal Medical, Tanke Svilandsgate 30 4002, Stavanger, Norway
[c] Department of Paediatrics, Chungbuk National University Hospital, 776, 1st Sunhwan-ro, Seowon-gu, Cheongju-si, Chungcheongbuk-do 28646, South Korea
[d] Department of Infection Control and Prevention, Chungbuk National University Hospital, South Korea
[e] Department of Neurosurgery, Chungbuk National University Hospital, South Korea

A R T I C L E I N F O

Article history:
Received 24 June 2020
Received in revised form 27 August 2020
Accepted 27 September 2020

A B S T R A C T

Objective: There are growing concerns regarding the lack of COVID-19 pandemic response capacity in already overwhelmed emergency departments (EDs), and lack of proper isolation facilities. This study evaluated the effectiveness of the negative pressure isolation stretcher (NPIS) and additional negative pressure isolation rooms (NPIRs) on the maintenance of emergency care capacity during the COVID-19 outbreak.
Methods: A before and after intervention study was performed between February 27, 2020 and March 31, 2020 at the ED of Chungbuk National University Hospital, Cheongju, South Korea. A total of 2455 patients who visited the ED during the study period were included. Interventions included the introduction of the NPIS and additional NPIRs in the ED. The main outcome of the study was frequency of medical cessation. Secondary outcomes were the average number of ED visits and lengths of stay.
Results: After the intervention, average frequency of medical cessation was significantly decreased from 1.6 times per day (range 0–4) in the pre-intervention period to 0.6 times per day (range 0–3) in the post-intervention period (p-value <0.01). On the other hand, the number of patients visiting the ED increased significantly from 67.2 persons per day (range 58–79) pre-intervention to 76.3 persons per day (range 61–88) post-intervention (p value <0.01). However, there were no statistically significant differences in the average ED length of stay across the study phases (p value = 0.50).
Conclusions: This intervention may provide an effective way to prepare and meet the ED response needs of the COVID-19 pandemic.

1. Introduction

1.1. Background

On January 20, 2020 the first coronavirus disease 2019 (COVID-19) case was reported in South Korea. The number of confirmed cases surged within a few weeks, leading to the second largest COVID-19 outbreak, after China, in February. Hence, South Korea has implemented extensive national response strategies including extensive tracing, testing and isolation, and enhanced infection control measures in hospitals to mitigate the transmission of the virus [1,2].

While the entire health system is challenged with the response to the COVID-19 pandemic, the emergency department (ED) is a major gateway at the forefront in response to this global emergency [3]. Moreover, besides COVID-19, the ED still needs to provide treatment for patients both infected and critically ill from other diseases. Furthermore, infection prevention is also a major challenge because of the dynamic and high-volume setting of the EDs [4]. Consequently, there are growing concerns about the lack of capacity and preparedness in the already overwhelmed EDs [5]. Many EDs lack proper isolation facilities, risking spread of the virus to other patients and medical staff, and further limiting ED capacity [6].

National and international COVID-19 guidelines stipulate that for infection prevention, control, and preparedness, healthcare facilities

* Corresponding author.
E-mail addresses: ksc2038@cbnu.or.kr (S.-C. Kim), jklee@cbnuh.or.kr (J.-K. Lee), mslee@cbnuh.or.kr (M.-S. Lee), hshan@cbnuh.or.kr (H.S. Han).
[1] Dr. SC Kim and Dr. SY Kong contributed equally as co-first authors.

https://doi.org/10.1016/j.ajem.2020.09.081
0735-6757/

should create a separate area in the ED for the assessment and management of suspected patients presenting with respiratory symptoms [7-9]. However, a number of asymptomatic cases of COVID-19 have been reported [10-13]. Asymptomatic cases or individuals with mistriage may visit the normal ED area posing the risk of transmission of the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) to other patients, visitors, and healthcare workers. Moreover, once mistriage is identified, hospital facilities may be closed for hours for disinfection, causing disruptions in services, and further impairing the already overwhelmed ED capacity.

Therefore, stricter and advanced infection prevention and control practices in healthcare settings, especially in EDs, should be considered. Suspected COVID-19 patients should be screened and treated in negative pressure isolation rooms (NPIRs). However, potential breaches of infection control could occur due to nosocomial spread through intra-hospital patient transfers, especially from asymptomatic patients who need to be transferred to radiology suites for computed tomography (CT) scans [14].

In order to maximise infection control and ED capacity, we have implemented use of a negative pressure isolation stretcher (NPIS) and additional NPIRs. In this study, we sought to evaluate the effectiveness of the NPIS and NPIRs on our emergency care system in maintaining emergency care capacity (through minimizing medical cessations and maintaining the number of ED visiting patients and ED length of stay) during the COVID-19 outbreak.

2. Methods

2.1. Study design and setting

This before and after intervention study was performed at the Chungbuk National University Hospital (CBNUH), Cheongju, South Korea. The CBNUH is an 807-bed tertiary-care University Hospital with five NPIRs and approximately 240,000 annual admissions. Since the onset of the COVID-19 outbreak, the CBNUH was designated as one of the twenty-nine national treatment centres in South Korea, for infectious diseases, with over five NPIRs. The CBNUH ED has been prepared to serve critically ill patients due to COVID-19 while continue providing emergency care for other patients. From February 25 to 27, in response to the COVID-19 outbreak, we remodelled our emergency centre to create a designated isolation area for spatially separating patients presenting with fever or respiratory symptoms.

2.2. Selection of participants

At the entrance of the hospital, patients were asked if they had 1) close contact with a confirmed case of COVID-19 within the past 14 days, 2), visited countries with active outbreaks of COVID-19 (including China) within the past 14 days, and 3) links to the Shincheonji Church of Jesus in Daegu, a known cluster of infections. Patients who answered yes to any of these questions and presented with fever or respiratory symptoms were directed to the triage room for screening. The triage room was connected to the designated isolation area. If a COVID-19 test was required, a sample was taken in a sample collection room and an X-ray was performed in a radiology room using a mobile X-ray. Patients visiting the ED without fever or respiratory symptoms were screened and treated in the normal ED area.

For ED visiting patients with fever, chest CT was performed to identify the cause and for diagnosis. In the CBNUH, one CT scanner (Revolution™ CT 128; GE Healthcare, USA) is dedicated to the emergency centre. Patients from the designated isolation area who underwent CT imaging or asymptomatic patients from the normal ED area who had CT findings for pneumonia, were considered as suspected COVID-19 cases. Until the results of the COVID-19 tests were confirmed for these patients, the medical staff, including imaging technicians who were in contact with the suspected patients were temporarily quarantined and environmental cleaning and disinfection procedures were conducted, including door handles, registration counters, floors, equipment, CT room, and the ED area. Under the CBNUH policy, the disinfected areas are ventilated and closed for two hours, which leads to medical cessation.

In cases of mistriage, when asymptomatic patients were screened and treated at the normal ED area but later diagnosed with an unknown cause of pneumonia, the possibility of COVID-19 was considered and COVID-19 tests were performed. While waiting for the test results, the medical staff who were in contact with the mistriaged patients were temporarily quarantined if they had not been fully equipped with personal protective equipment (PPE), and environmental cleaning and disinfection procedures were conducted, followed by two hours of medical cessation.

This study was approved by the Institution Review Board (IRB) of Chungbuk National University Hospital through expediated review with the requirement for informed consent waived (IRB Number: CBNUH 2020–03-035).

2.3. Data source

Demographic and medical data for patients of all ages who visited the CBNUH emergency centre from February 27 to March 31, 2020 was retrospectively extracted from the hospital electronic medical records and reviewed. All the patients who were screened and treated in either the normal ED or designated isolation area were included. The data included age, sex, date of ED visit, cause of ED visit, level of acuity, mental status, vital signs, radiologic and chemical evaluation, ED disposition, ED results, and ED length of stay. The level of acuity was measured using the Korean Triage and Acuity Scale (KTAS). The KTAS is a five-level triage scale (Level 1 being most severe), which was developed and implemented in all EDs in South Korea since 2015 [15].

2.4. Interventions

2.4.1. Negative pressure isolation stretcher (NPIS)

The NPIS (Bio Bag EBV-30/40, EGO Zlin, Ltd., Czech Republic) (Fig. 1A) was introduced in the CBNUH on March 12, 2020. The isolation stretcher was used to transfer suspected COVID-19 patients requiring CT scans from the designated isolation area to the CT room. During the scan, patients remained in the NPIS (Fig. 1B). From March 12 to March 17, hospital staff was trained and adapted to the use of the NPIS (implementation period). During training, an instructor explained on structure (bag and aluminium frame) and components (filtration–ventilation unit and filter) of the NPIS, and methods on how to move a patient into the NPIS and to work the filtration-ventilation unit. Hospital staff also conducted simulation tests on using the NPIS.

2.4.2. Negative pressure isolation rooms (NPIRs)

In order to increase the ED capacity, we constructed thirteen additional NPIRs. The five existing NPIRs were mainly used for treatment of severe confirmed COVID-19 patients, who were transferred from other medical institutions. The added thirteen NPIRs were mainly used to treat suspected patients from the ED isolation area. When the suspected patient's test result was found to be negative, the quarantine was lifted, and the patient was moved to a general ward or the ICU. The construction of the additional NPIRs was completed and use begun on March 18, 2020.

2.5. Outcome measures

The main outcome of the study was the frequency of medical cessation. Medical cessation was defined as closure of the entire emergency centre for two hours for the process of disinfection and ventilation after patients from the designated isolation area and asymptomatic patients from the normal ED area were found to be suspected patients.

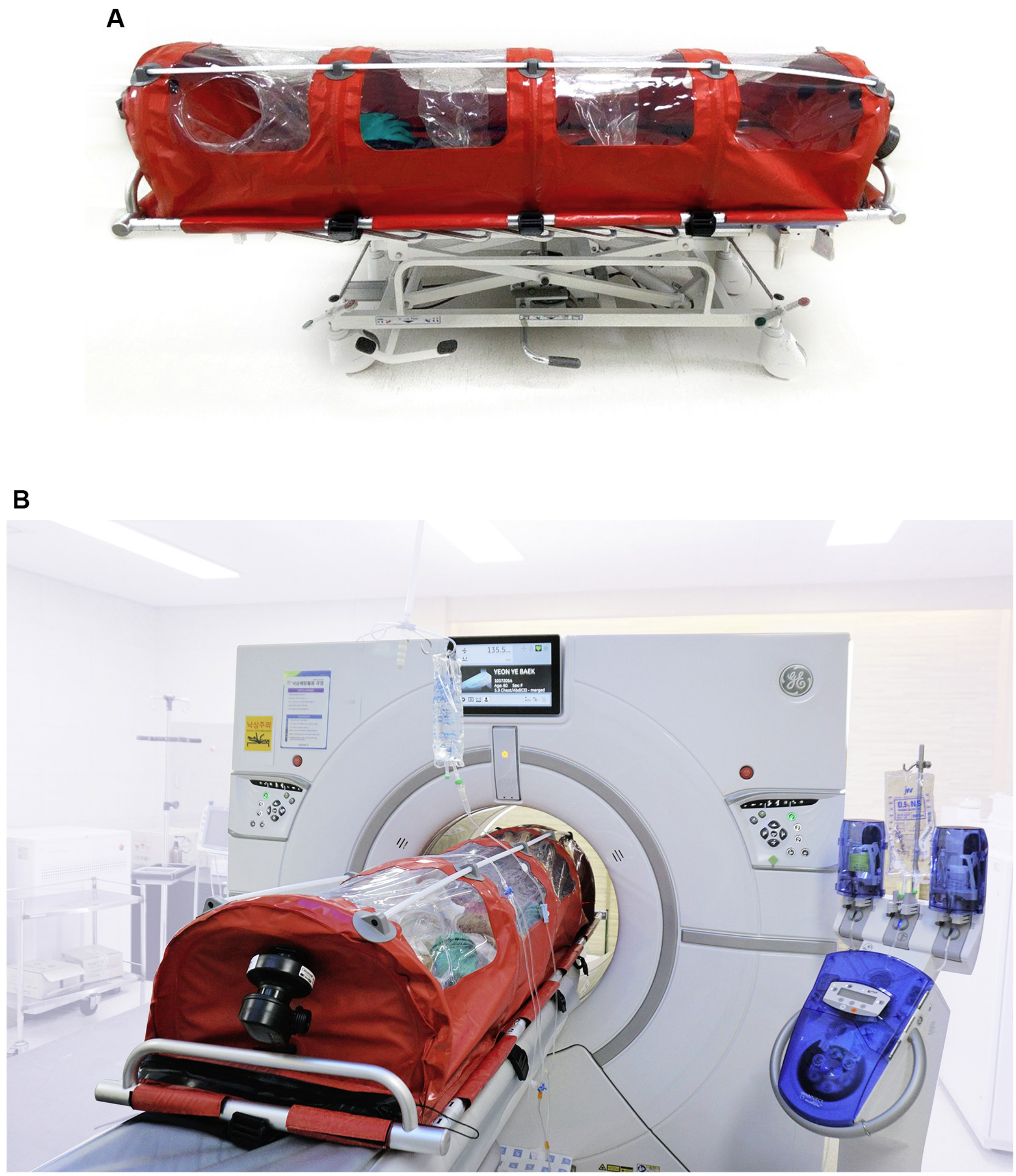

Fig. 1. Negative pressure isolation stretcher (A) and CT scanning of a patient in the negative pressure isolation stretcher (B).

Secondary outcomes were the average number of ED visits and ED length of stay. The average number of ED visits were defined as average number of daily ED patients visiting the ED during pre-intervention period, implementation period, and post-intervention period. The ED length of stay was calculated as the difference between the inflow time and the outflow time of each ED patient, and average ED length of stay was calculated as average ED length of stay (in hours) of all the ED visiting patients in each of the three study phases.

2.6. Statistical analysis

The study consisted of a two-week pre-intervention period (from February 27 to March 11), an implementation period (from March 12 to 17), and a two-week intervention period (from March 18–31). At the start of the intervention period, all the hospital staff were fully informed and had trained/good knowledge of the intervention.

Statistical analyses were performed to compare the demographic and clinical characteristics of the patients and the outcomes (frequency of medical cessation, number of patients admitted/treated in the ED, and ED length of stay) across the three study phases by using appropriate bivariate analysis. Chi-square test was used for categorical variables and Kruskal-Wallis test for continuous variables. All statistical analysis was performed using SAS software (version 9.4; SAS Institute, Inc., Cary, NC).

3. Results

3.1. Characteristics of study subjects

Of the 2455 patients included in the study, 941 visited the ED before the intervention, 446 during the implementation period, and 1068 after the intervention. Of the total ED patients, 1852 (75.4%) patients were admitted and treated in the main ED area while 603 (24.6%) patients

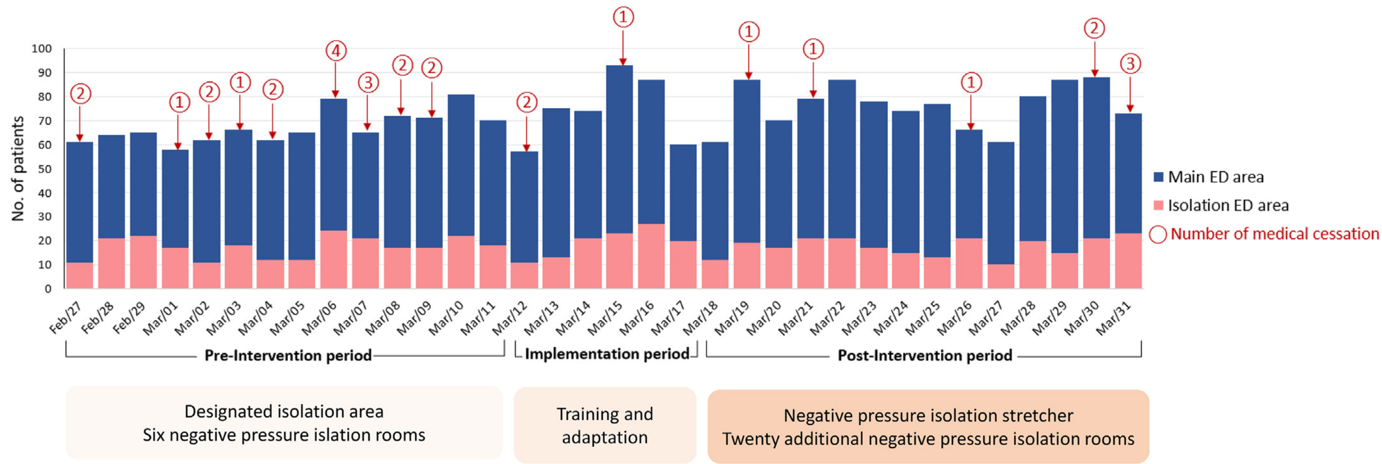

Fig. 2. Number of patients who visited and were treated in the main ED and isolation ED areas during pre-intervention, implementation, and post-intervention periods.

were admitted and treated in the isolation ED area. Fig. 2 depicts the trend of the number of patients treated in the main ED and isolation ED areas, and the daily number of medical cessations during the pre-intervention, implementation, and post-intervention periods.

3.1.1. Characteristics of patients who visited the ED

Demographic and clinical characteristics of all the patients are described in Table 1. Overall, the median age of the patients who visited the CBNUH ED during the study period was 55 years (IQR: 30–71) and 46.2% were female. The number of patients transferred from and to other hospitals decreased during the post-intervention period from 17.3% to 15.2% for transfer-in ($p = 0.02$) and from 5.1% to 2.4% for transfer-out patients ($p < 0.01$). The median ED length of stay remained unchanged during the study period (3.1 h). After the introduction of the isolation stretcher, 65 patients were transferred to the CT room and CT scanned in the isolation stretcher (11 patients during the implementation period and 54 patients during the post-intervention period). The number of medical cessations was significantly decreased from 19 times during the pre-intervention period to eight times during the post-intervention period (p-value <0.01). Fever was the most common cause of medical cessation, followed by pneumonia.

3.1.2. Characteristics of patients cared for at the isolation ED area

The demographic and clinical characteristics of the 603 patients cared for at the isolation ED area during the study period are outlined in Table 2. There was a higher proportion of patients with a high acuity level (KTAS 1–3) in the post-intervention period compared with the pre-intervention period (89.8% vs. 83.5%; p-value <0.01). The proportion of patients with an abnormal respiratory rate (≥30 or <10/min) at the time of the ED visit was higher in the post-intervention period (27.8% vs. 14.8%; p-value <0.01). The median ED length of stay decreased from 6.1 h during the pre-intervention period to 5.4 h during the post-intervention period (p-value = 0.09). Of all the patients cared for at the isolation ED area, the RT-PCR COVID-19 test was performed in 84.0% of the patients during the pre-intervention period and 92.2% during the post-intervention period (p-value <0.01). (See Table 3.)

3.2. Main results

The average frequency of medical cessation was significantly decreased from 1.6 times per day (range 0–4) in the pre-intervention period to 0.6 times per day (range 0–3) in the post-intervention period (p-value <0.01). On the other hand, the number of patients visiting the ED increased from 67 per day (range 58–79) during the pre-intervention period to 76 per day (range 61–88) during the post-intervention period (p value <0.01). However, there were no statistically significant differences in the average ED length of stay across the study phases (p-value = 0.5).

4. Discussion

In this before and after study, we observed that the introduction of the NPIS and additional NPIRs in our ED was effective in reducing medical cessations and the number of patients transferring to other hospitals. A greater number of patients was also treated in the ED due to the intervention. There was no difference in the ED length of stay before and after the intervention.

Globally, many healthcare systems have experienced patient numbers exceeding their surge capacities during the COVID-19 pandemic; not only to tend suspected and confirmed COVID-19 cases, but also many patients critically ill from other diseases simultaneously [16,17]. Of 4877 ICU clinicians who participated in a Society of Critical Care Medicine survey, 61% were concerned about patient surge and overcrowding during the COVID-19 outbreak [18]. Moreover, in these critical times, there has been temporary closure of emergency rooms in several hospitals globally to perform thorough and extensive terminal cleaning and disinfection after confirmed COVID-19 cases [19]. Closure of the ED even for a few hours can increase the acute pressure on the ED system after re-opening and hinders the hospitals' operational capability.

RT-PCR tests were performed on all the patients presenting with fever and respiratory symptoms. Additionally, it is essential to perform CT scans to diagnose the cause of the fever. In our emergency centre, we only have one CT scan that is dedicated to the ED. Therefore, prior to the implementation of the NPIS, whenever a CT scan was performed on a patient from the isolated ED area, the CT room had to be thoroughly decontaminated and closed for two hours. Additionally, when an asymptomatic patient from the normal ED area was later diagnosed with an unknown cause of pneumonia by CT scan, the patient was considered a suspected or confirmed COVID-19 patient and the entire ED area and the CT room had to be decontaminated with ED closure for two hours, causing a medical cessation. During the study period, we had a total of 30 medical cessations with over 63% (19 cases) of them happening during the pre-intervention period. However, after the introduction of the NPIS as a part of our intervention, we observed a significantly reduced number of medical cessations. We believe that as a result of the fewer medical cessations, more patients were treated in our ED

Table 1
Demographic and clinical characteristics of patients visiting CBNUH ED during pre-, implementation, and post-intervention periods.

	Total	Pre-Intervention (Feb.27-Mar.11, 2020)	Implementation (Mar.12–17, 2020)	Post-Intervention (Mar.18–31, 2020)	*p*-value
	N (%)	*N* (%)	*N* (%)	*N* (%)	
Total number of patients	2455 (100)	941 (38.3)	446 (18.2)	1068 (43.5)	..
Main ED area	1852 (75.4)	698 (74.2)	331 (74.2)	823 (77.1)	0.26
Isolation ED area	603 (24.6)	243 (25.8)	115 (25.8)	245 (22.9)	..
Age, median (IQR), years	55 (30–71)	54 (31–70)	54 (29–69)	55 (30–71)	0.54
Gender	..	..	..	..	0.04
Female	1135 (46.2)	440 (46.8)	227 (50.9)	468 (43.8)	..
Day of ED visit					<0.01
Weekend	760 (31.0)	260 (27.6)	167 (37.4)	333 (31.2)	..
Time of ED visit	..	..	..	..	0.48
00–06	327 (13.3)	137 (14.6)	54 (12.1)	136 (12.7)	..
06–12	684 (27.9)	261 (27.7)	124 (27.8)	299 (28.0)	..
12–18	756 (30.8)	301 (32.0)	134 (30.0)	321 (30.1)	..
18–00	688 (28.0)	242 (25.7)	134 (30.0)	312 (29.2)	..
Transfer from other hospital	377 (15.4)	163 (17.3)	52 (11.7)	162 (15.2)	0.02
Transfer to other hospital	85 (3.5)	48 (5.1)	11 (2.5)	26 (2.4)	<0.01
EMS use	..	..	..	..	0.14
Yes	673 (27.4)	279 (29.6)	119 (26.7)	275 (25.7)	..
Disease category	..	..	..	..	0.44
ED visit due to Injury	440 (17.9)	157 (16.7)	85 (19.1)	198 (18.5)	..
Level of acuity (KTAS)	..	..	..	..	0.01
KTAS 1–3 (Severe)	1715 (69.9)	668 (71.0)	286 (64.1)	761 (71.3)	..
KTAS 4–5 (Non-severe)	740 (30.1)	273 (29.0)	160 (35.9)	307 (28.7)	..
Abnormal mental status[a]	214 (8.7)	87 (9.2)	35 (7.8)	92 (8.6)	0.68
Abnormal vital signs	..	..	..	..	..
Systolic blood pressure <90 mmHg	392 (16.0)	148 (15.7)	74 (16.6)	170 (15.9)	0.92
Respiratory rate ≥30 or <10/min	294 (12.0)	108 (11.5)	47 (10.5)	139 (13.0)	0.33
Body temperature ≥37.5 °C	434 (17.7)	156 (16.6)	83 (18.6)	195 (18.3)	0.52
ED disposition	..	..	..	..	0.54
Discharge	1522 (62.0)	569 (60.5)	284 (63.7)	669 (62.6)	..
Transfer to other hospital	39 (1.6)	14 (1.5)	6 (1.3)	19 (1.8)	..
Admission	851 (34.7)	343 (36.5)	147 (33.0)	361 (33.8)	..
Death	40 (1.6)	15 (1.6)	9 (2.0)	16 (1.5)	..
Others	3 (0.1)	0 (0.0)	0 (0.0)	3 (0.3)	..
Admission to ICU	188 (7.7)	83 (8.8)	32 (7.2)	73 (6.8)	0.23
Overall mortality	82 (3.3)	39 (4.1)	20 (4.5)	23 (2.2)	0.02
ED length of stay, median (IQR), hours	3 1 (1 9–5.4)	3 1 (2 0–5.2)	3 2 (2.0–5.9)	3 1 (1.9–5.3)	0.5
COVID-19 testing	575 (23.4)	217 (23.1)	115 (25.8)	243 (22.8)	0.42
CT scanning	..	..	..	..	<0.01
No	2368 (96.5)	922 (98.0)	433 (97.1)	1013 (94.9)	..
Yes - use of isolation stretcher	65 (2.6)	0 (0.0)	11 (2.5)	54 (5.1)	..
Yes - without use of isolation stretcher	22 (0.9)	19 (2.0)	2 (0.4)	1 (0.1)	..
Frequency of medical cessation	30 (1.2)	19 (2.0)	3 (0.7)	8 (0.7)	0.02
Cause of medical cessation[b]	..	..	..	..	<0.01
Fever	22 (0.9)	15 (1.6)	3 (0.7)	4 (0.4)	..
Pneumonia	5 (0.2)	3 (0.3)	0 (0.0)	2 (0.2)	..
Dyspnea	1 (0.0)	0 (0.0)	0 (0.0)	1 (0.1)	..
CPR	1 (0.0)	0 (0.0)	0 (0.0)	1 (0.1)	..
Others	1 (0.0)	1 (0.1)	0 (0.0)	0 (0.0)	..

Abbreviations: CBNUH = Chungbuk National University Hospital; ED = emergency department; Feb = February; Mar = March; IQR = interquartile range; KTAS=Korean Triage and Acuity Scales; COVID-19 = coronavirus disease 2019; ED = emergency department; ICU = intensive care unit; CT = computed tomography; CPR = cardiopulmonary resuscitation.
[a] Abnormal mental status includes verbal response, painful stimulus, and unresponsive.
[b] Among the number of medical cessations.

and admitted to our hospital. Moreover, extra NPIRs originally constructed to treat COVID-19 confirmed patients, were mainly used to admit and observe suspected COVID-19 patients. Because of the extra NPIRs, the suspected COVID-19 patients were able to stay and wait for the RT-PCR test result, which takes over six hours, in their NPIRs, instead of staying in the emergency room.

There are a few reported cases of transportation of patients with highly contagious infectious diseases (e.g. SARS and Ebola viruses) using negative isolation transfer equipment in aeromedical [20,21] and ambulance [22,23] transfers. However, there are no studies reporting the use of mobile negative isolation transfer equipment for intra-hospital transport of suspected or confirmed patients with infectious diseases. There are also a few studies evaluating the effect of increasing the number of NPIRs as an intervention to maintain ED capacity or even to meet surge capacity during an infectious outbreak. To our best knowledge, this is the first intervention study suggesting the use of NPIS for intra-hospital transfer as an effective intervention for infection control and maintenance of ED capacity during a large-scale infectious disease outbreak, such as COVID-19.

Nosocomial transmission to health care workers, patients and visitors was a prominent feature of SARS-CoV and MERS-CoV outbreaks [24,25]. The risk of SARS-CoV-2 nosocomial infection has also been reported [26,27]. In a single-centre case series of 138 hospitalised patients with confirmed COVID-19 in Wuhan, China, Wang et al. reported that about 41% of the patients were presumed to be infected through hospital-related transmission of COVID-19, including 17 patients (12.3%) who were already hospitalised for other reasons and 40 (29%) health care workers [26]. During the study period, we only had one

Table 2
Demographic and clinical characteristics of patients visiting CBNUH isolation ED area during pre-, implementation, and post-intervention periods.

	Total	Pre-Intervention (Feb.27–Mar.11, 2020)	Implementation (Mar.12–17, 2020)	Post-Intervention (Mar.18–31, 2020)	*p*-value
	N (%)	*N* (%)	*N* (%)	*N* (%)	..
Total number of patients	603 (100)	243 (40.3)	115 (19.1)	245 (40.6)	..
Age, median (IQR), years	62 (31–77)	63 (35–77)	62 (26–77)	59 (27–77)	0.48
Gender	..	..	..	..	0.06
Female	292 (48.4)	115 (47.3)	67 (58.3)	110 (44.9)	..
Day of ED visit	..	..	..	..	0.39
Weekend	198 (32.8)	77 (31.7)	44 (38.3)	77 (31.4)	..
Time of ED visit	..	..	..	..	0.6
00–06	80 (13.3)	32 (13.2)	14 (12.2)	34 (13.9)	..
06–12	167 (27.7)	65 (26.7)	30 (26.1)	72 (29.4)	..
12–18	204 (33.8)	85 (35.0)	34 (29.6)	85 (34.7)	..
18–00	152 (25.2)	61 (25.1)	37 (32.2)	54 (22.0)	..
Transfer from other hospital	60 (10.0)	34 (14.0)	8 (7.0)	18 (7.3)	0.02
Transfer to other hospital	38 (6.3)	23 (9.5)	7 (6.1)	8 (3.3)	0.02
EMS use	210 (34.8)	87 (35.8)	46 (40.0)	77 (31.4)	0.26
Disease category	..	..	..	..	0.44
ED visit due to Injury	27 (4.5)	12 (4.9)	7 (6.1)	8 (3.3)	..
Level of acuity (KTAS)	..	..	..	..	<0.01
KTAS 1–3 (Severe)	501 (83.1)	203 (83.5)	78 (67.8)	220 (89.8)	..
KTAS 4–5 (Non-severe)	102 (16.9)	40 (16.5)	37 (32.2)	25 (10.2)	..
Abnormal mental status[a]	77 (12.8)	25 (10.3)	16 (13.9)	36 (14.7)	0.32
Abnormal vital signs	..	..	..	..	..
Systolic blood pressure <90 mmHg	128 (21.2)	46 (18.9)	27 (23.5)	55 (22.4)	0.51
Respiratory rate ≥30 or <10/min	118 (19.6)	36 (14.8)	14 (12.2)	68 (27.8)	<0.01
Body temperature ≥37.5 °C	337 (55.9)	125 (51.4)	70 (60.9)	142 (58.0)	0.17
ED disposition	..	..	..	..	0.89
Discharge	294 (48.8)	112 (46.1)	66 (57.4)	116 (47.3)	..
Transfer to other hospital	14 (2.3)	5 (2.1)	4 (3.5)	5 (2.0)	..
Admission	286 (47.4)	123 (50.6)	43 (37.4)	120 (49.0)	..
Death	7 (1.2)	3 (1.2)	2 (1.7)	2 (0.8)	..
Others	2 (0.3)	0 (0.0)	0 (0.0)	2 (0.8)	..
Admission to ICU	40 (6.6)	15 (6.2)	10 (8.7)	15 (6.1)	0.61
Overall mortality	24 (4.0)	9 (3.7)	7 (6.1)	8 (3.3)	0.42
ED length of stay, median (IQR), hours	5.7 (3.1–9.4)	6.1 (3.0–10.1)	6.2 (3.4–10.4)	5.4 (3.0–8.1)	0.09
COVID-19 testing	538 (89.2)	204 (84.0)	108 (93.9)	226 (92.2)	<0.01
CT scanning	..	..	..	..	<0.01
No	527 (87.4)	233 (95.9)	103 (89.6)	191 (78.0)	..
Yes- with use of isolation stretcher	63 (10.4)	0 (0.0)	10 (8.7)	53 (21.6)	..
Yes - without use of isolation stretcher	13 (2.2)	10 (4.1)	2 (1.7)	1 (0.4)	..

Abbreviations: CBNUH = Chungbuk National University Hospital; ED = emergency department; Feb = February; Mar = March; IQR = interquartile range; KTAS=Korean Triage and Acuity Scales; COVID-19 = coronavirus disease 2019; ICU = intensive care unit; CT = computed tomography.
[a] Abnormal mental status includes verbal response, painful stimulus, and unresponsive.

Table 3
Effect of the intervention on the main outcomes of the study (average frequency of medical cessation and average number of patients treated during pre-, implementation, and post-intervention periods[a]).

Outcomes	Total	Pre-intervention (Feb.27–Mar.11, 2020)	Implementation (Mar.12–17, 2020)	Post-Intervention (Mar.18–31, 2020)	*p*-value
Average frequency of medical cessation (per day)	0.9 (0–4)	1.6 (0–4)	0.4 (0–2)	0.6 (0–3)	<0.01
Average number of patients treated at CBNUH ED (per day)	..	..	..	..	
Total	72.2 (57–93)	67.2 (58–79)	74.6 (57–93)	76.3 (61–88)	<0.01
Main ED Area	54.5 (40–72)	49.9 (41–55)	55.3 (40–70)	58.8 (45–72)	<0.01
Isolated ED Area	17.7 (10–27)	17.4 (11–24)	19.4 (11–27)	17.5 (10−23)	<0.01
Average ED length of stay, hours	4.5 (0–60)	4.6 (0−32)	4.7 (0−23)	4.3 (0–60)	0.50

Abbreviations: Feb = February; Mar = March; CBNUH = Chungbuk National University Hospital; ED = emergency department.
[a] Values are expressed as number (range).

patient, who tested positive at the first RT-PCR test, but finally proved negative at the second test. In the epidemiological investigation conducted by the Department of Infection Control, none of our ED staff was quarantined because most of the emergency medicine providers were well equipped with PPE. In addition, COVID-19 confirmed patients, who were transferred from other hospitals bypassed the emergency room and were directly admitted to NPIRs to prevent any potential SARS-CoV-2 transmission. While we were not able to measure the effect of our intervention on nosocomial infection, we believe that one of the main benefits of NPIS and NPIRs is prevention of nosocomial COVID-19 infection.

Our study had several limitations. We only had 14 data points (days) for pre- and post-intervention periods. The short intervention period may have skewed our findings and resulted in statistical significance. However, as the COVID-19 was such an emergency both nationally and internationally, a rapid evaluation of the intervention effect was needed. While more time points before and after the intervention may have provided better understanding and long-term effect of the intervention, we believe that our study results show a meaningful effect of the COVID-19 intervention. Future study is warranted with longer intervention period to have more meaningful and reliable evidence-based recommendation. Another limitation was that we had a comparatively long implementation period (six days). While our hospital had daily COVID-19 Task Force Team meetings, the policy decisions made at the meetings were not effectively communicated to the entire hospital staff, resulting in a long implementation period. Additionally, we implemented two interventions at the same time, therefore were unable to measure the effectiveness of each individual intervention.

5. Conclusion

In summary, after the introduction of the NPIS and additional NPIRs as a COVID-19 intervention, we observed a notable decrease in the number of medical cessations and an increased number of patients admitted and treated in our ED. As the COVID-19 pandemic is straining healthcare systems globally, this study may provide healthcare providers, hospital administrators, and policy makers an effective way to prepare and meet the response needs of this unprecedented challenge.

Funding/support

This work was supported by the research grant of the Chungbuk National University in 2020.

Author contributions

SCK, HSH, MSL, and JKL developed the study concept. SCK, SYK and GJP designed the study. JHL and JKL collected the data. SCK, SYK, and GJP analysed the data and interpreted data. SCK and SYK created the figures. SCK, SYK, and GJP wrote the first draft of the manuscript. All the authors contributed to the reviewing and editing of the manuscript and approved the final version. SCK and SYK contributed equally as co-first authors and revised the manuscript.

Declaration of Competing Interest

All authors declare no competing interests.

Acknowledgement

We thank the hospital staff and administrators who supported this project. This work was supported by the research grant of the Chungbuk National University in 2020.

References

[1] Shim E, Tariq A, Choi W, Lee Y, Chowell G. Transmission potential and severity of COVID-19 in South Korea. Int J Infect Dis. 2020;93:339–44. https://doi.org/10.1016/j.ijid.2020.03.031.

[2] Cho S. Academic Community's efforts to guide the fight against coronavirus disease 2019 (COVID-19) epidemic in Korea. J Prev Med Public Health. 2020;53:65–6. https://doi.org/10.3961/jpmph.20.084.

[3] Freund Y. The challenge of emergency medicine facing the COVID-19 outbreak. Eur J Emerg Med. 2020;1. https://doi.org/10.1097/MEJ.0000000000000699.

[4] Liang SY, Theodoro DL, Schuur JD, Marschall J. Infection prevention in the emergency department. Ann Emerg Med. 2014;64:299–313. https://doi.org/10.1016/j.annemergmed.2014.02.024.

[5] Mareiniss DP. The impending storm: COVID-19, pandemics and our overwhelmed emergency departments. Am J Emerg Med. 2020. https://doi.org/10.1016/j.ajem.2020.03.033 S0735675720301753.

[6] Iacobucci G. Covid-19: emergency departments lack proper isolation facilities, senior medic warns. BMJ. 2020:m953. https://doi.org/10.1136/bmj.m953.

[7] Interim Infection Prevention and Control Recommendations for Patients with Suspected or Confirmed Coronavirus Disease 2019 (COVID-19) in Healthcare Settings. https://www.cdc.gov/coronavirus/2019-ncov/infection-control/control-recommendations.html; 2020. (accessed March 29, 2020).

[8] World Health Organization. Infection Prevention and Control during Health Care when COVID-19 is Suspected: Interim Guidance; 2020.

[9] European Centre for Disease Prevention and Control. Infection Prevention and Control and Preparedness for COVID-19 in Healthcare Settings: ECDC Technical Report; 2020.

[10] Chan JF-W, Yuan S, Kok K-H, To KK-W, Chu H, Yang J, et al. A familial cluster of pneumonia associated with the 2019 novel coronavirus indicating person-to-person transmission: a study of a family cluster. The Lancet. 2020;395:514–23. https://doi.org/10.1016/S0140-6736(20)30154-9.

[11] Rothe C, Schunk M, Sothmann P, Bretzel G, Froeschl G, Wallrauch C, et al. Transmission of 2019-nCoV infection from an asymptomatic contact in Germany. N Engl J Med. 2020;382:970–1. https://doi.org/10.1056/NEJMc2001468.

[12] Pan X, Chen D, Xia Y, Wu X, Li T, Ou X, et al. Asymptomatic cases in a family cluster with SARS-CoV-2 infection. Lancet Infect Dis. 2020;20:410–1. https://doi.org/10.1016/S1473-3099(20)30114-6.

[13] Kimball A, Hatfield KM, Arons M, James A, Taylor J, Spicer K, et al. Asymptomatic and presymptomatic SARS-CoV-2 infections in residents of a long-term care skilled nursing facility — King County, Washington, March 2020. MMWR Morb Mortal Wkly Rep. 2020;69:377–81. https://doi.org/10.15585/mmwr.mm6913e1.

[14] Liew MF, Siow WT, Yau YW, See KC. Safe patient transport for COVID-19. Crit Care. 2020;24:94. https://doi.org/10.1186/s13054-020-2828-4.

[15] Kwon H, Kim YJ, Jo YH, Lee JH, Lee JH, Kim J, et al. The Korean triage and acuity scale: associations with admission, disposition, mortality and length of stay in the emergency department. International J Qual Health Care. 2019;31:449–55. https://doi.org/10.1093/intqhc/mzy184.

[16] Hunter DJ. Covid-19 and the stiff upper lip — the pandemic response in the United Kingdom. N Engl J Med. 2020. https://doi.org/10.1056/NEJMp2005755 NEJMp2005755.

[17] Rosenbaum L. Facing Covid-19 in Italy — Ethics, logistics, and therapeutics on the epidemic's front line. N Engl J Med. 2020. https://doi.org/10.1056/NEJMp2005492 NEJMp2005492.

[18] Society of Critical Care Medicine. COVID-19 Survey Summary Report. Society of Critical Care Medicine; 2020.

[19] Three Covid-19 cases reported at SJMC. ER Closed for Disinfection. New Straits Times; 2020.

[20] Nicol ED, Mepham S, Naylor J, Mollan I, Adam M, d'Arcy J, et al. Aeromedical transfer of patients with viral hemorrhagic fever. Emerg Infect Dis. 2019;25:5–14. https://doi.org/10.3201/eid2501.180662.

[21] Dindart J-M, Peyrouset O, Palich R, Bing A, Kojan R, Barbe S, et al. Aerial medical evacuation of health workers with suspected Ebola virus disease in Guinea Conakry-interest of a negative pressure isolation pod-a case series. BMC Emerg Med. 2016;17:9. https://doi.org/10.1186/s12873-017-0121-x.

[22] Schilling S, Follin P, Jarhall B, Tegnell A, Lastilla M, Bannister B, et al. European concepts for the domestic transport of highly infectious patients. Clin Microbiol Infect. 2009;15:727–33. https://doi.org/10.1111/j.1469-0691.2009.02871.x.

[23] Hao L, Wu J, Zhang J, Liu Z, Yi Y, Zhang Z, et al. Development of a negative pressure hood for isolation and transportation of individual patient with respiratory infectious disease. Biosaf Health. 2019;1:144–9. https://doi.org/10.1016/j.bsheal.2019.12.007.

[24] Ho P-L, Tang X-P, Seto W-H. SARS: hospital infection control and admission strategies. Respirology. 2003;8:S41–5. https://doi.org/10.1046/j.1440-1843.2003.00523.x.

[25] The Korean Society of Infectious Diseases, and Korean Society for Healthcare-associated Infection Control and Prevention. The Same Middle East Respiratory Syndrome-Coronavirus (MERS-CoV) yet different outbreak patterns and public health impacts on the Far East expert opinion from the rapid response team of the Republic of Korea. Infect Chemother. 2015;47:247. https://doi.org/10.3947/ic.2015.47.4.247.

[26] Wang D, Hu B, Hu C, Zhu F, Liu X, Zhang J, et al. Clinical characteristics of 138 hospitalized patients with 2019 novel coronavirus–infected pneumonia in Wuhan. China JAMA. 2020;323:1061. https://doi.org/10.1001/jama.2020.1585.

[27] Zhou Q, Gao Y, Wang X, Liu R, Du P, Wang X, et al. Nosocomial infections among patients with COVID-19, SARS and MERS: a rapid review and meta-analysis. Infect Dis (except HIV/AIDS). 2020. https://doi.org/10.1101/2020.04.14.20065730.