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Original Article

# One-year changes in the pediatric emergency department caused by prolonged coronavirus disease 2019 pandemic

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**Abstract** ***Background*:** With the coronavirus disease 2019 (COVID-19) pandemic lasting for more than a year, it is imperative to identify the associated changes in the use of emergency medical care for efficient operation of the pediatric emergency department (PED). This study was conducted to determine the long-term impact of the COVID-19 pandemic on patterns of PED visits.

***Methods*:** This is a retrospective observational study of visits to the PED of six hospitals, between January 1, 2017, and December 31, 2020. We compared changes in the characteristics of patients before and during the COVID-19 pandemic.

***Results*:** A total of 245 022 visits were included in this analysis. After the first case of COVID-19 was reported in Korea, we observed a significant decrease (54.2%) in PED visits compared with the annual average number of visits in the previous 3 years. Since then, the weekly number of PED visits decreased by 11.9 person/week (95% CI: −15.3–−8.4, $P < 0.001$), which included an increase of 0.21% (95% CI: 0.15%–0.26%, $P < 0.001$) per week in high acuity patients. From 2017 to 2020, the proportion of infectious respiratory diseases by year was 25.9%, 27.0%, 28.6%, and 16.3%, respectively, demonstrating a significant decrease in 2020 ($P < 0.001$).

***Conclusions*:** During the COVID-19 pandemic, the number of patient visits to PEDs continues to decline, especially among those with infectious diseases. However, the disease severity of patients has gradually increased. There has been a change in the characteristics of visits to PEDs after COVID-19 which will require an appropriate response from a long-term perspective.

**Key words** child, COVID-19, emergency department, respiratory disease.

At the end of 2019, coronavirus disease 2019 (COVID-19) caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) was first reported in Wuhan, Hubei province, China.[1] Since then, COVID-19 has rapidly spread to Europe and Asia, including Korea, with 108 822 960 cases in 223 countries, prompting the World Health Organization to declare a COVID-19 pandemic on March 11, 2020.[2] To prevent the spread of COVID-19, governments and health systems around the world have imposed various rules and restrictions on daily life. In Wuhan, Chinese authorities implemented non-pharmaceutical interventions, including an unprecedented policy of *cordon sanitaire*, imposing severe restrictions on people leaving the city.[3] The USA, and other local governments, also implemented social distancing measures, including bans on large social gatherings; school closures; closure of entertainment venues, gyms, bars, and restaurant dining areas; and shelter-in-place orders.[4] These government-led initiatives have discouraged participation in community activities and changed the pattern of health care practices.

The first COVID-19 confirmed case in Korea was reported on January 20, 2020, and as of October 13, 2021, there were 1,571 new cases of COVID-19, 335 742 cumulative confirmed cases, and 2,605 cumulative COVID-19 related deaths.[3-5] The Korean government implemented social distancing measures on March 22 2020, which included the following guidelines: cancellation of meetings that include eating or sharing of food; restriction of individuals with fever or respiratory symptoms from visiting work-places; avoiding physical contact with

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others outside of the family context; social distancing of ≥2 m; frequent handwashing; encouraging individuals to work from home and rely on video conferencing for meetings; and individual monitoring for fever and respiratory symptoms when entering confined spaces.[6] Nevertheless, the current COVID-19 pandemic has lasted for a long period of more than a year, bringing about various changes in the social and economic as well as the public health system and medical utilities.

In the early days of the COVID-19 pandemic, there were reports that individuals were reluctant to visit hospitals leading to fewer visits to the pediatric emergency departments (PED). Foreign studies report that the number of patients visiting PEDs for about 1 to 2 months after the start of the COVID-19 pandemic decreased by 50–88%.[7-9] In Korea, there are reports that the number of patients visiting PEDs for about 2–3 months after the COVID-19 pandemic decreased by 58–77%.[10,11] The above studies report changes over a short period after the beginning of the COVID-19 pandemic.

Korea's public medical system and medical operations are constantly changing owing to this long-term COVID-19 pandemic. In addition, the overcrowding of PEDs on account of seasonal and other epidemic diseases is evolving due to the COVID-19 pandemic. The purpose of our study was to determine the long-term impact of COVID-19 pandemic on the patterns of PED visit.

## Methods

### *Study setting, design, and population*

We conducted a retrospective observational study of visits to the PEDs of the following six hospitals in metropolitan areas of Korea, between January 1, 2017, and December 31, 2020; Seoul Saint Mary's Hospital, Yeouido Saint Mary's Hospital, Incheon Saint Mary's Hospital, Bucheon Saint Mary's Hospital, Saint Vincent Hospital, and Daejeon Saint Mary's Hospital. Seoul Saint Mary's Hospital is a tertiary hospital in Seoul, and Yeouido Saint Mary's Hospital is a secondary hospital in Seoul. Incheon Saint Mary's Hospital is a tertiary hospital in the Incheon Metropolitan City. Bucheon Saint Mary's Hospital and Saint Vincent Hospital are secondary hospitals in the metropolitan area. Daejeon Saint Mary's Hospital is a secondary hospital in Daejeon Metropolitan City.

We included patients <18 years of age. Those who visited the PED for certificate issuance or were diagnosed with R-codes, indicating symptoms or signs, were excluded. Cases with missing data during the intake process were excluded. Diagnoses were made using the diagnostic codes of the Korean Standard Classification of Diseases-7 (KCD-7), based on the International Classification of Diseases-10 (ICD-10) of the World Health Organization.[12,13] Each PED visit, from arrival to departure, was considered an independent case. The following variables were extracted from the electronic medical records of each hospital for all eligible visits over the study period: demographic variables, chief complaint, acuity of the condition at triage, diagnoses made in the PED, and discharge time from the PED. Demographic variables included age and sex. Acuity of the condition at triage is determined using the Korean Triage and Acuity Scale (KTAS).[14] The KTAS, was developed based on the Canadian Triage and Acuity Scale[15] and scores the acuity of a condition on a scale of 1 (critical) to 5 (non-urgent) based on anticipated resource use and patient factors, such as medical history, age, and vital signs. The KTAS has been used for triage in all emergency medical institutions in Korea since 2016. We considered patients with a KTAS score of 1, 2, or 3 as high-acuity ones. Diagnoses were classified as infectious and noninfectious diseases, with infectious diseases further subdivided into infectious respiratory diseases and other infectious diseases.

### *Outcomes*

We assessed visit count by week during the study period for four consecutive years; 2017 through 2020, and compared data from 2020, at the onset of the COVID-19 pandemic to data from 2017 through 2019. We also assessed the change in the proportion of children with an infectious respiratory disease, before and after the onset of the COVID-19 pandemic, as well as differences in the acuity of patients visiting the PED.

### *Statistical analysis*

We evaluated differences in age, sex, acuity of health condition, mode of arrival, and discharge between the years of comparison using a $\chi^2$ test. We used segmented regression analysis to confirm the regression model for the change in the weekly number of patients visiting the PED. As seasonal variation exists in the trend of PED visits, the data were adjusted for seasonality. We also applied the same analysis to the number of visits for infectious diseases and infectious respiratory diseases, as well as to the proportion of high-acuity patients.

All analyses were performed using R version 4.0.0 (R Foundation for Statistical Computing, Vienna, Austria), with the probability level for significance set at a $P < 0.05$.

### *Ethics statements*

Our study was approved by the Institutional Review Board (IRB) of the Catholic University of Korea (IRB approval no. XC20RADI0168).

## Results

From January 2017 to December 2020, 257 835 patients attended the PED of the six hospitals. Among these, 1,923 cases who visited the PED for issuance of a certificate and 9,484 cases who were discharged from the PED with R-codes, indicating symptoms or signs as diagnosis, were excluded. In addition, 1,358 cases with missing diagnostic codes and 48 cases with missing records of arrival were excluded, and 245 022 cases were included in the analysis (Fig. 1). From

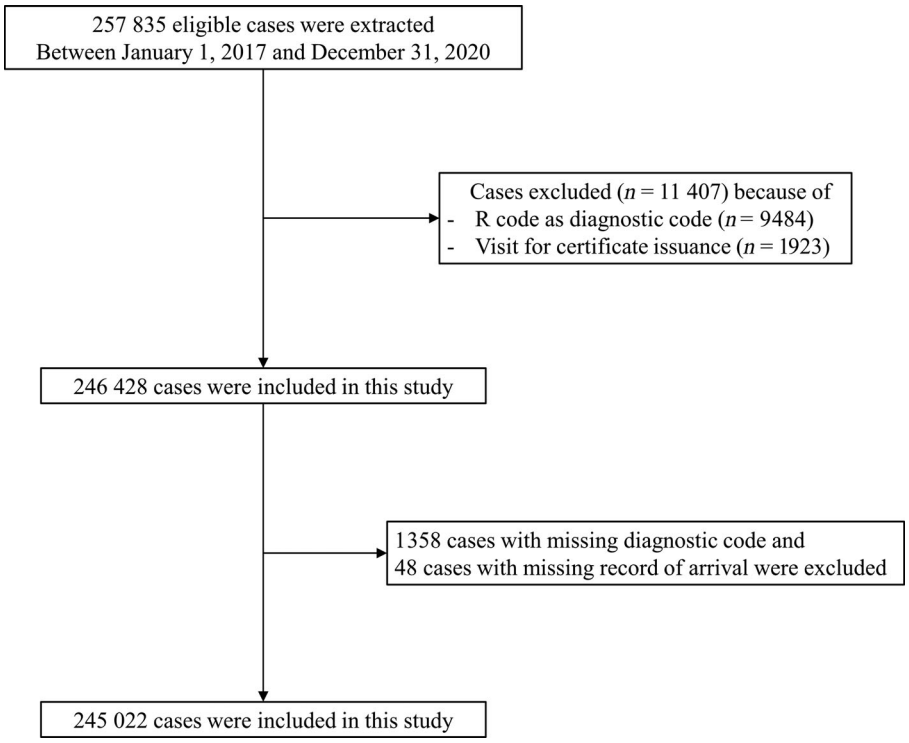



**Fig. 1** Flowchart of the study population.

2017 to 2020, the annual numbers of PED visits were 70 888, 73 234, 68 469, and 32 431, respectively. The annual PED visits in 2020 declined by 54.2% compared to the average number of visits in the previous 3 years. There was a decrease in the proportion of visits of the 1–3-year-old age group and an increase for the 8–17-year-old age group in 2020 compared with the previous 3 years. The proportion of females was approximately 43%. Demographic data of the patients in the study group are summarized in Table 1.

Segmented regression analysis revealed a clear impact of the COVID-19 pandemic on the number of visits, with a significant decrease in the number of patients from January, week 4, 2020, which is when the first case of COVID-19 was reported in Korea, with the commencement of public health instructions to wear masks and perform frequent hand hygiene. After this time point, the number of patient visits continued decreasing at a rate of 11.9 person/week (95% CI: −15.3–−8.4, $P < 0.001$) compared to a rate of 0.5 person/week (95% CI: −1.1–0.1, $P = 0.09$) before this time point. Specifically, at January week 4, 2020, there was a decrease of 453.1 person visits (95% CI: −564.3–−341.8, $P < 0.001$) (Fig. 2a).

With regard to the number of patients with an infectious disease or an infectious respiratory disease, the number increased by 0.23 person/week and decreased by 0.13 person/week, respectively (95% CI: −0.01–0.48, $P = 0.06$, and 95% CI: −0.27–0.01, $P = 0.07$, respectively) at January week 4, 2020. After this time point, the number of patients with an infectious disease or an infectious respiratory disease decreased at a rate of 5.7 person/week and 2.5 person/week, respectively (95% CI: −7.1–−4.2, $P < 0.001$, and 95% CI: −3.4–−1.7, $P < 0.001$, respectively). Specifically, at this time point, there was a decrease of 176.3 person visits and 110.5 person visits, respectively (95% CI: −223.5–−129.1, $P < 0.001$, and 95% CI: −137.6–−83.4, $P < 0.001$, respectively) (Fig. 2b,c).

From 2017 to 2020, the proportions of patient visits to the PED for infectious respiratory diseases by year were 25.9%, 27.0%, 28.6%, and 16.3%, respectively. Over the same years, the proportions of patients with other infectious diseases were 21.2%, 19.7%, 21.1%, and 17.5%, respectively. In 2020, the proportion of patients with infectious respiratory diseases decreased significantly compared to other infectious diseases ($P < 0.001$) (Table 2).

Before January week 4, 2020, the proportion of high-acuity patients decreased by a rate of 0.04% (95% CI: −0.05%–−0.03%, $P < 0.001$) per week, subsequently increasing by 0.21% (95% CI: 0.15%–0.26%, $P < 0.001$) per week. From that time point onwards, the proportion of high-acuity patients with an infectious disease or an infectious respiratory disease significantly increased by 0.55% and 0.61% (95% CI: 0.45%–0.65%, $P < 0.001$, and 95% CI 0.50%–0.71%, $P < 0.001$) per week, respectively (Fig. 3).

## Discussion

Our data demonstrated that during the year after the spread of the COVID-19 pandemic, the number of patients visiting PEDs in metropolitan areas of Korea continued to decline.

**Table 1** Characteristics of patients in the pediatric emergency department, *N* (%)

| Variables | 2017 | 2018 | 2019 | 2020 | *P* |
|---|---|---|---|---|---|
| Total visits | 70 888 | 73 234 | 68 469 | 32 431 | NA |
| Daily visits, mean ± SD | 191 ± 34 | 197 ± 36 | 185 ± 32 | 87 ± 36 | <0.001* |
| Age | | | | | |
| 0–12 months | 9,428 (13.30) | 9,077 (12.39) | 8,028 (11.73) | 3,919 (12.08) | < 0.001** |
| 1–3 years | 28 607 (40.36) | 29 450 (40.21) | 26 962 (39.38) | 11 129 (34.32) | |
| 4–7 years | 15 463 (21.81) | 16 306 (22.27) | 16 043 (23.43) | 7,336 (22.62) | |
| 8–17 years | 17 390 (24.53) | 18 401 (25.13) | 17 436 (25.47) | 10 047 (30.98) | |
| Sex | | | | | |
| Female | 30 433 (42.93) | 31 648 (43.21) | 30 110 (43.98) | 14 017 (43.29) | < 0.001** |
| KTAS level | | | | | |
| 1 | 106 (0.15) | 77 (0.11) | 81 (0.12) | 66 (0.20) | < 0.001** |
| 2 | 2,016 (2.84) | 2,046 (2.79) | 1,288 (1.88) | 704 (2.17) | |
| 3 | 21 751 (30.68) | 22 407 (30.60) | 18 820 (27.49) | 8,183 (25.23) | |
| 4 | 40 909 (57.71) | 43 854 (59.88) | 44 077 (64.38) | 21 738 (67.03) | |
| 5 | 6,106 (8.61) | 4,850 (6.62) | 4,203 (6.14) | 1,740 (5.37) | |
| Mode of arrival | | | | | |
| Self-referred | 65 149 (91.90) | 66 625 (90.98) | 61 658 (90.05) | 28 782 (88.75) | < 0.001** |
| Referred from clinic | 4,418 (6.23) | 5,147 (7.03) | 5,148 (7.52) | 2,828 (8.72) | |
| Outpatient department | 1,321 (1.86) | 1,462 (2.00) | 1,663 (2.43) | 821 (2.53) | |
| Disposition | | | | | |
| Admission | 6,919 (9.76) | 6,991 (9.55) | 6,442 (9.41) | 3,085 (9.51) | 0.016** |

All values are frequencies (%) except where otherwise indicated.
KTAS, Korean triage and acuity scale; NA, not applicable.
**P*-value from the *t*-test.
***P*-value from the $\chi^2$ test.

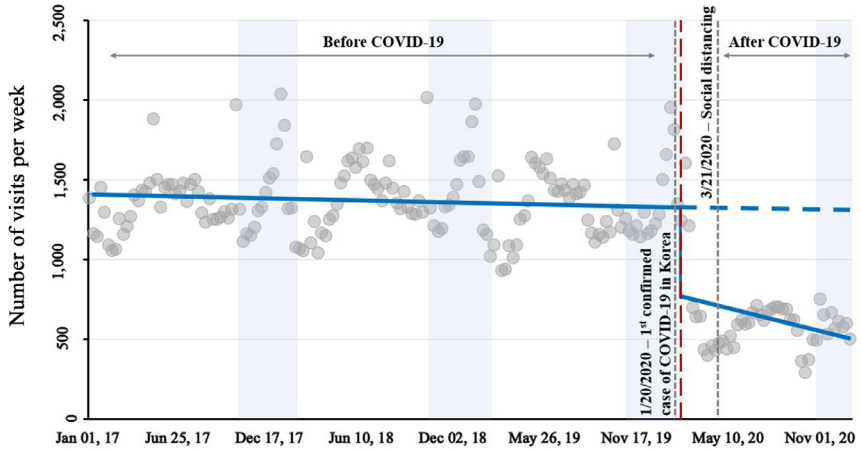
The decrease in the proportion of pediatric patients for an infectious respiratory disease was specifically greater than the decrease for other infectious diseases over the same period. In addition, the proportion of high-acuity patients in the PED gradually increased after the onset of spread COVID-19 pandemic.

The decrease in the total number of patient visits in PEDs is a global trend. Our findings also demonstrated a decrease in PED visits of 58% after the onset of COVID-19. Previous studies have reported that, for a month after the implementation of social distancing measures, the mean number of daily visits to PEDs decreased by 63%−75% compared with the same period in the previous years.[16-18] However, as the data used in these studies were based on a single institution, the results could not be generalized. In Korea, there have also been studies on changes in the PED visits during the early 2–3 months of the COVID-19 pandemic. One study revealed a decrease in the total number of PED visits and a disproportionate decrease in early childhood and low-acuity cases,[10] while another study reported a decrease in the total number of PED visits and an increase in the number of children with severe conditions.[11] However, these studies did not provide for control for known seasonal variations in PED visits as they included only a period of about 2–3 months after the onset of the COVID-19 outbreak. They also did not include data of patients in winter when infectious respiratory diseases increase. As the COVID-19 pandemic continues more than a year later, it is necessary to identify the long-term impact on PED visits in order to efficiently allocate human and material resources. Our findings are based on multicenter and long-term data for about a year after the COVID-19 pandemic and we controlled seasonal variations of PED visits.

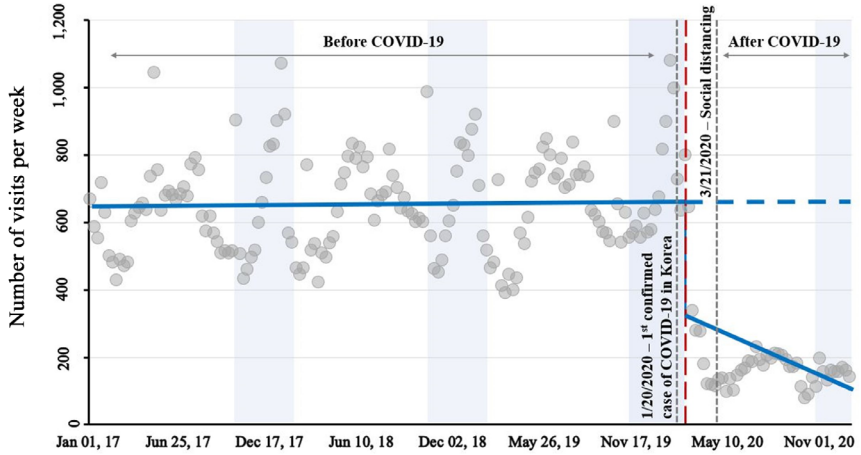
We identified several findings not reported in previous studies. First, we identified that the number of patients visiting PEDs continued to decrease during the 1 year after the COVID-19 outbreak. This may be because social distancing has been gradually strengthened. At the beginning of the COVID-19 pandemic, there were no restrictions on the hours and number of people who could use restaurants or shops. However, since the spread of COVID-19 has not diminished, the level of social distancing has been continuously raised, and there have been restrictions on the use of multi-use facilities after 10 p.m., with the number of people in gatherings being limited to four or less. As a result, human-to-human contact has been further reduced, and infectious diseases have also decreased, resulting in a continuous decrease in PED

**Fig. 2** Segmented regression analysis of weekly number of visits through the PED. Compared to before the COVID-19 pandemic, the weekly number of PED visits (a) and the number of patients with an infectious disease (b) or an infectious respiratory disease (c) have decreased significantly ($P < 0.001$, $P < 0.001$, and $P < 0.001$, respectively). COVID-19, coronavirus disease 2019; PED, pediatric emergency department.

**a Weekly number of PED visits**




**b Weekly number of PED visits for infectious disease**




**c Weekly number of PED visits for infectious respiratory disease**

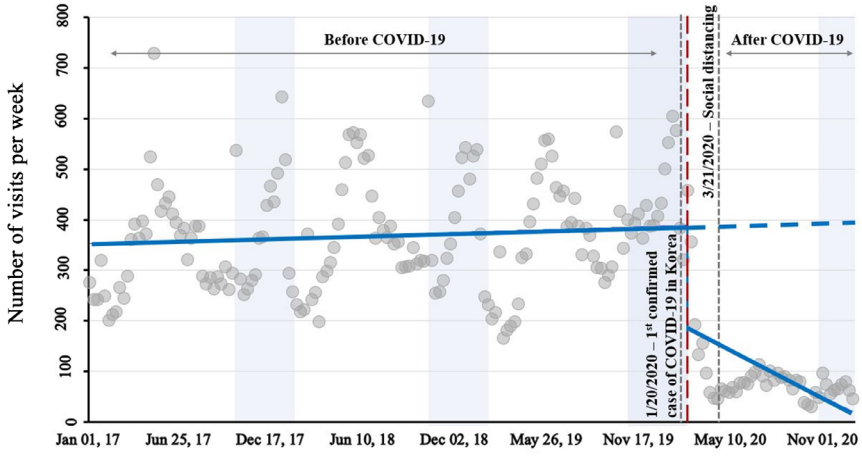


**Table 2** Diagnoses of patients visiting the pediatric emergency department

| Variables | 2017 ($n$ = 70 888) | 2018 ($n$ = 73 234) | 2019 ($n$ = 68 469) | 2020 ($n$ = 32 431) | $P$* |
|---|---|---|---|---|---|
| Infectious disease | | | | | |
| Infectious respiratory disease | 18 360 (25.90) | 19 804 (27.04) | 19 579 (28.60) | 5,298 (16.34) | <0.001 |
| Other infectious disease | 15 047 (21.23) | 14 417 (19.69) | 14 412 (21.05) | 5,662 (17.46) | |
| Noninfectious diseases | 37 963 (52.87) | 39 539 (53.27) | 39 853 (50.36) | 20 337 (66.21) | |

All values are frequency (%) except where otherwise indicated.
*$P$-value from the $\chi^2$ test.

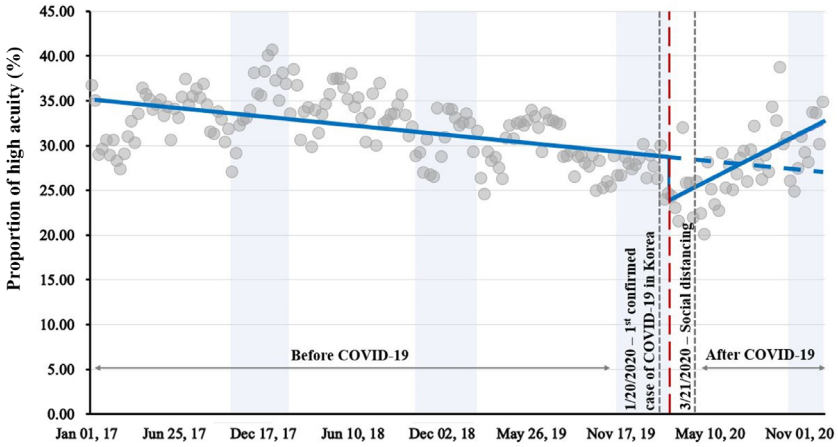
visits. Second, during the COVID-19 pandemic, the decrease in visits for infectious respiratory diseases was more remarkable than that in the decrease in visits for other infectious diseases. The reason may be that social distancing measures, in combination with hand washing, wearing of a mask, and delaying the opening of schools, had been implemented, having a positive impact on decreasing infectious respiratory diseases.[19] Thus, a thorough quarantine to prevent COVID-19 infection may have been effective in preventing the spread of all infectious diseases, especially infectious respiratory diseases. Third, we noted the gradual increase in the proportion of high-acuity patients visiting the PED after the COVID-19 outbreak began. In the early days of the COVID-19 pandemic, fear of COVID-19 would have prevented parents from visiting PEDs if their child had a low-severity health condition or was in the early phase of a disease. An Italian study reported a substantial decrease in pediatric care access due to the fear of parents and caregivers regarding the risk of exposure to COVID-19 in a health-care setting.[9] As this situation continues, the number of patients visiting PEDs only when the patient's condition was relatively critical has increased. The proportion of more urgent patients with KTAS 1 and 2 significantly decreased during the COVID-19 pandemic compared to before (2.64% vs 2.37%, $P = 0.005$). When KTAS 1 and KTAS 2 were analyzed separately, the proportion of patients with KTAS 1 increased significantly after COVID-19 (0.12% vs 0.20%, $P < 0.001$), and the proportion of patients with KTAS 2 decreased significantly (2.52% vs 2.17%, $P < 0.001$). The increase in the proportion of patients with KTAS 1 is similar to other studies in Korea, but the decrease in the proportion of patients with KTAS 2 is different from those studies.[10,11] Further research will be needed on this. Last, this study revealed a gradual decrease in the number of patients that visited the PED even before the spread of the COVID-19 pandemic. Due to the problem of low fertility in Korea, the number of children and adolescents under the age of 19 has continuously decreased from 9 706 738 in 2017 to 9 107 295 in 2019.[20] We think this could have had a direct effect on the decrease in the number of visits to the PED. This study also showed a decrease in the proportion of the 1–3-year-old age group and an increase in the proportion of the 8–17-year-old group during the COVID-19 pandemic. As the number of patients in the 1–3-year-old group decreased the most, it seems as if the number of patients in the 8–17-year-old group increased. However, the number of patients in the 8–17-year-old group actually decreased significantly.

This study also presented different results from previous foreign studies. Previous studies identified a decrease in the number of patient visits to the PED since the onset of government-led social distancing initiatives;[16,17] however, we identified a decrease in patient visits starting at the end of January 2020, about 2 months before the government implemented social distancing measures in Korea. These results are similar to previous studies in Korea.[10,11] First, this might reflect the high awareness of citizens in Korea regarding the prevention of infectious diseases. The Korean population learned about the risk of infectious diseases and the importance of self-quarantine during the Middle East respiratory syndrome (MERS) outbreak in 2015.[21] This experience may have affected the response of the Korean population to the COVID-19 outbreak. With most medical experts recommending wearing a mask and hand hygiene to prevent the spread of COVID-19,[22,23] 89% of citizens in Korea voluntarily wore masks and 80% used hand sanitizers.[24] A Korean study using mobile big data revealed that public movement declined from the end of January 2020, when the first patient of COVID-19 was diagnosed, decreasing to 38.1% by the end of February 2020.[25] Second, the early onset of the decrease in PED visits may reflect the close proximity of Korea to Wuhan, China, the site of the first source of COVID-19. As a result, it is estimated that the decrease in PED visits appeared earlier in Korea, despite the first outbreak of COVID-19 at a similar time in Europe or the USA.

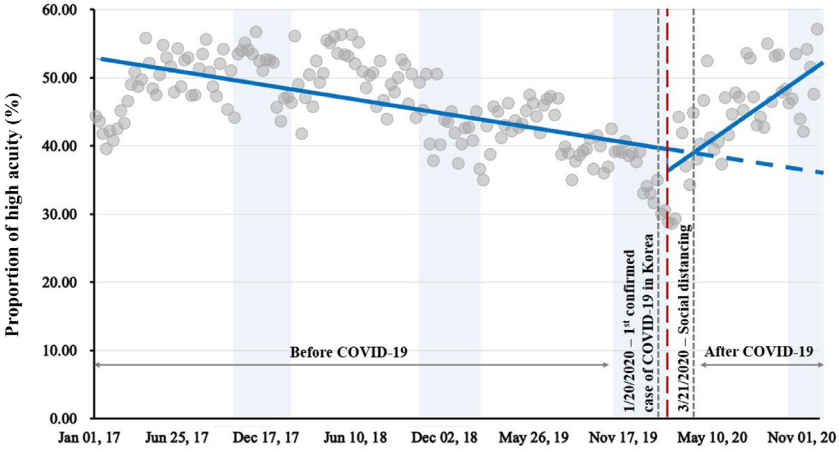
We had a similar experience to the COVID-19 pandemic during a MERS outbreak in 2015. MERS spread in Korea for 2 months from June to July 2015. There is a Korean study

**Fig. 3** Segmented regression analysis of the weekly proportion of high acuity patients of PED. Compared to before the COVID-19 pandemic, the proportion of high acuity patients of PED (a) and the proportion of high acuity patients with an infectious disease (b) or an infectious respiratory diseases (c) have increased significantly ($P < 0.001$, $P < 0.001$, and $P < 0.001$, respectively). COVID-19, coronavirus disease 2019; PED, pediatric emergency department.

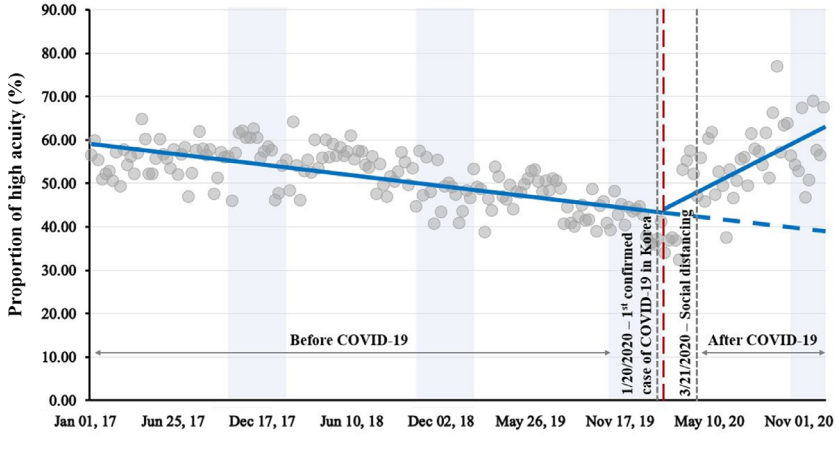
**a Proportion of high acuity patients in PED**




**b Proportion of high acuity patients with infectious diseases in PED**




**c Proportion of high acuity patients with infectious respiratory disease in PED**



that analyzed the utilization patterns of the PED during this period.[26] This study reported that the number of patients visiting the PED during this period decreased by about 40% compared to 2 years before the MERS outbreak, with a predominance of low-acuity visits. These results were similar to those shown in our study, but with significant differences in the duration of visit pattern changes. The number of PED visits decreased during the MERS outbreak, which lasted about 2 months, and then returned to the pre-MERS outbreak level. However, the COVID-19 pandemic has been going on for more than a year and is showing a steady decline in the number of PED visits. We believe this may be due to the difference in infectivity between COVID-19 and MERS. R0 indicates the average number of additional infectious among fully susceptible people. The R0 of MERS is 0.8–1.3,[27] whereas the R0 of COVID-19 is 2.2,[28,29] a much higher value.

Limitations should be acknowledged. First, this was a retrospective study that extracted data from the electronic medical records of each of the six participating hospitals. Case-mix due to differences in each hospital may exist, and as a result, sampling bias or information bias may occur. However, since the six hospitals cover areas where more than 50% of the total population reside, the above limitations may be reduced. Second, since the data of this study were provided anonymously, the possibility that information for the same patient might be included more than once cannot be excluded. These are inherent limitations of de-identified datasets and are not specific to this study.

The strength of our study is our use of a large data set from six hospitals during the COVID-19 pandemic for more than a year. Since data were obtained from six hospitals in metropolitan areas and provinces in Korea, regional deviations in the results of this study could be reduced. We consider our findings to be reliable because our analysis included 245 000 data entries, providing a comparison of the characteristics of visits to the PED for 3 years before and about 1 year after the onset of COVID-19 pandemic, controlling for known seasonal variation in PED visits.

### *Conclusions*

Our study revealed that the number of patients visiting the PED continued to decline during the COVID-19 pandemic. We also identified a specific decrease in visits related to infectious diseases, especially infectious respiratory diseases, accounting for a large proportion of the decrease in overall PED visits. However, we did note a gradual increase in the acuity of patients who visited the PED after January week 4, 2020. Therefore, as the COVID-19 pandemic persists, there is a need to implement longer term measures for the appropriate allocation of human and material resources necessary for the efficient operation of PEDs.

## Disclosure

The authors declare no conflict of interest.

## Author contributions

Bae W.R., Kim K.H., and Kim S.I. designed the study. Choi A.R. and Kim S.I. analyzed data. Bae W.R., Kang H.M., Kim S.Y., Lee H.Y., Yoo I.L., Yang E.A., Chun Y.H., Bin J.H., Kim H.H. and Jeong D.C. collected data. Bae W.R. wrote the manuscript. Kim K.H., Kang H.M., Yoon J.S., Lee S.H., Kim S.I. gave technical support and conceptual advice. All authors read and approved the final manuscript.

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