RESEARCH ARTICLE

Characteristics of Hospitalized Children With SARS-CoV-2 in the New York City Metropolitan Area

Sourabh Verma, MD,[a,b] Rishi Lumba, MD,[a] Heda M. Dapul, MD,[a,b] Gabrielle Gold-von Simson, MD, MS,[a] Colin K. Phoon, MD, MPhil,[a,b] Jennifer L. Lighter, MD,[a,b] Jonathan S. Farkas, MD,[a,b] Alexandra Vinci, MD,[c] Asif Noor, MD,[c] Vanessa N. Raabe, MD,[a,b,d] David Rhee, MD, MS,[a] Mona Rigaud, MD,[a] Pradeep V. Mally, MD,[a,b] Tara M. Randis, MD, MS,[e] Benard Dreyer, MD,[a,b] Adam J. Ratner, MD, MPH,[a,b,f] Catherine S. Manno, MD,[a] Arun Chopra, MD[a,b]

ABSTRACT

OBJECTIVES: To describe the characteristics of hospitalized children with severe acute respiratory syndrome coronavirus 2 in New York City metropolitan area.

PATIENTS AND METHODS: This was a multicenter, retrospective cohort study at 4 hospitals comprising 82 hospitalized children (0–21 years) who tested positive for severe acute respiratory syndrome coronavirus 2 after symptoms and risk screening between March 1 and May 10, 2020. We subdivided patients on the basis of their admission to acute or critical care units and by age groups. Further subanalyses were performed between patients requiring respiratory support or no respiratory support.

RESULTS: Twenty-three (28%) patients required critical care. Twenty-nine (35%) patients requiring respiratory support, with 9% needing mechanical ventilation, and 1 required extracorporeal support. All patients survived to discharge. Children with any comorbidity were more likely to require critical care (70% vs 37%, $P = .008$), with obesity as the most common risk factor for critical care (63% vs 28%, $P = .02$). Children with asthma were more likely to receive respiratory support (28% vs 8%, $P = .02$), with no difference in need for critical care ($P = .26$). Children admitted to critical care had higher rates of renal dysfunction at presentation (43% vs 10%, $P = .002$).

CONCLUSIONS: Children with comorbidities (obesity and asthma in particular) were at increased risk for critical care admission and/or need for respiratory support. Children with renal dysfunction at presentation were more likely to require critical care.

[a]Departments of Pediatrics and [f]Microbiology, Grossman School of Medicine, New York University, New York, New York; [b]Department of Pediatrics, Bellevue Hospital Center, New York, New York; [c]Department of Pediatrics, Long Island School of Medicine, New York University, New York, New York; [d]Department of Medicine, Vaccine Center, NYU Langone Health, New York, New York; and [e]Departments of Pediatrics and Molecular Medicine, University of South Florida, Tampa, Florida

www.hospitalpediatrics.org
DOI:https://doi.org/10.1542/hpeds.2020-001917

Address correspondence to Sourabh Verma, MD, Assistant Professor of Pediatrics, Department of Pediatrics, New York University Grossman School of Medicine, 317, East 34th St, Suite 902, New York, NY 10016. E-mail: sourabh.verma@nyulangone.org

HOSPITAL PEDIATRICS (ISSN Numbers: Print, 2154-1663; Online, 2154-1671).

FINANCIAL DISCLOSURE: The authors have indicated they have no financial relationships relevant to this article to disclose.

FUNDING: No external funding.

POTENTIAL CONFLICT OF INTEREST: The authors have indicated they have no potential conflicts of interest to disclose.

The coronavirus disease 2019 (COVID-19) pandemic has spread to >210 countries, with the highest number of infections and deaths reported in the United States. Although the number of new infections and deaths are declining in previous US hotspots, many other states are now reporting a concerning upsurge in the number of new infections.[1,2] Children have had a relatively low rate of symptomatic infections and a less-serious course of infection, as reported to date.[3,4] There is a recently described entity called multisystem inflammatory syndrome in children,[5–9] which is associated with recent infection or exposure to severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), suggesting that children may also suffer from distinctive consequences of this infection.

There is still a paucity of published data among hospitalized children with SARS-CoV-2. The early published reports originating from China[3] in which researchers describe the clinical spectrum of this infection in children have different results and risk factors from recent small case series from the United States.[10–15] In addition, the final clinical outcome for many patients (up to one-third) had not yet been determined at the time of publication from majority of smaller case series from the United States. To this end, we studied the clinical characteristics, laboratory findings, and short-term outcomes among pediatric and adolescent inpatients testing positive for SARS-CoV-2 through hospital discharge.

METHODS

This was a multicenter, retrospective cohort study including patients aged 0–21 years who were admitted to any of the pediatric acute or critical care units during hospitalization at a large health care system and its academic affiliate, between March 1 and May 10, 2020. All patients were managed until discharge or end of the study period (June 10, 2020). The patients were admitted to acute or critical care units on the basis of individual unit admission guidelines at clinical teams' discretion. The diagnosis of SARS-CoV-2 was made by real-time reverse transcriptase polymerase chain reaction of nasopharyngeal swabs of patients with any evolving symptoms of COVID-19 as described by the Centers for Disease Control and Prevention,[16] such as fever, respiratory symptoms, fatigue, headache, gastrointestinal symptoms, and new loss of taste or smell and on risk assessment based on history. The testing was mostly uniform across all institutions due to being a part of the same health care system or university affiliation. Initially, testing samples were sent to New York City (NYC) Department of Health and Mental Hygiene for processing. By April 1, all participating hospitals were performing "in-house" testing after Food and Drug Administration granted Emergency Use Authorization of reverse transcriptase polymerase chain reaction test for SARS-CoV-2 (Roche Cobas SARS-CoV-2 Test and Cepheid Xpert Xpress SARS-CoV-2 Test). The local institutional review boards approved the study with a waiver of consent and relevant data user agreements. Seven of these patients were included in other case series publications.[7,8,17,18]

Information collected included demographics, presenting symptoms, laboratory and imaging results, treatments, and clinical outcomes. Patients were subdivided and compared by highest level of care during admission (acute care versus critical care unit) and by age groups (<1, 1–5, 6–14, and 15–21 years). Further subanalyses of the data were performed comparing patients who received any respiratory support to those who required no respiratory support during hospitalization. BMI was calculated by using a BMI calculator from Centers for Disease Control and Prevention for age and sex, and subjects were categorized as obese if they were ≥95th percentile or BMI ≥30 and as overweight if they were 85th–95th percentile or BMI 25 to <30 for age ≥2 years.[19] Because of the nature of the study, data collection for obtaining history was not standardized within the cohort, and all testing and management plans were undertaken at the clinical team's discretion. Categorical variables were compared by using Pearson χ^2 test or Fisher exact test. Medians of continuous variables were compared by using the Mann–Whitney test, and means were compared by using Student *t* test. GraphPad Prism8 software was used for statistical analysis. A *P* value of <.05 was considered significant.

RESULTS

We identified 82 hospitalized children who tested positive for SARS-CoV-2. The majority were male (63%), and the median age was 5 years (interquartile range [IQR]: 2.5 months to 15.2 years) (Table 1). Among all patients, 23 (28%) were admitted to critical care units during hospitalization. One patient required venovenous extracorporeal membrane oxygenation (ECMO). At the end of the study period, all patients remained alive and were discharged from the hospital. The median duration from symptom onset to hospital admission was 1 day (IQR: 1–4 days) and length of stay was 3 days (IQR: 2–5 days). The majority of the patients were admitted because of respiratory distress, sepsis evaluation, or severity of gastrointestinal symptoms.

Demographics

About half of all patients (49%) were Hispanic and Latino, 22% were non-Hispanic white, 9% were non-Hispanic African American, 5% were non-Hispanic Asian, and 15% were multiple, other, or unknown race. This was consistent with overall patient population at these 4 institutions. African American, Hispanic, and Asian patients together were represented more frequently among those requiring critical care versus acute care but this difference was not statistically significant (74% vs 59%, $P = .22$). Thirty-three patients (40%) were aged <1 year, 9 (11%) were aged 1 to 5 years, 19 (23%) were aged 6 to 14 years, and 21 (26%) were aged 15 to 21 years. Distribution of presenting symptoms and need for admission to critical care or acute care units among patients of all age groups is shown in Figs 1 and 2. Fourteen patients (67%) in the 15 to 21 years age group and 9 patients (47%) in the 6 to 14 years age group had a BMI in the overweight or obese range.

Clinical Presentation

Fifty percent of the patients had a known sick contact with confirmed or suspected COVID-19. Forty-five percent of all patients

TABLE 1 Baseline Characteristics of all Hospitalized Pediatric and Adolescent Patients With SARS-CoV-2 and Comparison Between Those Admitted to Acute or Critical Care Units

	All Patients (n = 82)	Acute Care Admission (n = 59)	Critical Care Admission (n = 23)	P
Age, median (IQR)	5 y (2.5 mo–15.2 y)	6.7 mo (1 mo–11.5 y)	10 y (2.7 mo–18 y)	.16
Sick contacts, n (%)	45 (55)	27 (45)	18 (78)	.008
Comorbidities, n (%)				
Any comorbidity	38 (46)	22 (37)	16 (70)	.008
Asthma	12 (15)	7 (12)	5 (22)	.26
Obesity[a]	19 (40)	9 (28)	10 (63)	.02
Chronic lung disease	4 (5)	1 (2)	3 (13)	.06
Congenital heart disease	1 (1)	0	1 (4)	.28
Diabetes mellitus (type 1 or 2)	1 (1)	0	1 (4)	.28
Malignancy and/or immunosuppression	9 (11)	4 (7)	5 (22)	.10
Other	13 (16)	7 (12)	6 (26)	.11

[a] Denominator for obesity includes patients ≥2 y age, 32 in acute care vs 16 in critical care.

had at least 1 comorbidity at initial presentation, with obesity, asthma, and malignancy as the most common pre-existing conditions (Table 1). Fever (80%) was the most common presenting symptom, followed by cough (39%) and shortness of breath or dyspnea (29%) (Fig 1). Overall, older children had similar symptomatology to those described in adult patients with COVID-19.[20] There were 9 patients (11%) with acute appendicitis (7 were aged 6–14 years and 2 were aged 15–21 years; 3 patients had perforated appendix) and 2 children (2%) with intussusception.

Laboratory Characteristics at Initial Presentation

Leukopenia and lymphopenia were observed in 22% and 36% of the patients, respectively. C-reactive protein (CRP) was elevated in 67% (n = 54) of patients, and procalcitonin was elevated in 34% (n = 35) of patients. Other inflammatory markers, such as interleukin-6 (IL-6), D-dimer, and lactate dehydrogenase, were elevated in two-thirds and ferritin was increased in one-third of the patients (Table 2).

Chest Radiographic Imaging

Forty-eight (59%) patients had chest radiographs performed, of which 42 (88%) were abnormal. Chest radiographic findings included bilateral ground glass or hazy

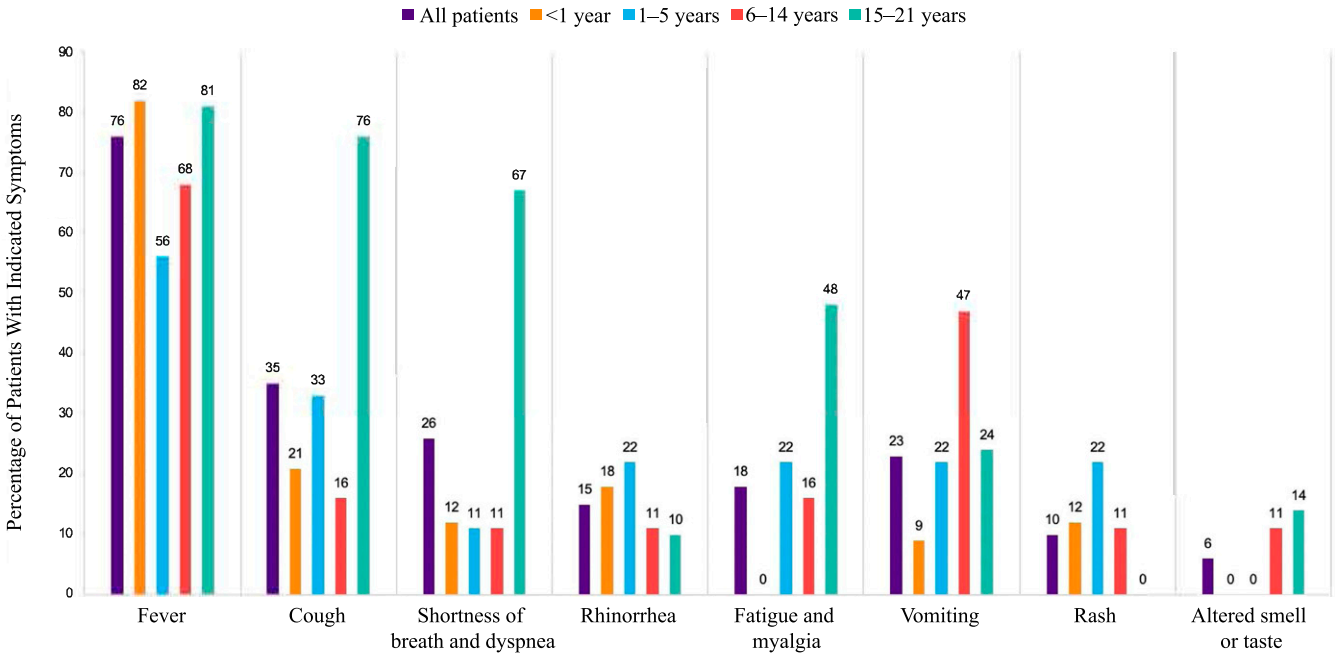

FIGURE 1 Presenting symptoms for all patients and their age wise distribution. (The percentages of symptoms in an age group for indicated symptom are on the y-axis, individual symptoms are on the x-axis, and the colors represent various age groups as shown in the figure).

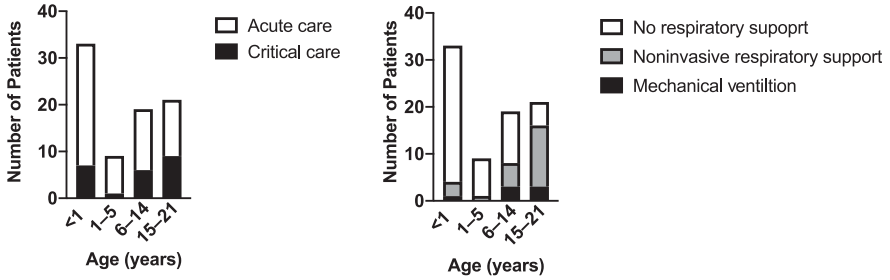

FIGURE 2 Distribution of pediatric and adolescent patients in various age groups, need for admission to acute versus critical care units, and type of respiratory support required. (The numbers of patients are on the y-axis, individual bars represent various age groups, and different shades represent support required as shown in the figure).

opacities in 20 (42%) patients, focal consolidation in 6 (13%), small airway inflammation in 15 (31%), pleural effusion in 3 (6%), and pneumothorax in 1 (1%) patient. Five children (6%) had computerized tomography of the chest, and 4 of them had bilateral ground glass or patchy airway opacities in the lungs.

Coinfections

Twelve patients (15%) in this cohort had coinfections. Sterile site culture results were negative, with the exception of 2 positive blood culture results (*Klebsiella pneumoniae* in a patient requiring mechanical ventilation and ECMO support; *Klebsiella oxytoca* and *Streptococcus constellatus* in a patient with a perforated appendix) and 2 positive urine cultures (*Pseudomonas aeruginosa* in patient with history of posterior urethral valve and Hutch diverticulum; and *Candida dubliniensis* in a patient with diabetic ketoacidosis). Three patients had viral coinfections (rhino/enterovirus, respiratory syncytial virus, and influenza B).

Therapies Used for COVID-19

Hydroxychloroquine (alone or in combination with other therapies) was administered to 26% of patients, predominately early in the reporting period. Other therapies included tocilizumab (10%), remdesivir (6%), lopinavir plus ritonavir (2%), and convalescent plasma (1%). Patients with respiratory symptoms or with comorbidities were more likely to receive medications for the treatment of COVID-19. In total, 76% patients requiring respiratory support received therapies for COVID-19, compared with 6% of those who did not require any respiratory support ($P < .001$). Similarly, higher proportions of patients with any comorbidity received medications for COVID-19 than those who had no comorbidities (53% vs 11%, $P < .001$).

Respiratory Support

Twenty-nine patients (35%) required some form of respiratory support, of which 7 patients (9%) needed mechanical ventilation. The noninvasive ventilation modalities (maximum respiratory support required) included 12 patients (15%) on nasal cannula, 9 (11%) on high-flow nasal cannula, and 1 (1%) on bilevel positive airway pressure support. We performed a subanalysis and comparison between children who required any form of respiratory support and those who required no respiratory support during hospitalization. Patients who required respiratory support were older (median age: 17.1 years IQR: 8.1–18.8 years] vs 9 months [IQR: 5 months–10.2 years], $P < .001$) and more frequently had pre-existing comorbidities (69% vs 32%, $P = .001$). Children with obesity had increased need for respiratory support, but this was not statistically significant (41% vs 30%, $P = .21$]. Children with a history of asthma were more likely to require respiratory support during hospitalization (28% vs 8%, $P = .02$).

Critical Care Versus Acute Care Admission

Children with any pre-existing comorbidity were more likely to require critical care than acute care during hospitalization (70% vs 37%, $P = .008$). Obesity is the most common risk factor associated with the need for critical care (63% vs 28%, $P = .02$). There was no difference in the proportions of overweight children (≥2 years) admitted to acute or critical care (25% vs 13%, $P = .41$). Children admitted to critical care were more likely to have sick contacts than those admitted to acute care units (78% vs 45%, $P = .008$). In addition, they were more likely to have elevated CRP, IL-6, and alanine aminotransferase (Table 2). Children admitted to critical care had higher rates of renal dysfunction at presentation than those admitted to acute care with elevated creatinine levels for age[21] (43% vs 10%, $P = .002$) and low estimated glomerular filtration rate[22,23] (56% vs 19%, $P = .01$). Initial vital signs were not significantly different between 2 groups. The median length of stay was higher among patients needing critical care (8 days [IQR: 4–24] vs 2 days [IQR: 2–4], $P < .001$).

DISCUSSION

In this study, we describe the largest pediatric case series to date in the United States of hospitalized children with SARS-CoV-2. In contrast to previously published pediatric SARS-CoV-2 inpatient cohorts, in which the final clinical outcome of many patients (up to one-third) had not yet been determined at the time of publication, we capture clinical outcomes through hospital discharge for all patients.[12–14] We compared these patients on the basis of their level of care and age groups. Additionally, we described a more-granular comparison between children who required respiratory support to those with no respiratory support than previously described in the literature.

Categorization of the disease severity among children with SARS-CoV-2 has been variable among limited published data,[3,11–15] with the main focus being patients requiring mechanical ventilation (Supplemental Table 3). Noninvasive respiratory support poses a significant morbidity burden for both patients and health care systems. The guidance regarding performing early intubation or trying noninvasive ventilation

TABLE 2 Laboratory and Microbiologic Indices Among Pediatric and Adolescent Patients With SARS-CoV-2 and Comparison Between Those Admitted to Acute or Critical Care Units

Laboratory Indices[a]	Available Data, *n*	All (*n* = 82)	Acute Care (*n* = 59)	Critical Care (*n* = 23)	*P*
Hemoglobin, <10 mg/dL	78	11/78 (14)	7/56 (13)	4/22 (18)	.49
Platelets, $<150 \times 10^3/\mu L$	76	11/76 (15)	6/54 (11)	5/22 (23)	.19
White blood cells count					
$<5 \times 10^3/\mu L$	78	17/78 (22)	14/56 (25)	3/22 (14)	.37
$>11 \times 10^3/\mu L$[b]	65[b]	21/65 (32)	12/45 (27)	9/20 (45)	.15
$>30 \times 10^3/\mu L$ for newborns <28 d of life	13	0/13	0/11	0/2	—
Absolute lymphocyte count, <1500 cells/μL	77	28/77 (36)	18/56 (32)	10/21 (48)	.21
Absolute neutrophils count, <1500 cells/μL	78	10/78 (13)	9/56 (16)	1/22 (5)	.27
CRP, >10 mg/dL	54	36/54 (67)	18/34 (53)	18/20 (90)	.005
Procalcitonin, ≥0.5 ng/mL	35	12/35 (34)	5/19 (26)	7/16 (44)	.41
IL-6, ≥5 pg/mL	29	20/29 (69)	10/18 (56)	10/11 (91)	.04
D-dimer, ≥250 ng/mL	23	15/23 (65)	9/14 (64)	6/9 (67)	.91
Ferritin, ≥250 ng/mL	21	8/21 (38)	4/11 (36)	4/10 (40)	.99
Lactate dehydrogenase, ≥250 IU/L	33	28/33 (85)	17/20 (85)	11/13 (85)	.97
Creatinine, elevated level for age[c]	69	14/69 (20)	5/48 (10)	9/21 (43)	.002
eGFR[d], <90 mL/min/1.73 m^2	42	14/42 (33)	5/26 (19)	9/16 (56)	.01
Troponins, >0.5 ng/dL	27	2/27 (7)	0/13 (0)	2/14 (14)	.48
Aspartate aminotransferase, >40 U/L	61	29/61 (48)	16/41 (39)	13/20 (65)	.06
Alanine aminotransferase, >40 U/L	62	13/62 (21)	4/42 (10)	9/20 (45)	.002
Microbiologic indices					
Blood culture positive	58	2/58 (3)	0/37 (0)	2/21 (10)	.13
Urine culture positive	34	2/34 (6)	1/21 (5)	1/13 (8)	.99
Cerebrospinal fluid culture positive	19	0/19	0/17	0/2	—
Respiratory viral panel positive[e] (except SARS-CoV-2)	47	3/47 (6)	1/32 (3)	2/15 (13)	.24
Coinfection (bacterial or viral or fungal)	82	12/82 (15)	5/59 (8)	7/23 (30)	.01

eGFR, estimated glomerular filtration rate; —, not applicable.

[a] All values expressed as *n*/number of patients with available data for a variable in that category (%).

[b] Excluding infants <28 d of life.

[c] Normal values range used for "creatinine for age[19]" in mg/dL: newborn: 0.3–1.0, infant: 0.2–0.4, 1 to 9 y: 0.3–0.7, 10 to 17 y: 0.5–1.0, 18 to 21 y: 0.9–1.3 (male), 0.6–1.1 (female).

[d] Denominator for eGFR includes patients ≥2 y age, eGFR calculated using "bedside Schwartz equation[21]" for patients aged 2 to 17 y and "Chronic Kidney Disease Epidemiology Collaboration creatinine equation[20]" for patients aged 18–21 y.

[e] BioFire FilmArray respiratory panel (bioMérieux).

modalities has rapidly evolved for patients with COVID-19 and worsening respiratory status. Therefore, in our study, we have looked at the data in a more comprehensive manner and compared children on the basis of their level of care to understand the burden of acute and critical care admissions in pediatric patients as well as elucidated the features of those children who required respiratory support (invasive or noninvasive). We recognize the need for standardizing descriptions of disease acuity and clinical course in the pediatric literature so we can arrive at a more meaningful understanding of the impact of SARS-CoV-2 infection in children.

Children with comorbidities were noted to be at increased risk for critical care admission and need for respiratory support in this study. Obesity is an important risk factor for SARS-CoV-2 admission in patients <60 years of age[24] and is associated with an increased need for mechanical ventilation in at least 1 pediatric study.[14] We speculate that children with obesity may be at increased risk for more severe illness because of SARS-CoV-2, as demonstrated for other viral infections, such as influenza A,[25] and among children requiring critical care during hospitalization.[26–28] This may be related to an altered immune response,[25] reduced baseline pulmonary function, and association of progression to an inflammatory syndrome as described with other comorbid conditions in patients with obesity.[29,30] In previously published case series from the United States,[11,12] children with asthma were not at increased risk for critical care admission, but morbidities such as need for respiratory support were not described among them. In our larger cohort, asthma as a comorbidity was significantly higher among children who required some form of respiratory support when compared with those who required no respiratory support, although there was no

statistically significant increase in the need for critical care admission. We suggest that pediatricians and other care providers consider all comorbidities, particularly obesity and asthma, as potential risk factors for severe illness while caring for children during this pandemic.

In the described cohort, patients aged 15 to 21 years were the most severely affected, with three-quarters of them requiring some form of respiratory support. Patients aged <1 and 1 to 5 years had relatively milder symptoms, and few of them required respiratory support. These findings are in contrast to a large retrospective pediatric study from China, in which the largest proportion of severe and critical cases were in children aged <1 and 1 to 5 years.[3] One-third of those cases were not laboratory confirmed for SARS-CoV-2, and there was no standardized testing for other viral illnesses in the Chinese study. The reasons for differences observed in disease severity among various age groups, despite higher nasopharyngeal viral load observed among infants compared with older children,[31] is yet to be determined. Some possible explanations could be from evolving immunologic response to the viral infections in early life and age-dependent differential expression of cell surface angiotensin-converting enzyme 2 receptors.[32–34]

Children <1 year of age were the most-represented age group in this study, which is similar to or slightly higher than other smaller studies from NYC.[15,31] In the beginning of pandemic spread in the United States, when data on children with COVID-19 from China suggested higher severity of infection among infants and younger children, it is possible that more infants with confirmed infection were admitted to ensure safety of these children. We did observe a decreasing trend of admitting infants from the emergency department over time during course of pandemic as our understanding of this infection in children increased.

The most-common presenting symptoms in this study were fever and/or dry cough. Several children had atypical nonrespiratory presenting symptoms, such as acute abdominal pain, new-onset seizure, and new-onset diabetes. Although some of these associations have been described in adult and pediatric literature,[14,35,36] it is unclear whether SARS-CoV-2 was the causative agent or if it was coincidentally diagnosed. Children admitted to critical care were more likely to have sick contacts than those admitted to acute care units. It is possible that families of patients admitted to critical care units may have reflected more on sick contacts or other aspects related to history (recall bias) or the clinical teams obtaining detailed history. Inflammatory markers were elevated in many of our patients, but only a few were associated with the need for critical care (CRP and IL-6). These findings suggest a similar, but likely less-severe, inflammatory process to that described in adult studies.[37,38] Renal dysfunction was observed more in patients requiring critical care, which has been previously described in pediatric patients with greater illness severity.[39] None of the patients required renal replacement therapy. The reasons for higher rate of renal dysfunction could be multifactorial, including hyperinflammation, cytokine storm, and complement dysregulation associated with COVID-19.[40,41] In addition, kidneys have increased expression of angiotensin-converting enzyme 2 receptor, potentially leading to viral entry and injury to the cells.[42] Among radiographic findings, a majority of the patients requiring respiratory support had bilateral ground glass or patchy opacities in lungs, whereas in a few cases these findings did not correlate with the level of clinical support required. Potential targeted therapies for COVID-19 have limited efficacy data among children. However, these treatments were given on the basis of individual patient clinical characteristics and in an effort to treat the most severely affected children.

Thirteen percent of patients in our described cohort were diagnosed with acute appendicitis or intussusception on presentation. This is a higher rate than previously published case series from NYC area.[14] All of these patients had gastrointestinal symptoms (abdominal pain, vomiting, or diarrhea), three-quarters of them had fever, and one-quarter had respiratory symptoms. It is possible that children taken to operating theater were more likely to get tested as per local infection prevention measures and were coincidentally found positive for SARS-CoV-2 during high prevalence of infection in the region. Viral infections are known to cause lymphadenopathy and hyperplasia of other lymphatic tissues, such as Peyer's patches in the intestines,[43–45] which may serve as a lead point resulting in intussusception,[46,47] and inflammation of lymphoid tissue around the appendix, resulting in acute appendicitis. This association of acute appendicitis and intussusception with SARS-CoV-2 infection needs further exploration, including analysis of pathologic changes in the surgically removed appendix.

Our study has several important limitations, including a small sample size, limited geographical range, and its observational nature. Because of rapidly evolving testing and management guidelines for suspected cases with SARS-CoV-2 at all study locations, there may have been some initial inconsistency in diagnosis and management over this study period. Also, some of the associations and risk factors observed in our relatively small study cohort need to be explored in detail on a larger data set. Nonetheless, our focus on hospitalized pediatric patients with SARS-CoV-2 in 4 NYC Metropolitan area hospitals with widespread community transmission provides important data for pediatric clinicians.

CONCLUSIONS

This described cohort is the largest case series to date of hospitalized children with confirmed SARS-CoV-2 managed from admission to discharge. We observed that children with comorbidities, particularly obesity and asthma, are at increased risk for critical care admission and/or the need for respiratory support. Children with renal dysfunction at presentation may be at greater risk for the need for critical care. Understanding risk factors associated with severity of illness among children requires further investigation on a larger data set.

Acknowledgments

We acknowledge the extraordinary work of all staff members who took care of these patients in the middle of this pandemic. We thank the patients and families of the children included in this study.

REFERENCES

1. . The New York Times. Coronavirus in the U.S.: latest map and case count. *The New York Times*. 2020. Available at: https://www.nytimes.com/interactive/2020/us/coronavirus-us-cases.html. Accessed June 18, 2020
2. Foster R, Mudnell EJ. Coronavirus cases rising in many states as reopening continues. *U.S. News & World Report*. June 15, 2020. Available at: https://www.usnews.com/news/health-news/articles/2020-06-15/coronavirus-cases-rising-in-many-states-as-reopening-continues. Accessed June 25, 2020
3. Dong Y, Mo X, Hu Y, et al. Epidemiology of COVID-19 among children in China. *Pediatrics*. 2020;145(6):e20200702
4. CDC COVID-19 Response Team. Coronavirus disease 2019 in children - United States, February 12-April 2, 2020. *MMWR Morb Mortal Wkly Rep*. 2020; 69(14):422–426
5. Riphagen S, Gomez X, Gonzalez-Martinez C, Wilkinson N, Theocharis P. Hyperinflammatory shock in children during COVID-19 pandemic. *Lancet*. 2020; 395(10237):1607–1608
6. Verdoni L, Mazza A, Gervasoni A, et al. An outbreak of severe Kawasaki-like disease at the Italian epicentre of the SARS-CoV-2 epidemic: an observational cohort study. *Lancet*. 2020;395(10239): 1771–1778
7. Dufort EM, Koumans EH, Chow EJ, et al; New York State and Centers for Disease Control and Prevention Multisystem Inflammatory Syndrome in Children Investigation Team. Multisystem inflammatory syndrome in children in New York state. *N Engl J Med*. 2020;383(4):347–358
8. Feldstein LR, Rose EB, Horwitz SM, et al; Overcoming COVID-19 Investigators; ; CDC COVID-19 Response Team. Multisystem inflammatory syndrome in U.S. Children and adolescents. *N Engl J Med*. 2020; 383(4):334–346
9. Whittaker E, Bamford A, Kenny J, et al; PIMS-TS Study Group and EUCLIDS and PERFORM Consortia. Clinical characteristics of 58 children with a pediatric inflammatory multisystem syndrome temporally associated with SARS-CoV-2. *JAMA*. 2020;324(3): 259–269
10. Rasmussen SA, Thompson LA. Coronavirus disease 2019 and children: what pediatric health care clinicians need to know. *JAMA Pediatr*. 2020;174(8): 743–744
11. Chao JY, Derespina KR, Herold BC, et al. Clinical characteristics and outcomes of hospitalized and critically ill children and adolescents with coronavirus disease 2019 at a tertiary care medical center in New York City. *J Pediatr*. 2020; 223:14–19.e2
12. DeBiasi RL, Song X, Delaney M, et al. Severe coronavirus disease-2019 in children and young adults in the Washington, DC, metropolitan region. *J Pediatr*. 2020;223: 199–203.e1
13. Shekerdemian LS, Mahmood NR, Wolfe KK, et al; International COVID-19 PICU Collaborative. Characteristics and outcomes of children with coronavirus disease 2019 (COVID-19) infection admitted to US and Canadian pediatric intensive care units. *JAMA Pediatr*. 2020; 174(9):1–6
14. Zachariah P, Johnson CL, Halabi KC, et al; Columbia Pediatric COVID-19 Management Group. Epidemiology, clinical features, and disease severity in patients with coronavirus disease 2019 (COVID-19) in a children's hospital in New York city, New York. *JAMA Pediatr*. 2020; 174(10):e202430
15. Kainth MK, Goenka PK, Williamson KA, et al; Northwell Health COVID-19 Research Consortium. Early experience of COVID-19 in a US children's hospital. *Pediatrics*. 2020;146(4): e2020003186
16. . Centers for Disease Control and Prevention. Symptoms of coronavirus. 2020. Available at: https://www.cdc.gov/coronavirus/2019-ncov/symptoms-testing/symptoms.html. Accessed June 20, 2020
17. Dumpa V, Kamity R, Vinci AN, Noyola E, Noor A. Neonatal coronavirus 2019 (COVID-19) infection: a case report and review of literature. *Cureus*. 2020;12(5): e8165
18. Paret M, Lighter J, Pellett Madan R, Raabe VN, Shust GF, Ratner AJ. Severe Acute Respiratory Syndrome Coronavirus 2 Infection (COVID-19) in febrile infants without respiratory distress. *Clin Infect Dis*. 2020; 71(16): 2243-2245
19. . Centers for Disease Control and Prevention. Defining childhood obesity. Available at: https://www.cdc.gov/obesity/childhood/defining.html. Accessed June 20, 2020
20. Guan WJ, Ni ZY, Hu Y, et al; China Medical Treatment Expert Group for Covid-19. Clinical characteristics of coronavirus disease 2019 in China. *N Engl J Med*. 2020;382(18):1708–1720
21. Engorn B, Flerlage J. Blood chemistries and body fluids. In: *The Harriet Lane Handbook*. 20th ed. Philadephia, PA: Elsevier Saunders; 2015:625
22. Levey AS, Stevens LA. Estimating GFR using the CKD Epidemiology Collaboration (CKD-EPI) creatinine equation: more accurate GFR estimates, lower CKD prevalence estimates, and better risk predictions. *Am J Kidney Dis*. 2010;55(4):622–627
23. Schwartz GJ, Muñoz A, Schneider MF, et al. New equations to estimate GFR in children with CKD. *J Am Soc Nephrol*. 2009;20(3):629–637
24. Lighter J, Phillips M, Hochman S, et al. Obesity in patients younger than 60 years is a risk factor for COVID-19 hospital admission. *Clin Infect Dis*. 2020;71(15):896–897
25. Honce R, Schultz-Cherry S. Impact of obesity on influenza A virus pathogenesis, immune response,

and evolution. *Front Immunol*. 2019;10:1071

26. Ross PA, Newth CJ, Leung D, Wetzel RC, Khemani RG. Obesity and mortality risk in critically ill children. *Pediatrics*. 2016;137(3):e20152035
27. Fiorino EK, Brooks LJ. Obesity and respiratory diseases in childhood. *Clin Chest Med*. 2009;30(3):601–608, x
28. Ross KR, Hart MA, Storfer-Isser A, et al. Obesity and obesity related co-morbidities in a referral population of children with asthma. *Pediatr Pulmonol*. 2009;44(9):877–884
29. Simonnet A, Chetboun M, Poissy J, et al; LICORN and the Lille COVID-19 and Obesity Study Group. High prevalence of obesity in Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-CoV-2) requiring invasive mechanical ventilation. *Obesity (Silver Spring)*. 2020;28(7):1195–1199
30. Stefan N, Birkenfeld AL, Schulze MB, Ludwig DS. Obesity and impaired metabolic health in patients with COVID-19. *Nat Rev Endocrinol*. 2020;16(7):341–342
31. Zachariah P, Halabi KC, Johnson CL, Whitter S, Sepulveda J, Green DA. Symptomatic infants have higher nasopharyngeal SARS-CoV-2 viral loads but less severe disease than older children. *Clin Infect Dis*. 2020;71(16):2305-2306
32. Bunyavanich S, Do A, Vicencio A. Nasal gene expression of angiotensin-converting enzyme 2 in children and adults. *JAMA*. 2020;323(23):2427–2429
33. Patel AB, Verma A. Nasal ACE2 levels and COVID-19 in children. *JAMA*. 2020;323(23):2386–2387
34. Cristiani L, Mancino E, Matera L, et al. Will children reveal their secret? the coronavirus dilemma. *Eur Respir J*. 2020;55(4):2000749
35. Chee YJ, Ng SJH, Yeoh E. Diabetic ketoacidosis precipitated by Covid-19 in a patient with newly diagnosed diabetes mellitus. *Diabetes Res Clin Pract*. 2020;164:108166
36. Rubino F, Amiel SA, Zimmet P, et al. New-onset diabetes in covid-19. *N Engl J Med*. 2020;383(8):789–790
37. Huang C, Wang Y, Li X, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. *Lancet*. 2020;395(10223):497–506
38. Qin C, Zhou L, Hu Z, et al. Dysregulation of immune response in patients with Coronavirus 2019 (COVID-19) in Wuhan, China. *Clin Infect Dis*. 2020;71(15):762–768
39. Bailey D, Phan V, Litalien C, et al. Risk factors of acute renal failure in critically ill children: a prospective descriptive epidemiological study. *Pediatr Crit Care Med*. 2007;8(1):29–35
40. Mehta P, McAuley DF, Brown M, Sanchez E, Tattersall RS, Manson JJ; HLH Across Speciality Collaboration, UK. COVID-19: consider cytokine storm syndromes and immunosuppression. *Lancet*. 2020;395(10229):1033–1034
41. Risitano AM, Mastellos DC, Huber-Lang M, et al. Complement as a target in COVID-19? *Nat Rev Immunol*. 2020;20(6):343–344
42. Soler MJ, Wysocki J, Batlle D. ACE2 alterations in kidney disease. *Nephrol Dial Transplant*. 2013;28(11):2687–2697
43. Alder AC, Fomby TB, Woodward WA, Haley RW, Sarosi G, Livingston EH. Association of viral infection and appendicitis. *Arch Surg*. 2010;145(1):63–71
44. Bhide SA, Wadekar KV, Koushik SA. Peyer's patches are precocious to the appendix in human development. *Dev Immunol*. 2001;8(2):159–166
45. Jung C, Hugot JP, Barreau F. Peyer's patches: the immune sensors of the intestine. *Int J Inflamm*. 2010;2010:823710
46. Buettcher M, Baer G, Bonhoeffer J, Schaad UB, Heininger U. Three-year surveillance of intussusception in children in Switzerland. *Pediatrics*. 2007;120(3):473–480
47. Marsicovetere P, Ivatury SJ, White B, Holubar SD. Intestinal intussusception: etiology, diagnosis, and treatment. *Clin Colon Rectal Surg*. 2017;30(1):30–39

Characteristics of Hospitalized Children With SARS-CoV-2 in the New York City Metropolitan Area

Sourabh Verma, Rishi Lumba, Heda M. Dapul, Gabrielle Gold-von Simson, Colin K. Phoon, Jennifer L. Lighter, Jonathan S. Farkas, Alexandra Vinci, Asif Noor, Vanessa N. Raabe, David Rhee, Mona Rigaud, Pradeep V. Mally, Tara M. Randis, Benard Dreyer, Adam J. Ratner, Catherine S. Manno and Arun Chopra

Hospital Pediatrics 2021;11;71
DOI: 10.1542/hpeds.2020-001917 originally published online October 8, 2020;

Hospital Pediatrics®

AN OFFICIAL JOURNAL OF THE AMERICAN ACADEMY OF PEDIATRICS

Characteristics of Hospitalized Children With SARS-CoV-2 in the New York City Metropolitan Area

Sourabh Verma, Rishi Lumba, Heda M. Dapul, Gabrielle Gold-von Simson, Colin K. Phoon, Jennifer L. Lighter, Jonathan S. Farkas, Alexandra Vinci, Asif Noor, Vanessa N. Raabe, David Rhee, Mona Rigaud, Pradeep V. Mally, Tara M. Randis, Benard Dreyer, Adam J. Ratner, Catherine S. Manno and Arun Chopra

Hospital Pediatrics 2021;11;71
DOI: 10.1542/hpeds.2020-001917 originally published online October 8, 2020;