THE JOURNAL OF PEDIATRICS

Elsevier

J Pediatr. 2020 May 11 PMCID: PMC7212947
doi: 10.1016/j.jpeds.2020.05.006 [Epub ahead of print] PMID: 32407719

Clinical Characteristics and Outcomes of Hospitalized and Critically Ill Children and Adolescents with Coronavirus Disease 2019 (COVID-19) at a Tertiary Care Medical Center in New York City

Jerry Y. Chao, MD, MSc,[1,*] Kim R. Derespina, MD,[2,*] Betsy C. Herold, MD,[3] David L. Goldman, MD,[3] Margaret Aldrich, MD,[3] Jacqueline Weingarten, MD,[2] Henry M. Ushay, MD, PhD,[2] Michael D. Cabana, MD, MPH,[4] and Shivanand S. Medar, MD[2,5,#]

[1]Department of Anesthesiology, Albert Einstein College of Medicine, Montefiore Medical Center
[2]Department of Pediatrics, Division of Critical Care Medicine, Albert Einstein College of Medicine, Children's Hospital at Montefiore
[3]Department of Pediatrics, Division of Infectious Diseases, Albert Einstein College of Medicine, Children's Hospital at Montefiore
[4]Department of Pediatrics, Division of General Pediatrics, Albert Einstein College of Medicine, Children's Hospital at Montefiore
[5]Department of Pediatrics, Division of Pediatric Cardiology, Albert Einstein College of Medicine, Children's Hospital at Montefiore
[#]Corresponding author: Shivanand S. Medar, MD, Assistant Professor of Pediatrics, Albert Einstein College of Medicine, Attending Physician, Division of Pediatric Critical Care Medicine, Children's Hospital at Montefiore, Bronx NY
[*]Contributed equally

Received 2020 Apr 27; Revised 2020 May 2; Accepted 2020 May 6.

Abstract

Objective

To describe the clinical profiles and risk factors for critical illness in hospitalized children and adolescents with COVID-19.

Study design

Children 1 month to 21 years with COVID-19 from a single tertiary care children's hospital between March 15-April 13, 2020 were included. Demographic and clinical data were collected.

Results

67 children tested positive for COVID-19; 21 (31.3%) were managed as outpatients. Of 46 admitted patients, 33 (72%) were admitted to the general pediatric medical unit and 13 (28%) to the pediatric intensive care unit (PICU). Obesity and asthma were highly prevalent but not significantly associated with PICU admission (p=0.99). Admission to the PICU was significantly associated with higher C-reactive protein, procalcitonin, and pro-B type natriuretic peptide levels and platelet counts ($p<0.05$ for all). Patients in the PICU were more likely to require high-flow nasal cannula (p=0.0001) and were more likely to have received Remdesivir through compassionate release ($p<0.05$). Severe sepsis and septic shock syndromes were observed in 7 (53.8%) PICU patients. Acute respiratory distress syndrome (ARDS) was observed in 10 (77%) PICU patients, 6 of whom (46.2%) required invasive mechanical ventilation for a median of 9 days. Of the 13 patients in the PICU, 8 (61.5%) were discharged home, and 4 (30.7%) patients remain hospitalized on ventilatory support at day 14. One patient died after withdrawal of life-sustaining therapy because of metastatic cancer.

Conclusions

We describe a higher than previously recognized rate of severe disease requiring PICU admission in pediatric patients admitted to the hospital with COVID-19.

The first reports of novel coronavirus disease 2019 (COVID-19) noted the infrequency of disease in children with one of the earliest studies including only 9 children under 14 years of age among 1,011 total patients (0.89%) (1,2). Since then, multiple reports have described children affected by COVID-19 with varying degrees of severity. ([3], [4], [5])

Epidemiologic studies have consistently demonstrated that children are at lower risk of developing severe symptoms or critical illness compared with adults. ([5],[6]) In a study of 2,143 pediatric patients in China with confirmed (n=731) or suspected (n=1412) COVID-19, over one-half had only mild illness, and <1% had severe or critical illness ([5]). In another study from China describing 36 children, no severe or critically ill case was observed. ([6]) The only study to describe children requiring admission to a pediatric intensive care unit (PICU) was a study from Spain of 365 children tested for COVID-19. ([7]) The authors found that 41 (11%) of children tested had virus detected; 25/41 (61%) required hospitalization, and 4/41 (16%) were admitted to the PICU. Details of clinical characteristics were not described.

Overall, the incidence of critical illness in children with COVID-19 is not well known, with limited data on possible associated risk factors. The objectives of this study were ([1]) to describe the clinical profile of critically ill children with SARS-CoV-2 infection admitted to our tertiary care facility, and ([2]) to study the risk factors associated with critical illness.

Methods

The Albert Einstein College of Medicine Institutional Review Board reviewed and approved this retrospective review of all children aged 1 month to 21 years admitted at the Children's Hospital at Montefiore between March 15- April 13, 2020 with a laboratory confirmed SARS-COV-2 infection. Infection was confirmed by real-time reverse transcription polymerase chain reaction (RT-PCR) testing a specimen using nasopharyngeal swab on one of several different platforms adopted by the Clinical Microbiology Laboratory in an effort to increase testing availability (Abbott laboratories, Abbott Park, IL; Luminex Aries; Cepheid Xpert Xpress, Sunnyvale CA and Hologic Panther Fusion, San Diego, CA).

Demographic data, clinical signs and symptoms at presentation, laboratory and radiologic results, treatments and outcomes on all pediatric patients admitted to the hospital during the study period were obtained from the electronic medical record (EMR) (EPIC, Verona, WI, USA). The decision to admit to the pediatric floor or ICU was at the discretion of treating physicians.

Acute respiratory distress syndrome (ARDS) was defined using Berlin criteria ([8]) (PaO_2/FiO_2 ratio 200-300 as mild ARDS, 100-200 as moderate ARDS, and <100 as severe ARDS). Oxygenation index (OI) was calculated using the formula (fraction inspired oxygen x mean airway pressure) x 100/partial pressure of arterial oxygen. Management of ARDS was based on ARDSNet guideline of low tidal volume and limiting peak/plateau pressure under 30 cm of water. ([9]) Sepsis, severe sepsis, and septic shock were defined as per the pediatric surviving sepsis guidelines. ([10]) Acute kidney Injury (AKI) was defined using the Kidney Disease: Improving Global Outcomes (KDIGO) classification based upon the change in serum level of creatinine and creatinine clearance. ([11]) Virus-associated sepsis was defined as presence of ≥2 systemic inflammatory syndrome (SIRS) criteria, severe sepsis as sepsis with organ dysfunction or tissue hypoperfusion, and septic shock as severe sepsis with volume resistant hypotension. ([10]) Obesity was defined as body mass index (BMI) > 30 kg/m^2, and asthma was recorded if it was documented in the EMR by a physician.

Statistical analyses

Clinical data were presented as counts and percentage, mean and standard deviation, and median and interquartile range. Comparison of means and medians was performed using the two-sample student t-test or Wilcoxon rank-sum test, respectively. Categorical data were compared using Pearson chi-squared or Fisher exact test if any expected cell size numbered < 5. All tests were two-tailed with a level of significance of $P < .05$. Statistical analyses were performed using STATA 13.1 (College Station, TX, USA).

Results

From March 15 to April 13, a total 1,747 children and adolescents visited the emergency department (ED); 194 were tested for SARS-CoV-2 infection. Test results were positive in 67 (34.5%) patients with 46 subsequent admissions to the hospital, with 13 (28.3%) patients requiring PICU care. In 21 patients SARS-CoV-2 infection was confirmed but did not require hospitalization. As the number of patients screened for COVID-19 was restricted during the first weeks of the outbreak because of limited testing availability, the number of mildly symptomatic patients is not known, and therefore these 21 patients are not included in the analysis.

The median age of the hospitalized cohort was 13.1 (IQR 0.4, 19.3) years with a preponderance of male sex (31, 67.4%). The majority of patients were Hispanic/Latino (78.8%, p=0.001), reflecting the demographics of the Bronx community. Median BMI was 22.8 kg/m^2 (IQR 17.6, 32.9). Eighty-four percentage of patients admitted to the PICU were 11 years of age or older.

The most common symptoms at admission were cough (63%) and fever (60.9%). Patients reported a median duration of symptoms of 3 (IQR 1, 5) days prior to admission. No patient in this cohort reported travel to areas heavily affected by COVID-19 prior to symptom onset, but 20 (43.5%) reported a COVID-confirmed contact. Demographic and clinical comparison of the 46 patients admitted to the medical unit and PICU is presented in Table 1 . The only clinical symptom found to be significantly associated with PICU admission was shortness of breath (92.3% vs. 30.3%, p <0.001).

Table 1

Demographics and Baseline Characteristics of Pediatric Patients with COVID-19

	Shortness of breath no. (%)	10 (30.3)	12 (92.3)	<0.001
	Known sick contact no. (%)	14 (42.4)	6 (46.2)	0.99
	Travel history	0 (0)	0 (0)	-
	Symptom (days) median (IQR)	2.5 (1,5.5)	3 (2,5)	0.44
	History of Ibuprofen use no. (%)	5 (15.2)	3 (23.1)	0.67
Vital Signs	**Adm Temp (^{0}C) median (IQR)**	37.9 (37, 38.7)	37.1 (36.9, 38.2)	0.32
	T-max (^{0}C) median (IQR)	39 (37.9, 39.5)	38.9 (37.9, 40.1)	0.46
	Hosp day of T-max median (IQR)	1 (1,2)	2 (1, 2)	0.32
	Adm HR/min Mean (SD)	136 (36)	117 (27.1)	0.1
	Adm SpO_2(%) median (IQR)	98 (95,100)	98 (97, 100)	0.9
	Adm SBP mm Hg Mean (SD)	113.8 (17.6)	111.6 (17.4)	0.71
	Adm DBP mm Hg Mean (SD)	66 (12.6)	68 (12.1)	0.64

Open in a separate window

*Comparison of patients admitted to medical unit vs. patients admitted to PICU using Chi-square test, Fisher's exact test or Wilcoxon rank sum test.

Data expressed in number (percentages), mean (SD), or median (IQR)

BMI: body mass index; PICU: pediatric intensive care unit; T-max: temperature maximum;

(^{o}C): degree Celsius; Adm: admission; HD: hospital day; SpO_2 : arterial oxygen saturation; SBP: systolic blood pressure; DBP: diastolic blood pressure; mm Hg: millimeters of mercury.

Obesity was present in 14 (30.4%) of admitted patients and asthma in 11 (24.4%) but neither was significantly associated with the need for PICU admission (p<0.99 for both). A higher proportion of PICU patients had a preexisting history of seizure disorder (3 patients, 25%) compared with just one patient (3%) admitted to the medical unit. There was no significant difference in the usage of Ibuprofen prior to hospitalization among patients admitted to medical unit compared with those admitted to the PICU.

Laboratory test results

Patients admitted to the PICU had lower platelet counts on admission compared with patients admitted to the medical unit (p=0.03) (Table II). Conversely, levels of inflammatory markers including C-reactive protein, procalcitonin, and pro-brain natriuretic peptide (BNP) were significantly elevated in patients admitted to PICU compared with those admitted to the medical unit ($p<0.05$ for all). Patients admitted to the PICU also had higher BUN (13 (IQR 10,16) vs 10 (IQR 7,11), p=0.03) and trended towards having higher creatinine levels (0.7 (IQR 0.4, 1.1) vs 0.5 (IQR 0.2, 0.8), p=0.12) on admission.

Table 2

Admission laboratory results and imaging studies in patients with COVID-19 admitted to floor and PICU

Total bilirubin (mg/dL)	0.4 (0.3, 0.6)	0.5 (0.1, 0.6)	0.099
BUN (mg/dL)	10 (7, 11)	13 (10, 16)	0.03
Creatinine (mg/dL)	0.5 (0.2, 0.8)	0.7 (0.4, 1.1)	0.12
C-reactive protein (mg/dL)	1.9 (0.5, 4.3)	6.6 (2.0, 11.8)	0.02
Peak C-reactive protein (mg/dL)	3.3 (0.5, 6.6)	12.1 (2, 19.8)	0.06
Procalcitonin (ng/mL)	0.1 (0.1, 0.2)	11.5 (1.4, 21.5)	0.03
Pro-BNP (pg/mL)	60 (60, 85)	1112 (1051, 1734)	0.01
Troponin (ng/mL)	0.01 (0.01, 0.01)	0.01 (0.01, 0.01)	0.13
CPK (U/L)	183 (100, 379)	199 (109, 302)	0.95
Lactate (mmol/L)	1.9 (1.5, 2.1)	1.5 (1.2, 1.5)	0.36
D-dimer (ug/mL FEU)	0.8 (0.3, 1.1)	0.8 (0.7, 2.3)	0.36
LDH (U/L)	417 (402, 765)	420 (378, 569)	0.84
+Blood culture admission	1 (3.0)	3 (23.1)	0.10
+Respiratory culture	0 (0)	3 (23.1)	0.08
+Urine culture	2 (6.1)	3 (23.1)	0.27
Chest radiograph performed	19 (57.6)	12 (92.3)	0.04
Normal CXR	4 (21.1)	2 (16.7)	<0.99
Bilateral opacities	12 (63.2)	8 (66.7)	<0.99
Unilateral opacity	3 (15.8)	2 (16.7)	<0.99
Pleural effusion	0 (0)	1 (8.3)	0.39
LV dysfunction by	0/3 (0)	2/4 (50)	0.43

Open in a separate window

*Comparison of patients admitted to floor vs. patients admitted to PICU using chi-square test, Fisher exact test or Wilcoxon rank-sum test.

WBC: white blood cell count; ALC: Absolute lymphocyte count; AST: aspartate aminotransferase; ALT: alanine aminotransferase; BUN: blood urea nitrogen; pro-BNP: pro-brain natriuretic peptide; CPK: creatine phosphokinase; LDH: lactate dehydrogenase; CXR: chest radiograph; LV: left ventricular

Chest radiographs were performed more often in patients admitted to the PICU compared with those admitted to the medical unit (92.3% vs 57.6%, respectively, p=0.04) and showed opacities in 10/13 of those admitted to the PICU and in 19/33 admitted to the medical unit. There was no difference in the finding of unilateral vs. bilateral opacities among patients in the medical unit compared with the PICU (p<0.99). One patient admitted to the PICU also had a pleural effusion on admission requiring drainage as he was requiring high ventilatory support.

Management and Clinical outcomes

All 33 patients admitted to the medical unit except one were discharged home with a median length of stay (LOS) of 3 (IQR 2,4) days (Table 3). The one exception was a 15-year-old patient who was transferred to the PICU on day 1 of hospitalization for worsening hypoxemia. He required high-flow nasal cannula (HFNC) oxygen support for 4 days before being discharged home on day 11. Details of the 13 patients admitted to the PICU are shown in the Figure (available at www.jpeds.com) and Table 4 (available at www.jpeds.com). The majority of patients initially admitted to the PICU (8/13, 61.5%) were discharged home with a median LOS of 7 (IQR 6,11) days. Four patients remain hospitalized in the PICU at day 14. In one patient with metastatic disease from underlying malignancy, the family chose to withdraw care (Table 4). All PICU patients had signs of SIRS, and 3 (23.1%) developed septic shock requiring vasopressor support and fluid resuscitation.

Table 3

Clinical outcomes and therapies administered to patients with COVID-19

RRT	1 (3)	1 (7.7)	0.99
Prone positioning	0 (0)	1 (7.7)	0.33
Medical therapy			
Hydroxychloroquine	6 (18.2)	4 (30.8)	0.44
Remdesivir	2 (7.1)	6 (46.2)	0.007
Methylprednisolone	5 (15.2)	6 (46.2)	0.051
Antibiotics <48 hours	18 (58.1)	7 (53.9)	0.80
Antibiotics >48 hours	10 (33.3)	4 (30.8)	0.99
Respiratory support			
NC	9 (27.3)	4 (30.8)	0.99
Duration of NC	5.5 (2, 11)	1.5 (1.0,3.5)	0.10
HFNC	1 (3.1)	7 (53.9)	0.0001
Duration of HFNC	0 (0,0)	4 (1, 5)	0.82
Non-IMV	0 (0,0)	2 (15.4)	0.08
Duration of Non-IMV	0 (0,0)	8 (3, 13)	0.005
IMV	0 (0,0)	6 (46.2)	<0.0001
Duration of IMV	0 (0,0)	9 (7, 14)	0.004
Outcomes			
Hospital stay	3 (2, 4)	7 (6, 11)	0.19
PICU stay	-	7 (5, 8)	-
Survivors	33 (100)	12 (92.3)	0.32

Open in a separate window

*Comparison of patients admitted to floor vs. patients admitted to PICU using Chi-square test, Fisher's exact test or Wilcoxon rank sum test.

**Chronic home RRT for end stage renal disease

Abbreviations: ARDS: acute respiratory distress syndrome; PICU: pediatric intensive care unit; AKI: acute kidney injury; RRT: renal replacement therapy; NC: nasal cannula; HFNC: high flow nasal cannula; IMV: Invasive mechanical ventilation.

Table 4

(Online only). Profile of 13 critically ill children in PICU with COVID-19

nbsp	1	2	3	4	5	6	7	8	
Age (years)nbsp	14	20	15	11	14	4 MO	19	15	1
Sexnbsp	F	M	F	M	M	F	M	M	M
Racenbsp	Black	Other	Other	Black	Other	Other	Other	Hispanic	H
BMI (kg/m^2)nbsp	23.54	19.5	**33.05**	18.85	21.06	20	**30.5**	**49.64**	**4**
Reason for PICU admissionnbsp	DKA	DKA	PNA AHRF	PNA AHRF	PNA AHRF	PNA AHRF	PNA AHRF	PNA AHRF	P A
Comorbiditiesnbsp	None	T2DM	Obesity	Metastatic Cancer	Seizures Asthma	CHD	Obesity	T2DM	C
WBC (k/uL)nbsp	28.2	8.8	5.9	14.8	17.1	20.8	10	6.7	9
ALC (k/uL)nbsp	2.8	0.9	0.53	1.12	2.7	5.6	0.9	1.3	0
CRP (mg/dL)nbsp	2	1.2	3.4	N	11.8	3.3	8.1	5	1
Procalcitonin (ng/mL)nbsp	N	N	N	N	1.4	0.6	N	N	0
Sepsisnbsp	N	N	N	N	Y	Y	N	N	N
AKInbsp	Y	Y	N	N	Y	Y	N	N	N
Respiratory supportnbsp	None	None	HFNC	IMV	IMV	IMV	IMV	HFNC	H
Remdesivir	N	N	N	N	Y	Y	N	Y	Y
HCQ	N	N	N	N	N	N	Y	Y	Y
Steroidsnbsp	N	N	N	N	Y	N	Y	Y	Y

Open in a separate window

MO: months old; F: female; M: male; BMI: body mass index; Y: yes; N: no;nbsp DM: diabetes mellitus; HTN: hypertension; ASD: atrial septal defect; PDA: patent ductus arteriosus; NAFLD: non-alcoholic fatty liver disease; OSA: obstructive sleep apnea; DKA: diabetic ketoacidosis;nbspT2DM: type 2 diabetes Mellitus;nbspPNA: pneumonia; WBC: white blood cell count; ALC: absolute lymphocyte count; CRP: C-reactive protein; MSSA: methicillin-sensitive Staphylococcus aureus; UTI: urinary tract infection; AKI: acute kidney injury; RRT: renal replacement therapy;nbspHFNC: high flow nasal canula; BiPAP: bilevel positive pressure ventilation; IMV: invasive mechanical ventilation;nbspPICU: pediatric intensive care unit; LOS: length of stay; HLOS: hospital length of stay; HD: hospital day; Hosp: Hospitalized.

ARDS and mechanical ventilation

ARDS was documented in 10 of the 13 patients (76.9%) admitted to the PICU compared with none on the medical unit (Table 4). Seven (53.9%) were supported with high-flow nasal cannula (HFNC), 4 of which required escalation to invasive mechanical ventilation. Two patients (15.4%) required non-invasive ventilatory (NIV) support, of which one required escalation to invasive mechanical ventilation. A total of six patients (46.2%) required invasive ventilatory support, for a median duration of invasive mechanical ventilatory support of 9 (IQR 7, 14) days (Table 3). These patients had moderate to severe hypoxemia diagnostic of ARDS, with a median PaO_2/FiO_2 ratio on day one of 178 which worsened to a PaO_2/FiO_2 ratio of 105 by day three. Worsening hypoxemia and lung disease also was reflected in the escalation of ventilatory support by day 3 (Table 5 ; available at www.jpeds.com). Lung protective strategies for mechanical ventilation in ARDS were insufficient in these patients by day 3 with a median PEEP requirement of 10 cm water, resulting in a median peak pressure of 35 cm water. One patient was successfully extubated after 6 days of ventilatory support, and one patient died after withdrawal of care. The remaining 4 patients remained on mechanical ventilatory support on day 14 of hospitalization.

Table 5

(Online only). Oxygenation and mechanical ventilation parameters

Parameter median (IQR)	Day 1	Day 2	Day 3
PaO_2/FiO_2ratio	178 (130, 219)	175 (130, 219)	105 (105, 160)
Oxygenation Index	7.7 (6.7, 11.6)	10 (8.8, 12)	10.6 (9, 15)
Tidal Volume (ml)	336 (231, 424)	297 (260, 350)	264 (194, 365)
Tidal Volume (ml/kg)	7.8 (6.4, 8.3)	6.6 (5.8, 7.5)	6.4 (5.5, 7)
PEEP (cm of water)	10 (7.75, 11.5)	10 (8, 12)	10 (8.5, 12)
MAP (cm of water)	16 (15, 17)	16 (15, 24)	17 (17, 24)
Peak Pressure (cm of water)	29.5 (25.5, 40.25)	30 (27, 37)	35.5 (25.25, 37.5)
FiO_2	1.0 (0.7, 1.0)	0.45 (0.4, 0.5)	0.57 (0.55, 0.75)

Data expressed as median (IQR); PaO_2: partial pressure of oxygen; FIO_2: oxygen concentration; PEEP: positive end expiratory pressure; MAP: mean airway pressure;

Treatment

Hydroxychloroquine was administered to 30.8% of patients admitted to the PICU compared with 18.2% of those admitted to the medical unit (Table 4). Compassionate use of Remdesivir was administered more often to patients in the PICU compared with the medical unit (46% vs. 7%, p = 0.007), and there was a trend toward increased use of methylprednisolone in PICU patients (46% vs. 15%, p=0.051). There was no age-related difference in patients who received Remdesivir or hydroxychloroquine both in the medical unit and in the PICU. Empiric antibiotics were begun on 25 (54%) patients, with 14 (56%) patients continuing antibiotic therapy; there was no significant difference among patients cared for in the medical unit vs. PICU in terms of antibiotic usage and

duration. AKI was diagnosed in 5 (38.4%) patients admitted to the PICU, of which 4 resolved with volume resuscitation. One patient (7.7%) required renal replacement therapy (RRT) for severe fluid overload associated with septic shock and multiorgan failure.

Discussion

We describe 46 hospitalized children with SARS-CoV-2 infection diagnosed in the first weeks of the New York City pandemic to add to the limited data on pediatric SARS-COV-2 infection. As expected, patients admitted to the PICU were noted to have more severe symptoms and markers of inflammatory response. However, as this cohort is from a unique, dense, urban setting, we note findings not previously observed in other hospitalized cohorts of children with COVID-19. Our patients had a higher rate of PICU admission per hospitalization (28.2%), which may be a reflection of a variety of social determinants that influence health outcomes. In previous studies ([5,6,7]), the ICU admission rate in children ranged from 1.7% to 16%. ([3,5,7]) In adults, the PICU admission rates range from 5% to 32%. ([1,2, 12,13,14,15]) Among PICU admissions, 84.6% were ≥11 years of age. The presence of comorbidities, including obesity, has been described to be one of the risk factors for critical illness with COVID-19 in children ([5]); however, in our small sample, age and obesity were not associated with increased likelihood of PICU admission. The overall high prevalence of obesity could partially explain our higher PICU admission rate. However, obesity may also be a marker for other risk factors associated with an increased risk of critical illness, such as poverty. ([16]) For example, Bronx County has the highest poverty rate of the New York City boroughs and is the least healthy county in New York state. Previous studies have demonstrated an association between social factors, such as poverty, and the increased risk of prolonged hospital stay as well as PICU admission for many different conditions. ([17, 18, 19, 20])

Less than one-half of our patients had the history of a known sick contact, which is lower than previously reported. ([3,21]) This high rate of community spread could be explained partially by the high population density in the Bronx, which is approximately 33,000 people per square mile, well above the national average of 90 people per square mile ([22]) and approximately 10 times more dense than Wuhan, China. The lack of a known sick contact reported in our study may have implications for how healthcare providers identify and screen for potential cases.

Children are reported to have milder SARS-COV-2 disease, but our findings suggest that a subset of pediatric patients develop severe disease requiring PICU admission. This subset had significantly higher markers of inflammation (CRP, pro-BNP, procalcitonin) compared with patients in the medical unit. Inflammation likely contributed to the high rate of ARDS we observed, although serum levels of IL-6 and other cytokines linked to ARDS were not determined.

ARDS is reported in 3-5.8% of all COVID-19 patients ([2,5]), in 17-42% of patients with COVID-19 pneumonia ([1,13,14,21]), and in about 67% of patients requiring ICU care. ([12]) Our rate of ARDS is higher than previously reported in children admitted to the hospital but is in line with that reported in critically ill adults at 67%. ([12]) The need for mechanical ventilation was seen in 46% of our PICU patients and 60% of patients with ARDS. These patients required high levels of ventilatory support due to worsening in oxygenation in the first few days of hospitalization. Our overall intubation rate (6 of

44, 13%) is higher than that reported by others: 1.7% to 10% in children ([3,7]); and 2.3% to 12.5% in adults. ([1,2,13,14,21]) Our PICU intubation rate of 46% (6 of 13 patients) is higher than reported PICU rates of 15-47% ([1, 13, 14, 15]) but lower compared with rates reported in adults. (23-25)

Our study has several limitations. We present observational data from a single, unique, urban, academic medical center with a limited sample size, predisposing to type II error. However, as COVID-19 is a new disease with a dearth of literature in the pediatric population, our study sheds light by providing additional data from hospitalized children. Larger multicenter experience and mechanistic data are needed to identify predictors of severe disease.

Uncited reference

23., 24.

Acknowledgments

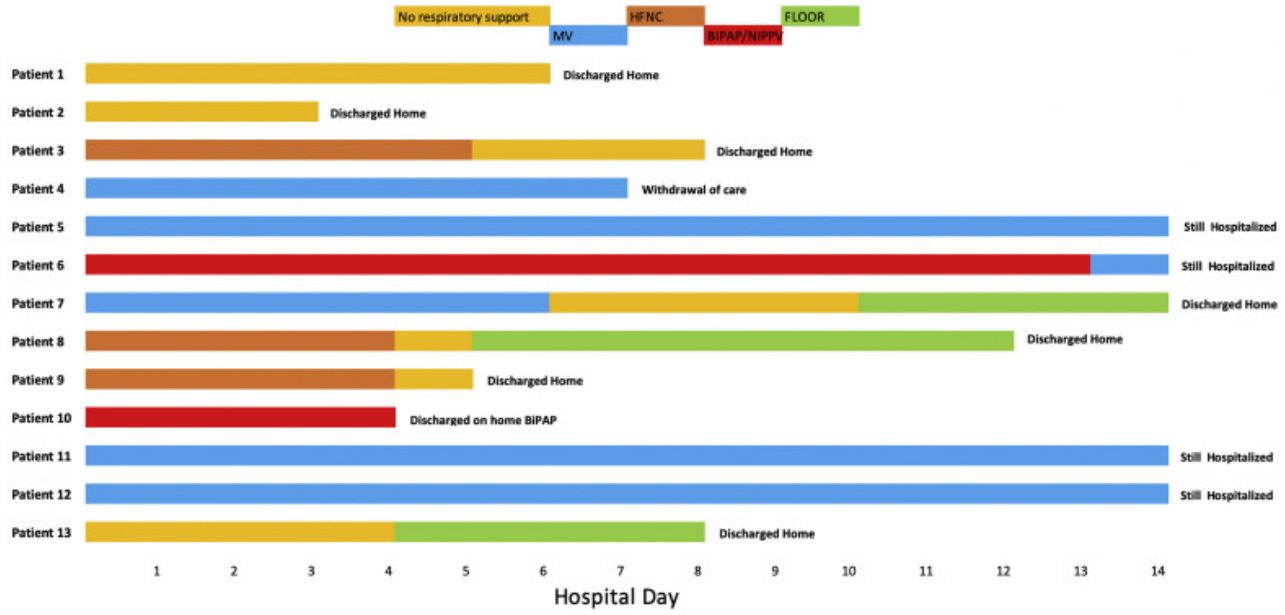
We thank Mark S. Teen, MD[1]; Isabel F. Pesola, MD[1]; Roshan S. Patel, MD[1]; Glenn E. Mann[1], MD; Agathe Streiff, MD[1]; Valerie Ivanova, DO[1]; Krupa Desai, MD, MSc[1]; Lewis Diamond, MB, BCh[1]; and Joanne Spaliaras, MD[1]

Footnotes

Supported by NIH/National Center for Advancing Translational Science (NCATS) Einstein-Montefiore CTSA (UL1TR001073) and the Departments of Anesthesiology and Pediatrics, Albert Einstein College of Medicine, Montefiore Medical Center, Children's Hospital at Montefiore. M.C. serve on the Editorial Board of *The Journal of Pediatrics* and is a member of the United States Preventive Services Task Force (USPSTF). This manuscript does not necessarily represent the views of the USPSTF. The other authors declare no conflicts of interest.

Supplementary data

Click here to view.(281 bytes, xml)



Open in a separate window

Figure (Online only). Outcomes for individual patients in the PICU. Respiratory support modalities as a function of time (in hospitalization days) presented by patient. Light orange color denotes no respiratory support. Blue color denotes mechanical ventilation (MV). Dark orange color denotes high flow nasal cannula (HFNC). Red color denotes bilevel positive airway pressure/non-invasive positive pressure ventilation (BiPAP/NIPPV). Green color denotes transfer to the pediatric floor.

References

1. Huang C., Wang Y., Li X. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China [published correction appears in Lancet. 2020 Jan 30] Lancet. 2020;395(10223):497–506. [PMC free article] [PubMed] [Google Scholar]

2. Guan W.J., Ni Z.Y., Hu Y. Clinical Characteristics of Coronavirus Disease 2019 in China [published online ahead of print, 2020 Feb 28] N Engl J Med. 2020 doi: 10.1056/NEJMoa2002032. [CrossRef] [Google Scholar]

3. Lu X, Zhang L, Du H, et al. SARS-CoV-2 Infection in Children [published online ahead of print, 2020 Mar 18]. N Engl J Med. 2020;10.1056

4. Liu W, Zhang Q, Chen J, et al. Detection of 2019-nCoV in Children in Early January 2020 in Wuhan, China [published online ahead of print, 2020 Mar 12]. N Engl J Med. 2020;10.1056

5. Dong Y., Mo X., Hu Y. Epidemiological characteristics of 2143 pediatric patients with 2019 coronavirus disease in China. Pediatrics. 2020 doi: 10.1542/peds.2020-0702. [CrossRef] [Google Scholar]

6. Qiu H., Wu J., Hong L., Luo Y., Song Q., Chen D. Clinical and epidemiological features of 36 children with coronavirus disease 2019 (COVID-19) in Zhejiang, China: an observational cohort study [published online ahead of print, 2020 Mar 25] Lancet Infect Dis. 2020;S1473-3099(20) doi: 10.1016/S1473-3099(20)30198-5. 30198-5. [CrossRef] [Google Scholar]

7. Tagarro A, Epalza C, Santos M, et al. Screening and Severity of Coronavirus Disease 2019 (COVID-19) in Children in Madrid, Spain [published online ahead of print, 2020 Apr 8]. JAMA Pediatr. 2020;10.1001/jamapediatrics.2020.1346. doi:10.1001/jamapediatrics.2020.1346

8. Ranieri V.M., Rubenfeld G.D., Thompson B.T., Ferguson N.D., Caldwell E., Fan E. Acute respiratory distress syndrome: the Berlin definition. JAMA. 2012;307:2526–2533. [PubMed] [Google Scholar]

9. Acute Respiratory Distress Syndrome Network. Brower R.G., Matthay M.A. Ventilation with lower tidal volumes as compared with traditional tidal volumes for acute lung injury and the acute respiratory distress syndrome. N Engl J Med. 2000;342(18):1301–1308. [PubMed] [Google Scholar]

10. Weiss S.L., Peters M.J., Alhazzani W. Surviving Sepsis Campaign International Guidelines for the Management of Septic Shock and Sepsis-Associated Organ Dysfunction in Children. Pediatr Crit Care Med. 2020;21(2) e52–e106. [Google Scholar]

11. Kellum J.A., Lameire N., KDIGO AKI Guideline Work Group Diagnosis, evaluation, and management of acute kidney injury: a KDIGO summary (Part 1) Crit Care. 2013;17(1):204. doi: 10.1186/cc11454. Published 2013 Feb 4. [PMC free article] [PubMed] [CrossRef] [Google Scholar]

12. Yang X., Yu Y., Xu J. Clinical course and outcomes of critically ill patients with SARS-CoV-2 pneumonia in Wuhan, China: a single-centered, retrospective, observational study [published online ahead of print, 2020 Feb 24] [published correction appears in Lancet Respir Med. 2020 Feb 28;:] Lancet Respir Med. 2020 S2213-2600(20)30079-5. [Google Scholar]

13. Wang D., Hu B., Hu C. Clinical Characteristics of 138 Hospitalized Patients With 2019 Novel Coronavirus-Infected Pneumonia in Wuhan, China [published online ahead of print, 2020 Feb 7] JAMA. 2020 [Google Scholar]

14. Chen N., Zhou M., Dong X. Epidemiological and clinical characteristics of 99 cases of 2019 novel coronavirus pneumonia in Wuhan, China: a descriptive study. Lancet. 2020;395(10223):507–513. [PMC free article] [PubMed] [Google Scholar]

15. Lee H., Harris K.M., Gordon-Larsen P. Life Course Perspectives on the Links between Poverty and Obesity during the Transition to Young Adulthood. Population Research and Policy Review. 2009;28:505–532. [PMC free article] [PubMed] [Google Scholar]

16. Keenan HT, Foster CM, Bratton SL. Social factors associated with prolonged hospitalization among diabetic children. Pediatrics. 2002109:40-44

17. Keet C.A., Matsui E.C., McCormack M.C., Peng R.D. Urban residence, neighborhood poverty, race/ethnicity, and asthma morbidity among children on Medicaid. J Allergy Clin Immunol. 2017;140:822–827. [PubMed] [Google Scholar]

18. Grunwell J.R., Travers C., Fitzpatrick A.M. Inflammatory and Comorbid Features of Children Admitted to a PICU for Status Asthmaticus. Pediatr Crit Care Med. 2018;19:e585–e594. [PMC free article] [PubMed] [Google Scholar]

19. Andrist E., Riley C.L., Brokamp C., Taylor S., Beck A.F. Neighborhood Poverty and Pediatric Intensive Care Use. Pediatrics. 2019;144 [Google Scholar]

20. Wu C., Chen X., Cai Y. Risk Factors Associated With Acute Respiratory Distress Syndrome and Death in Patients With Coronavirus Disease 2019 Pneumonia in Wuhan, China [published online ahead of print, 2020 Mar 13] JAMA Intern Med. 2020 doi: 10.1001/jamainternmed.2020.0994. [CrossRef] [Google Scholar]

21. https://www.census.gov/quickfacts/fact/table/bronxcountybronxboroughnewyork/IPE120218#IPE120218. Accessed on 4-20-2020

22. Grasselli G., Zangrillo A., Zanella A. Baseline Characteristics and Outcomes of 1591 Patients Infected With SARS-CoV-2 Admitted to ICUs of the Lombardy Region, Italy [published online ahead of print, 2020 Apr 6] JAMA. 2020 doi: 10.1001/jama.2020.5394. [CrossRef] [Google Scholar]

23. Arentz M., Yim E., Klaff L. Characteristics and Outcomes of 21 Critically Ill Patients With COVID-19 in Washington State [published online ahead of print, 2020 Mar 19] JAMA. 2020 doi: 10.1001/jama.2020.4326. [CrossRef] [Google Scholar]

24. Bhatraju PK, Ghassemieh BJ, Nichols M, et al. Covid-19 in Critically Ill Patients in the Seattle Region - Case Series [published online ahead of print, 2020 Mar 30]. N Engl J Med. 2020;NEJMoa2004500. doi:10.1056/NEJMoa2004500