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COVID-19–related hospitalizations among Aotearoa, New Zealand children during the Omicron era of SARS-CoV-2

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ABSTRACT

Objectives: This multicenter cohort study describes Aotearoa New Zealand children hospitalized during the country's first wave of sustained SARS-CoV-2 transmission, Omicron variant.
Methods: Children younger than 16 years, hospitalized for >6 hours with COVID-19 across New Zealand from January to May 2022 were included. Admissions for all Māori and Pacific and every second non-Maori non-Pacific children were selected to support equal explanatory power for ethnic grouping. Attribution of hospital admission, demography, clinical presentation, comorbidity, treatment, and outcome data were collected.
Results: Of 444 hospitalizations of children positive for COVID-19, 292 (65.5%) from 290 children were considered admissions attributable to COVID-19. Of these admissions, 126 (43.4%) were aged under 1; 118 (40.7%), 99 (34.1%), and 87 (30.0%) were children of Māori, Pacific, and non-Maori non-Pacific ethnicity, respectively. Underlying respiratory disease was the most common comorbidity, present in 22 children (7.6%); 16 children

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(5.5%) were immunosuppressed. Median length of stay was 1 day (interquartile range 0.0-2.0). Four children received antiviral, 69 (24%) antibacterial, and 24 (8%) supplemental oxygen. Although eight children required intensive care, there were no deaths.
Conclusions: Children hospitalized during the first significant wave of SARS-CoV-2 infection in New Zealand presented with a multi-system viral illness and rarely with severe disease.

Introduction

In early 2020, international reports of SARS-CoV-2 infection collectively indicated that severe acute coronavirus disease 2019 (COVID-19) in children was rare [1]. In the first 2 years of the COVID-19 pandemic, United Kingdom (UK) estimates of hospitalization rates were 0.9% for children younger than 18 years with COVID-19 with an infection fatality rate of five deaths per 100,000 infections (0.005%) [2,3]. However, clinical features of SARS-CoV-2 infection have changed considerably since the ancestral virus emerged with the evolution of SARS-CoV-2 variants and both natural and vaccine-acquired immunity.

In November 2021, the Omicron variant (B.1.1.529) was first detected in South Africa [4]. By January 2022, Omicron became the dominant circulating SARS-CoV-2 variant globally [5–7]. This variant demonstrated greater transmissibility and led to a significant rise in the absolute number of pediatric admissions described internationally, most notably in the 0-4-year-old age group [4,5]. This reported increase in hospitalizations was concurrent with surges in total SARS-CoV-2 infections and increased rapid antigen test availability, and it was hypothesized that hospitalization rates often included children who were incidentally SARS-CoV-2 positive [5]. Subsequent UK reports found that pediatric hospitalization rates attributable to Omicron SARS-CoV-2 infection had not increased compared to earlier variants [5]. Early United States reports on Omicron severity also described that children had lower rates of intensive care unit (ICU) admission, mechanical ventilation, and shorter lengths of stay with Omicron when compared with the Delta variant [6].

As a result of the national public health elimination strategy, including border closures, New Zealand (NZ) children were largely insulated from SARS-CoV-2 infection from 2020 to early 2022 [8]. This strategy also supported neighboring Polynesian nations in the elimination of SARS-CoV-2 [9]. By January 2022, when sustained community transmission with the Omicron variant began in NZ, fewer than 1% of NZ children younger than 15 years had prior SARS-CoV-2 infection, and only 17% of children had received their first dose of Pfizer/BioNTech BNT162b2 vaccine which was available only for those aged 5 years and older in NZ [10]. Although international reports suggested that most children infected with the Omicron variant would have a mild illness, the majority of data came from countries with at least three significant prior waves of SARS-CoV-2 infection, and it was unclear how this variant of concern would manifest in NZ children [4,6].

This study aimed to describe the clinical spectrum of COVID-19 in NZ children, a largely SARS-CoV-2 naive population, hospitalized during NZ's first wave of sustained community transmission with the Omicron variant [10].

Methods

We conducted a multicenter, retrospective cohort study of children younger than 16 years hospitalized with COVID-19 from January 01 to May 01, 2022. This pediatric cohort contributes to the broader COVID-19 severity prediction score validation study, COVID-19 HospitalisEd Patient SeverIty Observational NZ (COHESION), that recruited 2,375 adults, 16 years and older, admitted with COVID-19 across 11 NZ hospitals during the same time period [11]. Eligible children were admitted to one of four study hospitals across New Zealand, Kidz First (South Auckland), Starship (Central Auckland), Waikato, and Christchurch, for 6 or more hours and with a COVID-19 diagnosis within the 14 days prior or 2 days after hospitalization. Cases were identified through a review of administrative databases at each hospital site as well as the National Minimum Dataset.

This Te Tiriti o Waitangi (the founding document establishing the relationship between Māori and the British crown)-centered study was supported by an expert reference group that included expertise in Māori and Pacific health and epidemiology. A sampling strategy was used for data collection to achieve sufficient sample size and equal explanatory power for adult risk prediction score validation in patients of Māori and Pacific ethnicity. Data were collected from all children of Māori and Pacific ethnicity and from every second non-Māori non-Pacific child, ordered by admission date and time. Ethnicity was obtained from hospital records and was reported as total response ethnicity, meaning all identified ethnic groups were recorded (each child could have more than one ethnic group) [12]. Socioeconomic deprivation was measured using the New Zealand Index of Deprivation (NZ Dep) for 2018 [13].

A manual chart review of electronic and paper records was undertaken by study staff who completed a training module and scenario exercises to standardize attribution of admission to COVID-19 for both children and adults (defined below). Data collected included patient demographics, presenting symptoms and signs, comorbidities, usual medications, and specific COVID-19 treatments. Obesity and bacterial pneumonia were defined by the clinician and recorded if described in patient records by the medical team. COVID-19 complications and outcomes were recorded, including inpatient or 28-day mortality and readmission to hospital within 28 days of discharge. Admissions were defined as:

- Attributable to COVID-19–related illness or treatment of COVID-19: Patients admitted due to symptoms caused primarily by COVID-19 viral infection. This included respiratory insufficiency, hemodynamic changes, and other common viral symptoms, as well as patients admitted due to an exacerbation of any underlying condition where the treating clinician or reviewing physician considered COVID-19 contributory.
- Admission unrelated to COVID-19: Admission history unlikely related to COVID-19, and clinicians did not specifically admit the patient for COVID-19 related care. The admission could be due to, but not limited to (a) trauma, (b) procedure or operation requiring hospitalization, and (c) alternative causes such as non-respiratory severe infection.
- Admission unrelated to COVID-19, but COVID-19 subsequently contributed to hospital stay: Admission was for an unrelated cause but subsequently met criteria of "Attributable to COVID-19 related illness or treatment of COVID-19."

Consensus review by pediatric specialists (EB, TW, and RW) was performed when study staff were unable to determine if admission was attributable to COVID-19.

Study data were entered into a standardized case report form on a secure REDCap electronic data capture tool hosted by The University of Otago. Ethics approval was granted by the NZ Health and Disability Ethics Committee (20NTB72). Descriptive statistics of key variables are listed in tables. Ethnicity was reported by total response, meaning that multiple ethnicity responses were recorded, and ethnic groups were not mutually exclusive [12].

Results

Of 444 eligible admissions, 292 (65.8%) admissions from 290 children were attributed to COVID-19 (Table 1), whereas 152 (34.2%) ad-

Table 1
Demographic characteristics and attribution of health episodes to COVID-19 among children (age <16 years) admitted to hospital, Aotearoa, New Zealand, 2022.

Characteristic (%)	Admission attributable to COVID-19 (n = 292)	Admission not attributable to COVID-19 (n = 152)
Age at admission (years), median (interquartile range)	1.0 (0.0-5.0)	4.0 (1.0-11.0)
0 to <3 months	60 (20.5%)	13 (8.6%)
3 to <6 months	31 (10.6%)	9 (5.9%)
6 to <9 months	22 (7.5%)	8 (5.3%)
9 to <12 months	13 (4.5%)	4 (2.6%)
1 to <5 years	83 (28.4%)	40 (26.3%)
5 to <10 years	46 (15.8%)	25 (16.4%)
10 to <16 years	37 (12.7%)	51 (33.6%)
Female	128 (43.8%)	80 (52.6%)
Total response ethnicity		
European	115 (39.4%)	60 (39.5%)
Māori	119 (40.8%)	58 (38.2%)
Pacific	101 (34.6%)	56 (36.8%)
Asian	24 (8.2%)	11 (7.2%)
Other[a]	12 (4.1%)	1 (0.7%)
New Zeeland deprivation index quintile		
1 (least deprived)	29 (9.9%)	N/A
2	26 (8.9%)	N/A
3	45 (15.4%)	N/A
4	50 (17.1%)	N/A
5 (most deprived)	141 (48.3%)	N/A

[a] Other includes Middle Eastern/ Latin American/African

Table 2
Symptoms at presentation of children younger than 16 years with admissions attributable to COVID-19, by total response ethnicity, Aotearoa, New Zealand, 2022, n = 290.

Symptoms (%)	Māori (n = 118)	Pacific (n = 99)	All (n = 290)
Fever	85 (72.0%)	64 (64.6%)	191 (65.9%)
Cough	48 (40.7%)	59 (59.6%)	131 (45.2%)
Coryza	42 (35.6%)	46 (46.5%)	110 (37.9%)
Vomiting/ nausea	43 (36.4%)	28 (28.3%)	100 (34.5%)
Shortness of breath	31 (26.3%)	39 (39.4%)	86 (29.7%)
Fatigue/ malaise	31 (26.3%)	14 (14.1%)	66 (22.8%)
Diarrhea	20 (16.9%)	11 (11.1%)	42 (14.5%)
Sore throat	15 (12.7%)	13 (13.1%)	41 (14.1%)
Altered consciousness/ confusion	12 (10.2%)	11 (11.1%)	29 (10.0%)
Skin rash	14 (11.9%)	3 (3.0%)	26 (9.0%)
Seizures	10 (8.5%)	11 (11.1%)	24 (8.3%)
Headache	14 (11.9%)	6 (6.1%)	24 (8.3%)
Abdominal pain	6 (5.1%)	6 (6.1%)	23 (7.9%)
Irritability/ meningism	2 (1.7%)	3 (3.0%)	9 (3.1%)
Apnea	2 (1.7%)	1 (1.0%)	8 (2.8%)
Chest pain	4 (3.4%)	2 (2.0%)	8 (2.8%)

Māori and Pacific ethnicity are not mutually exclusive because of the use of total response ethnicity.

Table 3
Complications among children younger than 16 years during admissions attributable to COVID-19, Aotearoa, New Zealand, 2022, n = 290.

Complication (%)	All (n = 290)
Seizure	27 (9.3%)
Croup	21 (7.2%)
Bronchiolitis	7 (2.4%)
Acute renal injury	6 (2.1%)
Liver dysfunction	4 (1.4%)
Bacterial Pneumonia	4 (1.4%)
Bacteremia	3 (1.0%)
Pancreatitis	3 (1.0%)
Cardiac arrhythmia	2 (0.7%)
Myocarditis/Pericarditis	0 (0.0%)
Arterial or venous thromboembolism	0 (0.0%)

missions, COVID-19 was assessed as incidental. There were no instances where a pediatric admission was not attributable to COVID-19, but subsequent infection, symptoms, or other COVID-19–related management were considered by clinicians to contribute toward length of hospital stay.

Of 290 children admitted due to COVID-19, 126 (43.4%) were younger than 1 year and 59 (20.3%) were younger than 3 months. A total of 118 (40.7%) were Māori, 99 (34.1%) Pacific ethnicity, and 87 (30.0%) non-Māori non-Pacific. Almost half of the children with admissions attributed to COVID-19 (140, 48.3%) lived in the most socioeconomically deprived regions of NZ, NZ Dep quintile 5.

At admission, 44 children (15.2% of the total cohort) had received one or more doses of the SARS-CoV-2 vaccine, 22 children (7.6%) had one dose, 21 children (7.2%) had two doses, and one child (0.3%) had three doses. Among the 16 children who were immunosuppressed, only eight (50.0%) had received one or more doses of SARS-CoV-2 vaccine prior to admission.

The most common symptoms at presentation in children with admission attributable to COVID-19 were fever in 191 (65.9%), cough in 131 (45.2%), coryza in 110 (37.9%), vomiting/nausea in 100 (34.5%), and shortness of breath in 26 (29.7%) (Table 2). The most common complication reported during admission was seizures 27 (9.3%) (Table 3). Of all seizures, 15 (55.6%) were febrile convulsions, six (22.2%) were afebrile, and six (22.2%) were not specified. Respiratory syndromes were the second most common complication, including croup in 21 children (7.2%) and bronchiolitis in seven (2.4%). Three (1.0%) patients were bacteremic during admission, and bacterial pneumonia was reported in four children (1.4%). The median C-reactive protein was 3.0 mg/l (interquartile range [IQR] 1.0-7.9), median neutrophil count 3.4×10^9/l (IQR 2.0-6.5), and median lymphocyte count 2.0×10^9/l (IQR 1.1-3.4).

Influenza and respiratory syncytial virus polymerase chain reaction testing was performed on specimens from 58 children (20.0%). All of the 56 available results were negative for both influenza and respiratory syncytial virus. Extended respiratory virus polymerase chain reaction panels were performed in 49 children. Eight children had additional viruses detected; seven were rhinovirus/enterovirus positive, and one was human metapneumovirus positive.

Comorbidities and risk factors

Underlying respiratory disease was the most common comorbidity present in 22 children (7.6%) and asthma in 12 (4.1%) (Table 4). A history of premature birth (<37 weeks' gestation) was the second most common comorbidity in 21 children (7.2%), followed by pre-existing

Table 4
Comorbidities and risk factors present at admission among children younger than 16 years with admissions attributable to COVID-19, Aotearoa, New Zealand, 2022, n = 290.

Comorbidities (%)	All (n = 290)
Chronic pulmonary disease[a]	22 (7.6%)
Pre-term birth(≤37-week gestational age)	21 (7.2%)
Chronic neurological disorder	19 (6.6%)
Chronic cardiac disease	14 (4.8%)
Asthma	12 (4.1%)
Diabetes	9 (3.1%)
Obesity	6 (2.3%)
Chronic kidney disease	5 (1.7%)
Immunosuppressive medications within last 3 months	14 (4.8%)
Active malignancy	6 (2.1%)
Solid organ transplant	3 (1.0%)
Leukemia	2 (0.7%)
Hematologic stem cell transplant	0 (0.0%)
Other immunosuppressive disease	2 (0.7%)

[a] Chronic pulmonary disease included asthma n = 12, not otherwise specified = 4, and chronic lung disease of prematurity n = 3.

Table 5
Treatment given during admission of children with admissions attributable to COVID-19, Aotearoa, New Zealand, 2022, n = 290.

Treatment (%)	All (n = 290)
Antibacterial medication	69 (23.8%)
Intravenous fluids	49 (16.9%)
Oral or intravenous corticosteroid	37 (12.8%)
Supplementary oxygen	24 (8.3%)
Antiviral medication (remdesivir)	4 (1.4%)
Anticoagulation	3 (1.0%)
Inotrope or vasopressor therapy	2 (0.7%)
Convalescent plasma	1 (0.3%)
Non-invasive ventilation	1 (0.3%)
Invasive ventilation	1 (0.3%)

No baricitinib nor tocilizumab were used in study period.

chronic neurologic disorders in 19 (6.6%). Sixteen (5.5%) children had immunosuppressive conditions or had received immunosuppressant medications within the last 3 months (Table 4). Diabetes was present in nine (3.1%) children, and obesity was recorded in six (2.3%) children.

Treatment and resource use

Treatment was largely supportive; 49 children (16.9%) required intravenous fluids and 24 (8.3%) supplemental oxygen (Table 5). Thirty-seven children (12.8%) received intravenous or oral corticosteroids, and one child (0.3%) received convalescent plasma. Four children (1.4%) received antivirals (all remdesivir), and 69 (23.8%) were given antibacterials during their admission.

Severity and outcome

The median duration of hospital stay was 1 day (IQR 0.0-2.0). A total of eight (2.8%) children required ICU admission, and only one (0.3%) required invasive mechanical ventilation. There were no deaths in hospital or within the following 28 days. Thirty (10.3%) children were readmitted within 28 days.

Discussion

This study describes the clinical presentation and severity of COVID-19 in NZ children hospitalized during the first wave of sustained community transmission with the Omicron SARS-CoV-2 variant. In this cohort of largely SARS-CoV-2 naive children, the Omicron variant presented as a mild multi-system viral illness. There were no deaths in this cohort. Typically, children had very short stay admissions, and severe disease resulting in ICU admission was uncommon.

Two-thirds of children in this study cohort had hospitalizations attributable to COVID-19, a proportion consistent across all four study sites. The proportion of children with a positive SARS-CoV-2 test whose hospitalization is attributed to SARS-CoV-2 infection has been variably reported in the literature (55-75.3%) [14,15] and has been dependent on the SARS-CoV-2 variant and definition of attribution to COVID-19 [4,16].

The short duration of stay observed (median 1 day) may be partially explained by the young age of the cohort (median 1 year with 20.0% of the total cohort younger than 3 months), resulting in a lower threshold for initial admission [17]. Contributing factors may also include a lack of clinician familiarity with SARS-CoV-2 infection management and natural history, in particular in young children where clinical presentations included fevers, vomiting, seizures, croup, or bronchiolitis, conditions that often require observation and brief supportive treatment.

It is notable that children living in areas of socioeconomic deprivation are overrepresented in this cohort, with almost half (48.3%) of children living in quintile 5, the highest area of deprivation. Because of the over-sampling of Māori and Pacific children, who are more likely to experience socioeconomic deprivation, we recommend cautious interpretation of this finding. However, it is consistent with existing literature indicating an association of socioeconomic deprivation with COVID-19 hospitalizations and disease severity [3,5].

It is important to review health care resource utilization during waves of SARS-CoV-2 infection to consider the resource implications in potential further SARS-CoV-2 waves. In this cohort, low numbers of children required COVID-19-specific treatments (four were given remdesivir, and one received convalescent plasma). However, supportive treatment was common, with one in five children receiving intravenous fluids and one in four children given antibacterials. Although this study did not collect information on the specific indications for antibiotic use nor record all bacterial complications, low rates of clinician-defined bacterial pneumonia (1.4%), bacteremia (1.0%), and a median C-reactive protein of 3.0 mg/l suggest that antibiotics were overused. This may be partially explained by the young age of the study population and the high frequency of presentation with fevers and seizures. This high rate of antibiotic prescribing highlights a future target for antimicrobial stewardship interventions.

Our study provides insight into the relationship between COVID-19 disease severity and comorbidities. The most common comorbidity in children with admissions attributable to COVID-19 was underlying respiratory disease (22 children [7.6%] with asthma present in over half of these [12 children]). Previous pediatric studies have illustrated that chronic pulmonary disease, including asthma, is one of the strongest risk factors for moderate-severe COVID-19 disease in children and young people infected with the Omicron variant [17,18]. In our study, 16 children (5.5%) had some form of underlying immunosuppression, including 14 children (4.9%) who had received immunosuppressive medications within the prior 3 months, two children with leukemia, and three solid organ transplant recipients. Early in the pandemic, children with immunosuppressive conditions or medications were presumed to be at risk of severe COVID-19 [19]. However, the majority of cohort studies that have emerged suggest that immunocompromised children also have predominantly a mild illness, although they may shed SARS-CoV-2 for a prolonged period of time [19]. Diabetes was present in nine children (3.1%) in this cohort, and clinician-defined obesity was recorded in six (2.3%); both have been described in cohort studies as being associated with an increased risk of severe disease in children during the Omicron period [18,20,21]. Although obesity was not frequently described as a comorbidity in our cohort, this may be due to the recording of clinician-defined obesity rather than independently attributed based on measured age-specific growth centiles [22].

The median length of hospital stay in this cohort was 1 day, there were no deaths during or within 28 days of admission, and only eight

children (2.8%) required ICU admission. Although short hospitalizations and low pediatric mortality are consistent with international reports of non-severe COVID with the Omicron variant, we additionally report this in a predominantly SARS-CoV-2 naive pediatric population [3–5,17]. Although readmissions were reported in one in 10 admissions, it is noteworthy that admission with respiratory illness has been previously identified as a risk for readmission in NZ children [23].

The post-COVID-19 inflammatory syndrome known as multi-system inflammatory syndrome in childhood (MIS-C) was not captured in this data as this typically occurs 3-6 weeks following acute SARS-CoV-2 infection [24]. MIS-C is an important consideration in assessing pediatric COVID-19 disease severity. We have previously reviewed MIS-C incidence in NZ children during the first wave of Omicron transmission over a similar time period and demonstrated a very low incidence of MIS-C in NZ children (0.04/1,000 SARS-CoV-2 infections) consistent with international reports of lower MIS-C rates following infection with the Omicron variant [10,25–29].

The Omicron variant is now well recognized to have a lower risk of severe disease and MIS-C than ancestral SARS-CoV-2 infection and previous variants [5,10,16,18,21,25,28]. A UK analysis that included people of all ages estimated that the risk of hospitalization or death with acute SARs-CoV-2 infection, Omicron variant, was one-third of that reported with Delta when adjusted for age, sex, vaccine status, and prior infection [7]. A pediatric-specific national study from Qatar found a nearly eight-fold reduction in rates of moderate or severe disease in children infected with the Omicron variant compared with Delta [17]. It has been hypothesized that a significant contribution to the observed reduction in disease severity and incidence of MIS-C following Omicron infection may be conferred protection from prior SARS-CoV-2 infection or vaccination [21,25,28]. This is unlikely to be the case in NZ children with low rates of prior infection or vaccination. Therefore, this study supports that the Omicron variant is intrinsically less severe than ancestral SARS-CoV-2 infection and previous variants of concern [10,28,30].

A key strength of this study was the mandatory training of clinical research assistants in standardized attribution of admission due to COVID-19 and manual chart review, which allowed comprehensive and accurate descriptions of comorbidities and treatments. The study has been designed to support equitable health outcomes in Māori and Pacific children, populations known to have a high burden of infectious diseases. Although this study did not collect information on the infecting SARS-CoV-2 variant type, it was performed during a period where Omicron was well documented as the overwhelmingly dominant circulating variant in NZ in national virology surveillance and wastewater testing reports [8,31]. This study included only patients who were hospitalized for ≥6 hours and is therefore not representative of the full spectrum of COVID-19 illness, nor of emergency department and primary care resource use where mild disease is frequently managed. Furthermore, this study recruited only pediatric patients at four NZ pediatric centers, which may not be representative of smaller or more rural NZ department's experience. Because of the sampling strategy, descriptions of comorbidities, clinical presentation, treatments, and outcomes reflect the study population and not the total population of children admitted to study hospitals with COVID-19 during this period.

Conclusion

Children living in NZ were largely SARS-CoV-2 immune naive prior to widespread Omicron community transmission that occurred from January 2022. This cohort study illustrates that the Omicron variant of SARS-CoV-2 presented in hospitalized NZ children as a multi-system viral illness with short admission lengths and low prevalence of severe disease. Our data supports the hypothesis that Omicron disease in children is less severe than COVID-19 due to earlier SARS-CoV-2 variants.

Declaration of competing interest

The authors have no competing interests to declare.

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Ethical approval

Ethics approval was granted from the NZ Health and Disability Ethics Committee (20NTB72).

Authors' contributions

The authors confirm contribution to the paper as follows: study conception and design: MM, KW; analysis and interpretation of results AT, JW, EB, MM, KW, draft manuscript preparation AT, EB, JW, TW, RW, KW, MM. All authors participarted in investigation, data collection and supervision at their sites except AT. All authors reviewed results, provided edits and approved the final version of the manuscript.

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