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RESEARCH

SARS-CoV-2 infection in technology-dependent children: a multicenter case series

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Abstract

Purpose The objective of this study was to describe the clinical course and outcomes in children with technology dependence (TD) hospitalized with SARS-CoV-2 infection.

Methods Seventeen pediatric hospitals (15 Canadian and one each in Iran and Costa Rica) included children up to 17 years of age admitted February 1, 2020, through May 31, 2021, with detection of SARS-CoV-2. For those with TD, data were collected on demographics, clinical course and outcome.

Results Of 691 children entered in the database, 42 (6%) had TD of which 22 had feeding tube dependence only, 9 were on supplemental oxygen only, 3 had feeding tube dependence and were on supplemental oxygen, 2 had a tracheostomy but were not ventilated, 4 were on non-invasive ventilation, and 2 were on mechanical ventilation prior to admission. Three of 42 had incidental SARS-CoV-2 infection. Two with end-stage underlying conditions were transitioned to comfort care and died. Sixteen (43%) of the remaining 37 cases required increased respiratory support from baseline due to COVID-19 while 21 (57%) did not. All survivors were discharged home.

Conclusion Children with TD appear to have an increased risk of COVID-19 hospitalization. However, in the absence of end-stage chronic conditions, all survived to discharge.

Keywords SARS-CoV-2 · COVID-19 · Technology dependence · Pediatric

Abbreviations

TD	Technology dependent
COVID-19	Coronavirus disease of 2019
ICU	Intensive care unit
NIV	Non-invasive ventilation
MV	Mechanical ventilation
MIS-C	Multisystem inflammatory syndrome in children
WHO	World Health Organization

What is known?

Children with technology dependence have an increased risk of hospitalization with non-SARS-CoV-2 respiratory viral infections.
They appear to also be at increased risk of hospitalization and of severe disease when infected with SARS-CoV-2.

What is new?

Children with technology dependence accounted for 6% of COVID-19 admissions, verifying increased risk.

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About half required increased respiratory support but the only deaths were in children with end-stage chronic conditions.

Introduction

The severity of SARS-CoV-2 infection is increased in children with comorbidities [1]. The range of severity with specific comorbidities is just starting to be described. We report outcomes in hospitalized technology-dependent children, originally defined as those "who require a medical device to compensate for the loss of a vital bodily function and substantial and ongoing nursing care to avert death or further disability" [2].

Methods

Seventeen pediatric hospitals (15 Canadian and one each in Iran and Costa Rica) included children up to 17 years of age admitted February 1, 2020, through May 31, 2021, with detection of SARS-CoV-2. Methods are fully described in our previous report [3]. Following ethics approval at all sites, data were extracted into REDCap (Research Electronic Data Capture) tools hosted at the University of Alberta [4] from medical records by physician investigators or research assistants supervised by investigators. Technology dependence (TD) was defined as baseline need for one or more of (a) tube feeds, (b) supplemental oxygen, (c) tracheostomy, (d) non-invasive ventilation (NIV) including continuous or bilevel positive airway pressure, (e) mechanical ventilation (MV), or (f) intravenous nutrition prior to admission. Data collected included demographics, reason for admission (admitted because they had COVID-19, admitted for another indication but COVID-19 acquired before or during the admission prolonged the admission, or "incidental" SARS-CoV-2 infection which did not precipitate or prolong the admission), comorbidities including type of TD, clinical course including interventions required for COVID-19, and outcome. The Strengthening the Reporting of Observational studies in Epidemiology (STROBE) guidelines were followed [5].

Data analysis was descriptive.

Results

There were 691 children entered in the database of which 334 were admitted because of COVID-19, 23 were admitted for another indication but COVID-19 prolonged the admission, and 334 had incidental SARS-CoV-2 infection.

Forty-two of the 691 children (6%) had TD (Table 1) of which 22 had feeding tube dependence only, 9 were on supplemental oxygen only, 3 had feeding tube dependence and were on supplemental oxygen, 2 had a tracheostomy but were not ventilated, 4 were on non-invasive ventilation, and 2 were on mechanical ventilation prior to admission. None required intravenous nutrition. Three of the 42 had incidental SARS-CoV-2 infection. None acquired SARS-CoV-2 infection during hospitalization. Two with end-stage underlying conditions died of respiratory failure on day 2 of admission after being transitioned to comfort care. For the remaining 37 cases, 16 (43%) required increased respiratory support from baseline due to COVID-19 while 21 (57%) did not. The increased support included supplemental oxygen only ($N=6$; 16%), new NIV ($N=8$; 22%) and new MV ($N=2$; 5%). All survivors were eventually discharged home.

Discussion

We describe 42 children with TD and SARS-CoV-2 infection admitted to 15 centers over 17 months of which 40 survived to discharge. About half required increased respiratory support from baseline.

Children with TD accounted for 33 of 334 children (10%) admitted because of COVID-19 during the study period. A study from Ontario reported that children with medical complexity (defined as "complex underlying chronic health conditions that are typically associated with significant functional status limitation", encompassing TD and many other conditions) accounted for only 0.67% of the population [6]. This suggests that children with TD were at markedly increased risk of hospitalization with COVID-19 during our study period. It seems likely that some of the brief admissions early in the current study were due to uncertainty about the natural history of infection in children with TD. Now that we know that even children with significant comorbidities often have mild infection, hospitalization rates may be lower. It is unlikely that any of the children in our study were immunized as most were preschool aged and vaccines were just becoming available for 12-to-15-year-olds when the study ended. Hospitalization rates for children with TD may have decreased further with immunization given that most children with TD are immunocompetent so should have a normal response to vaccines. Length of stay was often prolonged (Table 1) but it is possible that admission duration will decrease over time as we learn how to optimize COVID-19 therapeutics.

It is not surprising that TD appears to be a risk factor for COVID-19 hospitalization. It is well known that children with TD stemming from disorders of the respiratory tract were at increased risk of severe disease when infected with respiratory viruses prior to the SARS-CoV-2 pandemic [7].

Table 1 Clinical course of admissions related to COVID-19 and admissions with incidental SARS-COV2 infection in 42 children dependent upon medical technology—the admission days refers to the entire hospitalization and not just the ICU stay

	Admitted because of COVID-19 ($N=33$)	Admitted for another indication—SARS-CoV-2 prolonged admission ($N=6$)	Admitted for another indication—SARS-CoV-2 infection did not prolong the admission ($N=3$)[a]
Home feeding tube dependence ($N=22$)	$N=16$	$N=6$	$N=0$
	Ward: observation (N=6, admitted for 1,2, 3, 4, 10 and 28 days)	Ward: (N=5), of which 1 required supplemental oxygen	
	Ward: supplemental oxygen ($N=4$, admitted for 1, 2, 5 and 20 days)	ICU: NIV	
	ICU: supplemental oxygen and vasopressors (admitted for 3 days)		
	ICU: NIV ($N=3$ admitted for 15, 15 and 16 days)		
	ICU: MV (admitted for unknown duration)		
	Ward: NIV but died 2 days (no MV, palliative)		
Home supplemental oxygen ($N=9$)	$N=7$	$N=0$	$N=2$
	Ward: supplemental oxygen ($N=3$ admitted for 3, 7 and 9 days) and in ICU ($N=1$ – admitted for 5 days)		
	ICU: HFNC (admitted for 47 days)		
	ICU: NIV ($N=2$ admitted for 9 and 18 days)		
Home feeding tube dependence and supplemental oxygen ($N=3$)	$N=2$	$N=0$	$N=1$
	ICU: HFNC (admitted for 8 and 22 days)		
Home tracheostomy ± supplemental oxygen ± feeding tube dependence ($N=2$)	$N=2$	$N=0$	$N=0$
	ICU: NIV (both admitted 16 days)		
Home non-invasive ventilation ± supplemental oxygen ± feeding tube dependence ($N=4$)	$N=4$	$N=0$	$N=0$
	Ward: NIV (N=1 admitted for 2 days) and in ICU ($N=1$ admitted 1 day)		
	Ward: NIV but died 2 days after admission (no MV, palliative)		
	ICU: MV (admitted 12 days)		
Home mechanical ventilation ± supplemental oxygen ± tube feeds ($N=2$)	$N=2$	$N=0$	$N=0$
	ICU: MV ICU (admitted for 7 days)		
	Ward: MV (admitted for 15 days)		

HFNC high-frequency nasal canula; *ICU* intensive care unit; *MV* mechanical ventilation; *NIV* non-invasive ventilation including continuous or bilevel positive airway pressure

[a]Details of clinical course are not provided as SARS-CoV-2 did not precipitate or prolong the admission

The contribution of type of virus, age, and nature and severity of comorbidities remains to be established. Two years into the pandemic, there are still minimal published data on the severity of COVID-19 in children with TD. One of the initial case series of 48 children admitted to intensive care units with COVID-19 reported that 19 (40%) had medical complexity (defined as "children who had a long-term dependence on technological support [including tracheostomy] associated with developmental delay and/or genetic anomalies") [8]. In a study of 2293 children hospitalized because of COVID-19, the adjusted risk ratio of severe COVID-19 in children with feeding tube dependence was 2.0 (95% CI 1.5−2.5; $P < 0.0001$) [9]; risk with other types of TD was not reported in this study. In a study of 43,465 children seen in an emergency department with a primary or secondary diagnosis of COVID-19, the adjusted risk ratio was 1.96 (95% CI 1.63–2.37) for hospitalization and 1.25 (95% CI 1.07–1.47) for severe COVID-19, using the TD definition that we used but also including children awaiting organ transplant) [10].

One limitation of our study and of the previous studies of children with TD is that they are not population based. We do not know how many children with TD were infected with SARS-CoV-2 and not diagnosed or not hospitalized. Eventually, review of large administrative databases may allow quantification of the risk of hospitalization and of severe COVID-19 in children with TD. Our cohort was collected before the Delta and then Omicron variants predominated and before vaccines were offered to younger children. One site did not include all cases as the physician entering cases relocated.

In conclusion, the novel finding from the current study is that even in the era prior to the availability of COVID-19 vaccines for children, those with TD hospitalized with COVID-19 all survived to discharge unless they had end-stage chronic conditions. Caregivers and healthcare professionals should continue to recognize the increased vulnerability of the TD population and that all should receive COVID-19 vaccines. They should be reassured that most children with TD have a relatively uneventful course even if hospitalized with COVID-19.

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Author contributions JR conceptualized and designed the study, acquired data, wrote the first draft of the manuscript, approved the final manuscript as submitted and agreed to be accountable for all aspects of the work. MB conceptualized and designed the study, acquired data and reviewed and revised the manuscript, approved the final manuscript as submitted and agreed to be accountable for all aspects of the work. Drs Morris, Bitnun, Gill, ET, Laxer, Yeh, Yea, U-G, B-C, Y-C, I-E, S-F, HM, Papenburg, Lefebvre, Nateghian, Aski, Manafi, Dwilow, Bullard, Cooke, Dewan, Restivo, Lopez, Sadarangani, Roberts, Le Saux, Bowes, Purewal, Lautermilch, Wong, Piche, Top, Leifso, Foo, and Panetta provided input on the case report form, acquired or supervised the acquisition of data, reviewed and revised the manuscript, approved the final manuscript as submitted and agreed to be accountable for all aspects of the work. Dr Merckx contributed to analysis and interpretation of the data, reviewed and revised the manuscript, approved the final manuscript as submitted and agreed to be accountable for all aspects of the work.

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Declarations

Conflict of interest Financial interests: E. Ann Yeh reports grants from Biogen, Roche, Horizon Therapeutics and Alexion; honoraria from Prime and Novartis; and participation on advisory boards with Roche and Horizon Therapeutics. Jesse Papenburg reports grants from AbbVie, Sanofi Pasteur, Merck and MedImmune; consulting fees from Merck; and honoraria from AbbVie, AstraZeneca and Seegene. He is a member of the National Advisory Committee on Immunization. Marie-Astrid Lefebvre reports an honorarium from Takeda Canada. Tammie Dewan reports grants from the Sick Kids Hospital Foundation, the Canadian Institutes for Health Research (CIHR) and the Department of Pediatrics at the University of Calgary. Jared Bullard reports grants from CIHR, the Manitoba Medical Service Foundation and Research Manitoba. Manish Sadarangani reports grants from GlaxoSmithKline, Merck, Moderna, Pfizer, Sanofi Pasteur, Seqirus, Symvivo and VBI Vaccines, as well as participating on 2 data safety monitoring boards for COVID-19 vaccine trials. Rupeena Purewal reports honoraria and consulting fees from Verity Pharmaceuticals. Kirk Leifso reports a grant from the Hospital for Sick Children. Joanna Merckx reports a role as medical director of bioMerieux Canada. She is also an independent researcher, with a contract with Public Health Belgium, Sciensano for a study on the seroprevalence of SARS-CoV-2 in schools.

Ethics approval This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Health Research Ethics Board of the University of Alberta (March 2020/Pro00099426) and subsequently by the ethics committee at each participating site.

Consent to participate The need to obtain written consent from patients or parents was waived by the ethics committee at all participating sites.

References

1. Tsankov BK, Allaire JM, Irvine MA, Lopez AA, Sauve LJ, Vallance VA, Jacobson K. Severe COVID-19 infection and pediatric comorbidities: a systematic review and meta-analysis. Int J Infect Dis. 2021;103:246–56. https://doi.org/10.1016/j.ijid.2020.11.163.
2. Gulla KM, Sahoo T, Sachdev A. Technology-dependent children. Int J Pediatr Adolesc Med. 2020;7:64–9.
3. Merckx J, Cooke S, El Tal T, et al. Multicenter cohort study of multisystem inflammatory syndrome in children (MIS-C). Can Med Assoc J. 2022;194:E513–23.
4. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap)—a metadata-driven methodology and workflow process for providing translational research informatics support. J Biomed Inform. 2009;42:377–81.

5. Cuschieri S. The STROBE guidelines. Saudi J Anaesth. 2019;13:S31–4.
6. Cohen E, Berry JG, Camacho X, Anderson G, Wodchis W, Guttmann A. Patterns and costs of health care use of children with medical complexity. Pediatrics. 2012;130:e1463–70. https://doi.org/10.1542/peds.2012-0175.
7. Panitch HB. Viral respiratory infections in children with technology dependence and neuromuscular disorders. Pediatr Infect Dis J. 2004;23:S222–7. https://doi.org/10.1097/01.inf.0000144670.78558.c7.
8. Shekerdemian LS, Mahmood NR, Wolfe KK, et al. Characteristics and outcomes of children with coronavirus disease 2019 (COVID-19) infection admitted to US and Canadian pediatric intensive care units. JAMAPediatr. 2020;174:868–73. https://doi.org/10.1001/jamapediatrics.2020.1948.
9. Woodruff RC, Campbell AP, Taylor CA, et al. Risk factors for severe COVID-19 in children. Pediatrics. 2021;2021:e2021053418. https://doi.org/10.1542/peds.2021-053418.
10. Kompaniyets L, Agathis NT, Nelson JM, et al. Underlying medical conditions associated with severe COVID-19 illness among children. JAMA Netw Open. 2021;4:e2111182. https://doi.org/10.1001/jamanetworkopen.2021.11182.

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