Hospital bed replacement for acute care of children at home during the COVID-19 pandemic through a Hospital-in-the-Home programme

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ABSTRACT

Objectives During the COVID-19 pandemic, we expanded our Hospital-in-the-Home (HITH) programme to increase capacity and manage COVID-19-positive children. We aimed to assess impact on overall HITH activity and COVID-19-positive outcomes.

Design Prospective comparative cohort study.

Setting The largest paediatric HITH in Australasia, at The Royal Children's Hospital Melbourne.

Patients Children 0–18 years admitted to HITH during the pandemic.

Intervention We developed a COVID-19 responsive service, and a guideline for COVID-19-positive patients. We compared overall activity prior to and during the pandemic, and COVID-19-positive admissions with different variants.

Main outcomes We compared outcomes for all HITH patients before and during the pandemic, and for COVID-19-positive patients admitted first to hospital versus directly to HITH.

Results HITH managed 7319 patients from March 2020 to March 2022, a 21% increase to previously, with a 132% telehealth increase. 421 COVID-19-positive patients (3 days–18.9 years) were admitted to HITH, predominantly high risk (63%) or moderately unwell (33%). Rates of childhood infection in Victoria, with proportion admitted to HITH were: original/alpha variant—3/100 000/month, 0.7%; delta—92/100 000/month, 0.8%; omicron—593/100 000/month, 0.3%. Eligible parents of only 29 of 71 (41%) high-risk children were vaccinated. COVID-19-positive children admitted directly to HITH were less likely to receive COVID-19-specific treatment than those admitted to hospital first (14 of 113 (12%) vs 33 of 46 (72%), p<0.001), reflecting more severe respiratory, but not other features in inpatients. 15 of 159 (10%) were readmitted to hospital, but none deteriorated rapidly.

Conclusions COVID-19-positive children at high risk or with moderate symptoms can be managed safely via HITH at home, the ideal place for children during the pandemic.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ COVID-19 has infected thousands of children in Australia, many of whom have been admitted to hospital.
⇒ Children do better if it is possible to manage them at home
⇒ The infectious nature of SARS-CoV-2 has increased the imperative to try to keep children out of hospital.

WHAT THIS STUDY ADDS

⇒ Resource-sensitive use of Hospital-in-the-Home during the first 2 years of the pandemic resulted in 421 children with and 3298 children without COVID-19 receiving care at home. many avoiding hospitalisation altogether.
⇒ Across all SARS-CoV-2 variants to date (original, alpha, delta, omicron), children with high-risk conditions and/or symptoms of clinical concern were managed at home safely and effectively.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Since different strains of the virus have impacted differently on paediatric admission rates, this study reassures that care at home has been safe regardless of strain.
⇒ This has the potential to take the burden off inpatient care.
⇒ There are opportunities to change the guidelines quickly to respond to strain changes.

Prior to the COVID-19 pandemic, treatment of children in out-of-hospital settings as an alternative to hospitalisation was increasingly in demand.[1–4] The benefits of home include improved child quality of life, higher parent satisfaction and avoidance of hospital-acquired infections.[5 6] Management at home has increased for children with acute illnesses including meningitis and bronchiolitis.[7 8] This has extended to children transferring directly from emergency departments (EDs), avoiding admission altogether.[9]

As COVID-19 initially spread, hospitals quickly became overwhelmed (memorably in Italy and New York). By the WHO pandemic declaration on 11 March 2020, there was a strong impetus to manage children in the community. Our well-established Hospital-in-the-Home (HITH) programme provided an ideal solution. The Royal Children's

Box 1 Profile of The Royal Children's Hospital (RCH) Melbourne Hospital-in-the-Home (HITH) service

Capacity: 61 patient home visits per day; longer or more frequent visits (eg, twice daily) reduce total patient number capacity; converting some visits to telehealth appointments increases patient number capacity.
Geographical coverage: in-person visits to a 60 km radius of the hospital where the service is primarily located; beyond 60 km patient care is outsourced to local HITH/community nursing services, with care coordinated centrally; telehealth appointments provided throughout the state of Victoria.
Hours of operation: 07:00–21:30 7 days a week, on-call nursing and medical service overnight.
Staffing per day: 1 medical consultant, 2 medical fellows, 6 intake/coordinating nurses, 10 on-the-road nurses, 3 physiotherapists, 1 dietitian, 1 speech pathologist, 1 occupational therapist, 1 social worker, 2 admin staff, 2 patient service attendants.
Patient flow: patients referred 24/7 from hospital wards, emergency department and outpatients; referrals also accepted from other hospitals and Department of Health, but not directly from primary care.
Governance: the RCH HITH programme functions with the compliance/staffing expectations (eg, hand hygiene) of an inpatient ward. It is overseen by the Ambulatory Services director and business manager and reports to the RCH Chief Operating Officer.
Common conditions managed: acute infectious exacerbation of cystic fibrosis, appendicitis, asthma, bacteraemia/central venous catheter infection, bronchiectasis, bronchiolitis, cellulitis, constipation, COVID-19, cystic fibrosis, eating disorders, eczema exacerbation, enzyme deficiency, infantile spasms, infant feeding difficulty, insulin-dependent diabetes, lymphadenitis, meningitis, osteomyelitis/septic arthritis, periorbital/orbital cellulitis, pneumonia, urinary tract infection/pyelonephritis, tuberculosis, venous thromboses, wounds (traumatic and surgical).
Treatment/interventions administered: intravenous antimicrobials (antibacterial, antifungal, antiviral) and blood monitoring, intravenous and subcutaneous chemotherapy administration, other intravenous medications (eg, methylprednisolone), intravenous fluids and electrolyte monitoring pre/post-chemotherapy, subcutaneous administration and education (eg, clexane, granulocyte colony-stimulating factor), ambulatory blood pressure monitoring, automatic positive airways pressure initiation/titration, acute oxygen delivery, cardiac assessment, respiratory assessment, hydration assessment and weight, central venous catheter care and troubleshooting, chest drain management, diabetes education and support, enzyme replacement, febrile neutropenia (chemotherapy-related and autoimmune), gastric aspirates, immunisations, infant feeding assessment and management, nasogastric feeding support, overnight oximetry, oxycapnography, polysomnography (sleep study), parenteral nutrition support, tonsillectomy post-assessment and care, stoma care, wound care.

Hospital (RCH) Melbourne has the largest paediatric HITH in Australasia and is a Victorian state-wide service. The programme provides care that usually requires hospital admission including frequent monitoring (eg, vital signs, urine output), clinical assessments (eg, respiratory/hydration status) and/or interventions usually administered in hospital (eg, intravenous antibiotics) (box 1). Our existing processes were pertinent to COVID-19-positive patients, including referrals direct from EDs,[10] telehealth reviews[11] and home oximetry.[8]

We issued our pandemic response plan to expand HITH on 13 March 2020, and the following day, the first child in Victoria was diagnosed with COVID-19. Uniquely in Australia, during these 2 years, Victoria experienced four waves of COVID-19, with the first patient diagnosed with the delta variant on 4 June 2021, and the first with omicron on 8 December 2021. With the arrival of highly transmissible omicron and subvariants, urgent lessons can be learnt from our experience. With our pandemic plan in place, we aimed to: (1) assess the impact of the pandemic on overall HITH activity for patients both with and without COVID-19; (2) determine rates of COVID-19 admissions to HITH and hospital within state-wide outbreaks; and (3) evaluate outcomes of COVID-19-positive children managed at home under HITH, comparing those admitted directly and to hospital first.

METHODS

Study design

A prospective study of the pandemic response of a programme delivering acute home management.

Setting

The RCH Melbourne HITH programme manages over 60 children/day. Patients are appropriate for HITH if they require hospital-level interventions, but are stable without the intensity of investigations/treatment/monitoring necessitating hospital.

Participants

All children admitted to HITH from 14 March 2020 to 13 March 2022 were included. Comparison was made with HITH admissions over the preceding 2 years (14 March 2018–13 March 2020). COVID-19-positive children were eligible for HITH if they had moderate COVID-19 symptoms/signs (figure 1) or mild symptoms with high-risk comorbidities (risk of worse outcomes; table 3) or infancy, but were not severely unwell enough to require hospitalisation. Although our HITH service administers oxygen and intravenous fluids, and supports nasogastric feeding, the decision was that there was insufficient experience with COVID-19 to provide these at home at this stage in the pandemic.

Data collection

Information was obtained from the electronic medical record (EMR) and hospital systems, and recorded in REDCap.[12] State-wide infection/immunisation data were accessed through publicly available information from the Department of Health.[13] SARS-CoV-2 variants were analysed from date first identified in Victoria, because uniquely in Australia, border closures meant no overlap of original, alpha and delta waves.

Statistical analysis

For categorical data, X^2 test was used and for continuous data t-test, with $p<0.05$ considered significant.

Development of the COVID-19 pandemic response plan

The pandemic response plan was developed in conjunction with HITH Society Australasia guidelines, consistent with Department of Health directions.[14] It involved de-escalating care[15] and providing additional home care[16] to keep patients without COVID-19 out of hospital, developing a model for

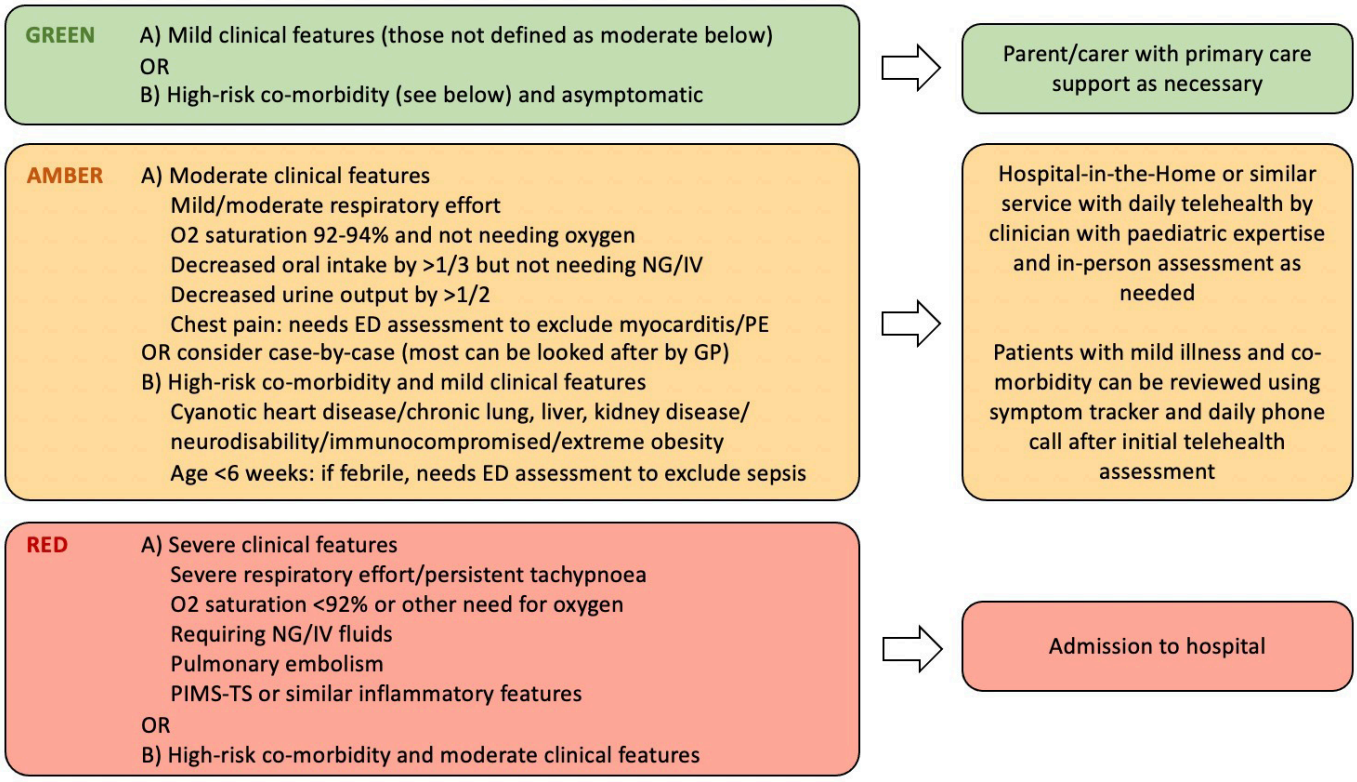

Figure 1 COVID-19 guideline for paediatric HITH eligibility developed early in the pandemic and updated with the delta variant (for progression of guideline, see online supplemental file 1). ED, emergency department; GP, general practitioner; HITH, Hospital-in-the-Home; IV, intravenous; NG, nasogastric; PE, pulmonary embolism; PIMS-TS, paediatric multisystem inflammatory syndrome – temporally associated with SARS-CoV-2.

COVID-19-positive patients, managing staff, exposure risk and logistics (box 2).

Clinical role of HITH for COVID-19

HITH eligibility: the role of HITH for children with COVID-19 was untested when we prepared our initial clinical 'traffic light' guideline (figure 1). This evolved during the pandemic to include only those with more severe symptoms (eg, respiratory, dehydration) or at highest risk (comorbidities) of more severe disease (online supplemental file 1).[17]

HITH model: patients were assessed in person or via telehealth by a doctor and/or nurse one to three times daily supported by relevant in-home monitoring (oximeter, scales, thermometer). A symptom tracker through the EMR patient portal was completed by parents twice daily including oxygen saturation to allow review and monitoring for deterioration. If deterioration occurred, patients were assessed in person at home or in ED.

RESULTS

All HITH patients

Over the 24 months of the pandemic, 7319 patients were admitted to HITH for 35 126 visits. This compares with 6051 patients (21% increase) and 32 174 visits (9% increase) in the previous 2 years. HITH activity increased with the COVID-19 wave (July–September 2020) and the delta wave (September–November 2021), with no further increase with omicron (figure 2). There was overall increase with time from 2019 to 2022. Patient complexity expanded with increased oncology episodes from 20% pre-COVID-19 to 24% during COVID-19 (OR 1.3 95% CI 1.2 to 1.4, p<0.001) (table 1). Acuity also escalated with direct admissions from ED increasing from 6% to 9% (OR 1.5, 95% CI 1.4 to 1.8, p<0.001). Despite this, there was shorter length of stay (LOS): mean LOS decreased from 4.3 to 3.7 days (p<0.001) (median 1.5 days), and HITH episodes lasting >1 week reduced from 15% to 13% (OR 0.85, 95% CI 0.8 to 0.9, p=0.001). Reassuringly, rates of readmission to hospital remained similarly low.

There was 132% increase in telehealth assessment visits from 1800 pre-pandemic to 4182 during COVID-19, 6% and 12% of all visits, respectively (OR 2.3, 95% CI 2.2 to 2.4, p<0.001). All clinicians increased telehealth, with the greatest growth for medical reviews (41 (15%) to 725 (86%)), although physiotherapists did the most telehealth sessions at 1608 during the pandemic. Telehealth assessments increased from 8% of visits during the original wave, to 14% with delta, to 21% with omicron (online supplemental file 1). This reflected increasing COVID-19-positive patients and concurrent staff shortages, meaning efficiencies were sought.

There were 1155 nasopharyngeal swabs for SARS-CoV-2 PCR for children via HITH, mostly for children already on HITH. There were 55 visits specifically to test patients, with 15 (27%) positive. There was one transmission to staff (despite protective equipment) from an asymptomatic child not suspected to have COVID-19.

Patients with COVID-19

Between March 2020 and March 2022, 421 patients with COVID-19 (3 days–18.9 years) were admitted to HITH: 16 with the original strain and alpha variant, at least 154 with delta and up to 251 with omicron (overlap between delta/omicron). In Victoria, a higher proportion of children <19 years were infected with delta compared with previous strains, with the increase

Box 2 Planning for Hospital-in-the-Home (HITH) requirements during the COVID-19 pandemic

Managing staffing numbers and flexibility
⇒ Determined trigger of visit numbers for additional staff or cap on patient numbers.
⇒ Changed some staff shift times to support the increased referrals later in the day.
⇒ Changed some staff to teleconferencing from home, especially for those at higher risk.
⇒ Separated staff groups with limited numbers (eg, medical staff), and had each half work from home alternate weeks to reduce risk of staff loss through furlough.

Managing HITH equipment use and availability
⇒ Minimised what was taken into the home for a visit to avert fomite spread.
⇒ Clarified equipment cleaning requirements with the infection control team.
⇒ Ensured sufficient stock or supply chain of usual equipment in advance.
⇒ Ensured stock of extra equipment (personal protective equipment (PPE), flocked swabs).
⇒ Determined lifespan of PPE stored in hot cars and optimal mask changing times.
⇒ Ensured telehealth ability at intake assessment for patients through a simple easy-to-connect system that was accessible online to all patients.

Managing patient workload
⇒ Maximising HITH patient cohorts.
  ⇒Ensured all patients in usual cohorts were transferred to HITH through hospital-wide communication and proactively seeking out of patients each day.
  ⇒Expanded our parameters to safely care for similar patients with slightly higher acuity.
  ⇒Sought opportunities to care for new cohorts of patients at home through team discussions, for example, infants with bronchiolitis, adolescents with eating disorders.
⇒ Reducing HITH patient workload to maintain capacity.
  ⇒Minimised simple referrals where general practitioner could oversee care and educated or provided short-term support for patients in their own care.
  ⇒Reduced frequency of intervention and safely shortened duration on HITH.[15]
  ⇒Deferred elective referrals with deferrals managed between surges in COVID-19 cases.
  ⇒Decreased staff driving distance from 60 km to 40 km from the hospital, and if a patient lived further, we engaged local services or rehoused patients locally.
  ⇒Managed the need for in-home visits by replacing some with telehealth and delivery of home observation kits (thermometer, oximeter) with remote monitoring.

Minimising risk of exposure to and transmission of SARS-CoV-2
⇒ Ensured staff awareness of current health department guidelines for screening, testing, PPE.
⇒ Developed a risk assessment script at patient referral and prior to every visit.
⇒ Educated staff on donning and doffing of PPE and waste disposal in the home, and provided guidance in the form of a laminated visual aide memoire in the car.
⇒ Advised only one family member should be present in the room, physically distanced where possible (acknowledging this was not always possible with a young child).
⇒ Advised if unwell, parents should not be in the room with visiting staff.
⇒ Prior to COVID-19 vaccination, for staff at higher risk of severe COVID-19 infection (comorbidities, increased age, pregnancy), we assigned non-patient-facing roles.

Communications and support
⇒ Weekly communications to HITH staff, to emphasise the importance of hand hygiene and other infection prevention measures, and provide reassurance and moral support.
⇒ Sought advice from the infection control team for staff in their role as front-line carers.
⇒ Communicated to referrers and coordinated care with community healthcare workers.
⇒ Developed written information for all families about HITH in the pandemic, COVID-19 care and special financial resources, including resources specifically for children.

greater for under 10s (6% to 17%, OR 3.1, 95% CI 2.9 to 3.3, p<0.001) than over 10s (10% to 16%, OR 1.7, 95% CI 1.6 to 1.8, p<0.001) (table 2).[13] The infection rate in children jumped from 3/100 000/month with the original strain to 92/100 000/month with delta, and to 593/100 000/month with omicron. However, with omicron, the proportion of infections in children reduced again: under 10s from 17% to 10% (OR 0.5 95% CI 0.5 to 0.5, p<0.001). Pre-delta, HITH and hospital admission rates for children were similarly low: HITH 16 patients (0.7%) vs hospital 12 (0.5%), p=0.5 (table 2). With delta, while remaining low, a higher proportion of patients were referred to HITH: 154 (0.7%) vs 77 (0.4%) (OR 1.9, 95% CI 1.4 to 2.6, p<0.001). With omicron, both HITH and hospital admissions dropped to 0.3%. The pattern of HITH and hospital admissions reflected community transmission, but admission rates were higher with delta than omicron (figure 3).

We examined clinical progress of the 170 children with original and delta variants, as more severe than omicron.[18] For 11 (6%) HITH referrals, after the first respiratory/hydration assessment, no further management was needed. For the remaining 159, referrals were from RCH ED or wards (88, 55%), public health workers (52, 33%), external hospitals (11, 7%) and adult HITH and child protection (8, 5%). Direct admission to HITH from ED attendance or public health referral from home occurred for 113 (71%) patients, with the remainder transferred following inpatient admission. Of the 159, 59 (37%) were admitted to HITH with moderate symptoms and 96 (60%) were high risk with milder symptoms, with a minority socially complex (table 3). Children with moderate symptoms were equally likely to be admitted to HITH directly or hospital first, unless features were respiratory: 12 of 13 (92%) with moderate respiratory effort and 16 of 22 (73%) with oxygen saturation below 94% were admitted to hospital first. Those admitted directly to HITH had less social complexity including parents being hospitalised (30 (27%) vs 23 (49%), OR 0.2, 95% CI 0.1 to 0.8, p=0.006).

Of 35 children eligible for COVID-19 vaccination at the time (over 12 years), only 5 (14%) had had any dose. Of 151 children with eligible parents during the delta wave, for 49 (32%), all parents/carers in the household were double-vaccinated, compared with 52 (34%) where at least one parent (majority both) was completely unvaccinated. For eligible children with high-risk comorbidities, 5 of 22 (23%) had had any vaccine

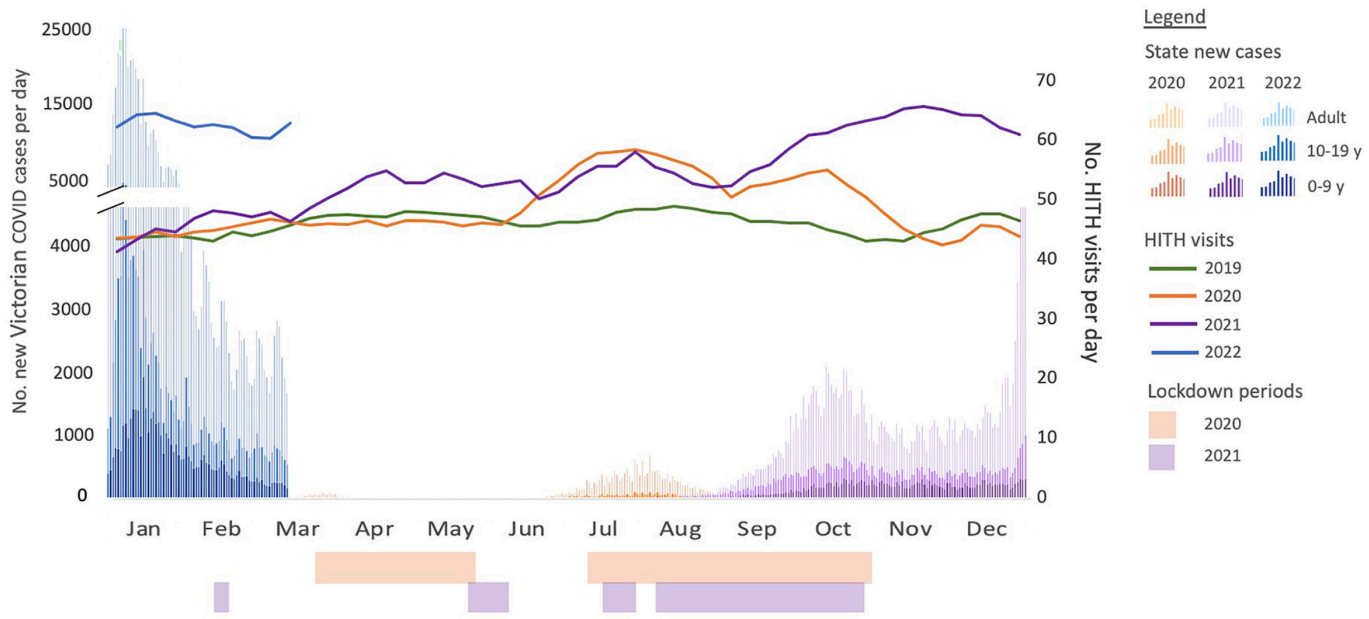

Figure 2 Victorian new cases by age and HITH visits for all patients by month and year (broken y axis with changed scale to show magnitude of case numbers during omicron wave). HITH, Hospital-in-the-Home.

doses, and parents of 29 of 71 (41%) high-risk children were fully vaccinated.

Children admitted directly to HITH were less likely to receive COVID-19-related treatment (oxygen, fluids, steroids, biologics) than those admitted to hospital first (14 of 113, 12%) vs 33 of 46 (72%) (OR 0.06, 95% CI 0.02 to 0.13, p<0.001), reflecting differential respiratory severity (table 3). No interventions were required for 31 of 59 (53%) children with moderate features, or for 13 (28%) of all 46 children admitted first to hospital.

There were 15 of 159 (10%) children readmitted to hospital, although only 8 (5%) received an intervention. None deteriorated suddenly, including two children with declining oxygen saturation. Of these, 14 of 15 (93%) were subsequently transferred back to HITH.

Table 1 Demographics and HITH admission before and during COVID-19 pandemic

	Pre-pandemic No (%)	During pandemic No (%)	OR (95% CI)	P value
Demographics				
No of patient admissions	5071	5808		
Female	2180 (43)	2496 (43)	1.0 (0.9 to 1.1)	0.8
Age (years)				
Median (IQR)	5 (1–10)	5 (1–10)		
Under 1 year	824 (16)	1003 (17)	1.1 (1.0 to 1.2)	0.2
Language at home				
Other than English	568 (11)	605 (10)	0.9 (0.8 to 1.0)	0.2
Needing interpreter	322 (6)	331 (6)	0.9 (0.7 to 1.0)	0.2
Aboriginal/First Nations	131 (3)	83 (1)	0.5 (0.4 to 0.7)	<0.001
HITH admissions				
No of patient visits	26964	28647		
No of visits per admission	5.3	4.9		
Top referring units				
Respiratory	2151 (42)	2376 (41)	0.9 (0.9 to 1.0)	
Oncology	932 (20)	1278 (24)	1.2 (1.1 to 1.3)	0.11
General Medicine	465 (9)	459 (8)	0.9 (0.7 to 0.97)	<0.001
Cardiac Med and Surgery	124 (2)	173 (3)	1.0 (1.0 to 1.5)	0.02
Orthopaedics	112 (2)	118 (2)	0.9 (0.7 to 1.1)	0.08
Direct from ED to HITH	276 (5)	407 (7)	1.1 (1.3 to 1.5)	<0.001
Length of stay (days)				
Median (IQR)	1.5 (1.2–4.1)	1.5 (1.2–3.4)		
Mean (SD)	4.3 (1–417)	3.7 (1–206)		<0.001
No of readmissions	661 (13)	611 (10)	0.8 (0.7 to 0.9)	<0.001

ED, emergency department; HITH, Hospital-in-the-Home.

Table 2 Rate of COVID-19 diagnoses in children and admissions to hospital and HITH

	Pre-delta 14 March 2020–3 June 2021	Delta 4 June 2021–7 December 2021	Omicron 8 December 2021–13 March 2022
Victorian population*	6 595 158	6 595 158	6 595 158
Total with COVID-19	20 565	110 371	561 519
Rate/100 000 (per month)	312 (21)	1674 (279)	8514 (2693)
0–9 years (% total)	1249 (6)	18 557 (17)	53 885 (10)
Rate/100 000 (per month)	19 (1)	281 (47)	817 (253)
10–19 years (% total)	2062 (10)	17 937 (16)	72 222 (13)
Rate/100 000 (per month)	31 (2)	272 (45)	1095 (339)
RCH catchment population	2 420 538	2 420 538	2 420 538
Total with COVID-19	14 048	66 182	415 819
Rate/100 000 (per month)	580 (40)	2734 (456)	17 178 (5325)
0–9 years with COVID-19†	853	11 127	39 903
10–19 years with COVID-19†	1409	10 756	53 482
Admitted to RCH 0–9 years, no (%)	7 (0.8)	48 (0.4)	148 (0.4)
Admitted to RCH 10–19 years, no (%)	5 (0.4)	29 (0.3)	100 (0.2)
RCH HITH 0–9 years, no (%)	10 (1.1)	108 (1.0)	178 (0.4)
RCH HITH 10–19 years, no (%)	6 (0.4)	46 (0.4)	73 (0.1)
Comparison of HITH (no, %) vs hospital (no, %) admission in children aged 0–19 years	16 (0.7) vs 12 (0.5)	154 (0.7) vs 77 (0.4)	251 (0.3) vs 248 (0.3)
	1.3 (0.6 to 2.8)	1.9 (1.4 to 2.6)	1.0 (0.8 to 1.2)
	p=0.5	p<0.001	p=0.9

*Victorian population based on 5-year census data.
†Children aged 0–19 years in RCH catchment estimated from overall age proportions in Victoria during each variant as age-specific data per region are unavailable.
HITH, Hospital-in-the-Home; RCH, Royal Children's Hospital.

DISCUSSION

The COVID-19 pandemic poses unique opportunities and challenges for home healthcare, and we developed a clearly articulated plan for safe expansion of our HITH programme. As a hospital bed replacement model, our HITH has more stringent admission criteria than many community-based telehealth-only services that developed concurrently. This allowed us to manage the dual impacts of increased referrals of patients without COVID-19, and new referrals with COVID-19 requiring some element of hospital-level care. For the first time, this study shows the comparative impact of different SARS-CoV-2 variants on rates of childhood infection, hospitalisation and HITH admission: a higher proportion was able to remain out of hospital through resource-sensitive use of HITH.

The increase in overall HITH activity (not simply patients with COVID-19) when most hospitals had dramatically reduced paediatric activity was due to a combination of (1) protecting inpatient beds as a COVID-19 referral hospital, (2) HITH preference due to concern about hospital outbreaks (which had occurred in other Australian hospitals[19]) and impact of visiting restrictions, (3) continuing elective admissions and (4) limited impact of reductions in viral infections and elective surgery, which only constitute a small proportion of HITH activity.

This activity increase raises the broader question about how much acute paediatric care could be relocated out of hospital. The answer is a combination of safety (required intensity of monitoring), resources (ability and capacity to provide interventions) and philosophy (whether benefits of home care outweigh efficiencies in hospital). The fact that ED presentations and admissions to RCH decreased from the pandemic outset gives some insight. From 1 March to 30 April 2020, there was 46% reduction in ED presentations and 37% reduction in admissions compared with the same period in 2019.[20 21] Although the greatest reduction (50%) was due to reduced viral infections and road accidents due to social distancing/movement restrictions, there was 17% reduction for conditions not obviously affected by the pandemic, for example, cardiac conditions. This was due to some reduced presentations and a 70% increase in admissions

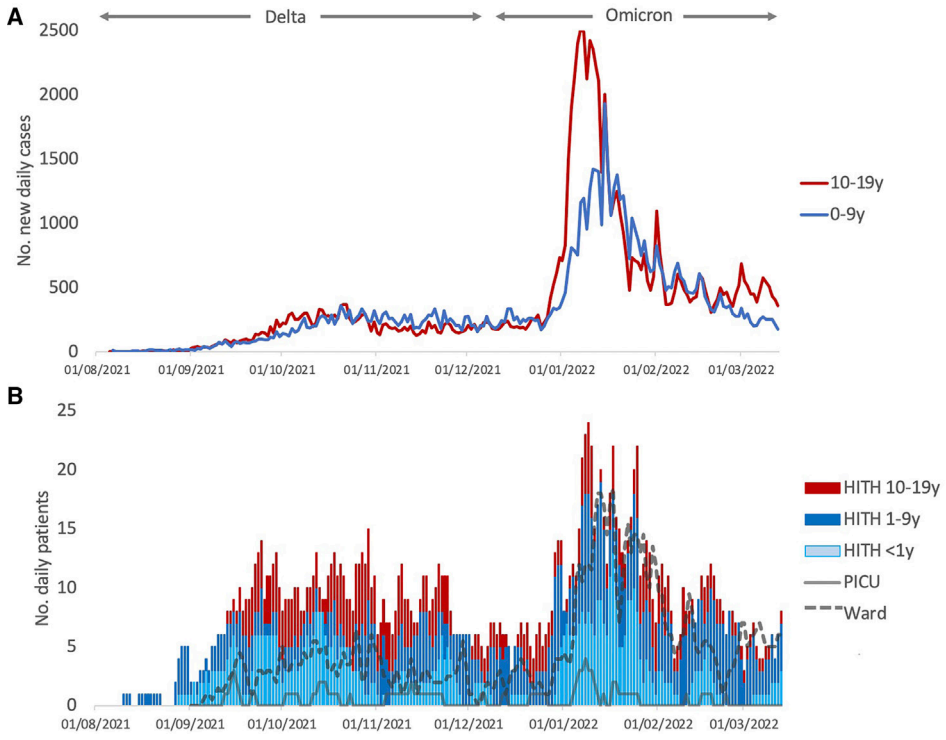

Figure 3 During the delta outbreak, the number of (A) daily new paediatric cases in Victoria and (B) COVID-19-positive patients on HITH (with inpatient numbers for comparison). HITH, Hospital-in-the-Home; PICU, paediatric intensive care unit.

Table 3 Comparison of patients admitted directly to HITH and those transferred to HITH after an inpatient admission (with original and delta variants)

	Total	Direct to HITH	Hospital admission then HITH		
	n=159	n=113	n=46		
	No (%)	No (%)	No (%)	OR (95% CI)	P value
Demographics					
Female	74 (46)	53 (47)	21 (45)	1.1 (0.6 to 2.2)	0.8
Age <3 months	33 (21)	21 (19)	12 (26)	0.7 (0.3 to 1.5)	0.3
Age 3–11 years	88 (56)	70 (62)	18 (39)	2.4 (1.2 to 4.8)	0.01
Age 12 years and above	38 (24)	22 (19)	16 (35)	0.5 (0.2 to 1.0)	0.049
Aboriginal/First Nations	6 (5)	4 (4)	2 (4)	0.8 (0.1 to 4.7)	0.8
Language other than English	36 (23)	26 (23)	10 (21)	1.1 (0.5 to 2.5)	0.8
Interpreter required	14 (9)	11 (10)	3 (6)	1.5 (0.4 to 5.9)	0.5
Social complexity impacting medical care	53 (33)	30 (27)	23 (49)	0.2 (0.1 to 0.8)	0.006
Primary reason for HITH admission (may have had >1 reason)					
Moderate clinical features	59 (37)	37 (33)	22 (48)	0.5 (0.3 to 1.0)	0.1
Dehydration	33 (56)	19 (51)	14 (64)	0.6 (0.2 to 1.8)	0.4
Increased respiratory effort	26 (44)	11 (30)	15 (68)	0.2 (0.1 to 0.6)	0.004
Chest pain	17 (29)	10 (27)	7 (32)	0.8 (0.3 to 2.4)	0.7
Mild symptoms and	96 (60)	73 (65)	23 (50)	1.8 (0.9 to 3.7)	0.1
High-risk comorbidities	49 (31)	37 (33)	12 (26)	1.4 (0.6 to 2.9)	0.4
Age under 3 months	45 (28)	30 (27)	15 (33)	0.7 (0.3 to 1.6)	0.4
Social complexity or anxiety	11 (7)	11 (10)	0	NA	0.8
Other HITH treatment and concomitant COVID-19	4 (3)	3 (3)	1 (3)	1.2 (0.1 to 12.1)	0.8
High-risk comorbidities					
Any comorbidity	80 (50)	53 (47)	27 (59)	0.6 (0.3 to 1.2)	0.1
Asthma/respiratory disease	23 (14)	19 (17)	4 (9)	2.1 (0.7 to 6.3)	0.2
Extreme obesity (BMI >30)	20 (13)	11 (10)	9 (20)	0.4 (0.2 to 1.1)	0.1
Complex neurodisability*	28 (18)	20 (18)	8 (17)	1.0 (0.4 to 2.5)	1
Immunosuppression	15 (10)	10 (9)	5 (11)	0.8 (0.3 to 2.4)	0.7
Prematurity (preterm <37 weeks)	20 (13)	13 (12)	7 (15)	0.7 (0.3 to 1.9)	0.5
Congenital cardiac disease	12 (8)	7 (6)	5 (11)	0.5 (0.2 to 1.7)	0.3
Renal disease	4 (3)	4 (4)	0	NA	
COVID-19 immunisation					
Child vaccinated, any dose	5/159 (3)	4/113 (4)	1/46 (2)	1.7 (0.2 to 15.1)	0.5
Child vaccinated, of 35 eligible†	5/35 (14)	4/21 (19)	1/14 (7)	3.1 (0.3 to 30.7)	0.3
Parent vaccinated, of 151 eligible		101	50		
All parents/carers 2 doses	49 (32)	39 (39)	10 (24)	2.2 (1.0 to 4.9)	0.1
All at least 1 dose but not all 2	30 (20)	20 (20)	10 (19)	1.4 (0.6 to 3.5)	0.4
Combination of 1 dose or none	20 (13)	15 (15)	5 (14)	1.3 (0.4 to 3.5)	0.7
None	32 (21)	17 (17)	15 (68)	0.4 (0.2 to 0.8)	0.008
Information unavailable	20 (13)	10 (10)	10 (10)		
Symptoms at presentation					
Symptoms	153 (96)	109 (96)	44 (96)	0.8 (0.1 to 4.5)	0.8
Fever >38°C	79 (50)	48 (42)	31 (67)	0.4 (0.2 to 0.7)	0.004
Cough	108 (68)	79 (70)	29 (63)	1.4 (0.7 to 2.8)	0.4
Coryza	89 (56)	69 (61)	20 (43)	2.0 (1.0 to 4.0)	0.04
Sore throat	26 (16)	23 (20)	3 (7)	3.6 (1.0 to 12.9)	0.04
Difficulty breathing	55 (35)	31 (27)	24 (52)	0.3 (0.2 to 0.7)	0.003
Headache	25 (16)	19 (17)	6 (13)	1.3 (0.5 to 3.5)	0.6
Chest pain	25 (16)	18 (16)	7 (15)	1.1 (0.4 to 2.7)	0.9
Calf pain	7 (4)	3 (2)	4 (9)	0.1 (0.0 to 0.3)	<0.001
Clinical signs at presentation					
Increased respiratory muscle use					
Nil/mild	146 (92)	112 (99)	34 (74)‡		
Moderate/severe	13 (8)	1 (1)	12 (26)	0.0 (0.0 to 0.2)	0.001
O2 saturation <94%	22 (14)	6 (5)	16 (35)	0.1 (0.0 to 0.3)	<0.001
Dehydration					

Continued

Table 3 Continued

	Total	Direct to HITH	Hospital admission then HITH		
	n=159	n=113	n=46		
	No (%)	No (%)	No (%)	OR (95% CI)	P value
Nil/mild	149 (94)	108 (96)	41 (89)‡		
Moderate/severe	10 (6)	5 (4)	5 (11)	0.4 (0.1 to 1.4)	0.1
Irritable/lethargic					
Nil/mild	155 (97)	112 (99)	43 (93)‡		
Moderate/severe	4 (3)	1 (1)	3 (7)	0.1 (0.0 to 1.3)	0.1
Management					
Oxygen	15 (9)	1 (1)	14 (30)	0.0 (0.0 to 0.2)	0.001
Nasogastric or IV fluids	24 (15)	5 (4)	19 (41)	0.1 (0.0 to 0.2)	<0.001
IV antibiotics	15 (10)	1 (1)	14 (30)	0.0 (0 to 0.2)	0.001
Steroids for COVID-19	17 (11)	3 (3)	14 (30)	0.1 (0.0 to 0.2)	0.001
Biologic for COVID-19	13 (8)	4 (4)	9 (20)	0.2 (0.0 to 0.5)	0.003
Anticoagulant prophylaxis*	17 (11)	2 (2)	15 (33)	0.0 (0 to 0.2)	0.001
Did not receive any of above	112 (70)	99 (88)	13 (28)	18.0 (7.7 to 41.8)	<0.001
Outcomes					
Length of stay, days					
Median (IQR)	5 (3–7)	4 (3–6)	7 (5–9)	−4.3 (−5.9 to −2.7)	<0.001
Complications	8 (5)	2 (2)	6 (13)	−0.1 (−0.2 to −0.0)	0.003
Acute respiratory distress syndrome	2 (1)	0	2 (4)		
Acute kidney injury	1 (1)	0	1 (1)		
Deep vein thrombosis	1 (1)	0	1 (2)		
Pulmonary embolism	2 (0)	0	2 (0)		
Systemic inflammation	3 (2)	0	3 (7)		
Intensive care admission	7 (4)	0	7 (15)	NA	
Readmitted to ward from HITH	15 (10)	11 (10)	4 (9)	1.1 (0.4 to 3.6)	0.8
Respiratory deterioration	4 (3)	2 (2)	2 (4)	NA	
Dehydrated	4 (3)	2 (2)	2 (4)	NA	
Parental anxiety	3 (2)	3 (3)	0	NA	
Worsening chest pain	2 (2)	2 (2)	0	NA	
Abdominal pain	1 (1)	0	1 (1)	NA	
Persistent fever	2 (1)	1 (1)	1 (2)	NA	
Sotrovimab infusion	1 (1)	1 (1)	0	NA	
Transferred back to HITH after	14 (9)	11 (10)	3 (7)	1.5 (0.4 to 5.4)	0.5
Length of stay after readmission, days, median (IQR)	2 (1–2)	1 (1–2)	2 (1–19)	−5.7 (−11.7 to 0.3)	0.1
Readmission within 14 days	1 (1)	0	1 (2)	NA	
Mortality	0	0	0		

*Anticoagulant prophylaxis was routinely prescribed to more unwell children admitted to hospital.
†Eligibility based on timing of vaccine rollout in Victoria for different age groups.
‡All had nil/mild features by the time of transfer to HITH, except two patients who still had oxygen saturation <94%.
BMI, body mass index; HITH, Hospital-in-the-Home; IV, intravenous.

to HITH directly from ED during this 2-month period (50% during the whole study). Therefore, with external pressure only, a substantial proportion of care was moved out of hospital. Additional education and resourcing would likely increase this and is worthy of further attention.

COVID-19 infections in Victoria were higher with delta during similar lockdown restrictions as with the original strain—Melbourne is famously the most locked-down city worldwide at 262 days of restrictions with essential needs only, 1 hour of outdoor exercise/day, 20:00–06:00 curfew.[22] Although the proportion of children infected was higher with delta, hospital and HITH admission rates remained similarly low. The fact that one-third of COVID-19-positive patients admitted directly to HITH had symptoms similar to those admitted to hospital shows the potential for HITH to prevent hospital admission, in addition to shortening LOS.

For COVID-19-positive children, there are additional benefits to being out of hospital, where safety prioritisation means visiting restrictions and children confined to rooms. The challenge for HITH eligibility is identifying the cohort between the mildly unwell (parent care sufficient) and the more severely unwell (needing hospital admission). Appropriate use of HITH resources should be for patients needing paediatric expertise and some hospital-level care, but whose management/monitoring intensity allows them to remain safely at home.

Patients with COVID-19 managed through HITH did well, with low readmission. As with other studies, some children admitted first to hospital were simply observed in hospital without intervention.[23 24] In New South Wales during 2 months of delta outbreak, 2% children with COVID-19 were hospitalised, only 43 of 70 for medical reasons, with the remaining 39% for social reasons.[25] Our data compare favourably with only 7%

of admissions to HITH being for social reasons. US data show no worse paediatric outcomes with delta.[26] Our study shows that even with moderately increased respiratory effort, many children did not require oxygen. For the two patients with respiratory deterioration while on HITH, it was gradual with adequate time to escalate management. This should reassure clinicians about the safety of managing children with COVID-19 at home even with more severe variants, and highlights that perhaps even fewer children need hospital.

COVID-19 vaccinations began in Australia in February 2021, with everyone ≥12 years eligible in Victoria from September 2021. Despite early delays, access was universal by the delta wave.[27] By December 2021, 14% vaccine uptake in those 12–17 years old with COVID-19 on HITH was substantially lower than the proportion who had had at least one dose in that age group in Victoria of 94%.[13] Since many of these adolescents had high-risk comorbidities with less available vaccine safety data, this is perhaps understandable. However, parents of these children might have been predicted to be vaccinated early, but 20% eligible parents receiving at least one dose was much lower than the 30–49 year population rate of 95%.[13]

There is no published guidance about which children benefit most from home-based management for COVID-19. Our traffic light guideline, developed by those with expertise in home care and infectious diseases, identified children with the most severe variant to date who can safely be managed at home. Guidelines should be re-evaluated with each new SARS-CoV-2 variant as clinical information becomes available. As the lower severity of omicron became clear,[18] we changed HITH eligibility to focus on respiratory symptoms, reduced age-based admissions from <3 months to <1 month old, and removed monitoring for most comorbidities as not high risk (online supplemental file 1). This also allowed us to cope with the massive surge in omicron numbers in a resource-sensitive way.

The limitation of this study is that these are findings from a well-resourced tertiary hospital HITH and may not be replicable in all settings. Our programme has differed from hospitals monitoring all children, through a conscious effort to be judicious with healthcare resources. The broad learning is translatable that moderately unwell children both with and without COVID-19 can be safely cared for at home during the pandemic. Each healthcare service should determine its own clinical criteria and models of care for children at home.

CONCLUSION

Based on our findings, we advocate that where possible, children should be cared for at home rather than hospital, knowing the benefit to quality of life and severe impact on children's mental health of this pandemic. Our expansion and adaptable guidelines provide a blueprint for other services to safely care for children with COVID-19 at home.

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Contributors PAB conceived and designed the study, analysed and interpreted the data, drafted the work, approved the final version and agrees to be accountable as guarantor for the work. JL, SB and CMS interpreted the data, revised the work critically, approved the final version and agree to be accountable for the work. GS, CC, PL, SL, RH, SD, CL, LCN, TES, SC and SL acquired the data, revised the work critically, approved the final version and agree to be accountable for the work. KH, KS and BS interpreted the data, revised the work critically, approved the final version and agree to be accountable for the work. LFI conceived the study, acquired and interpreted the data, revised the work critically, approved the final version and agrees to be accountable for the work.

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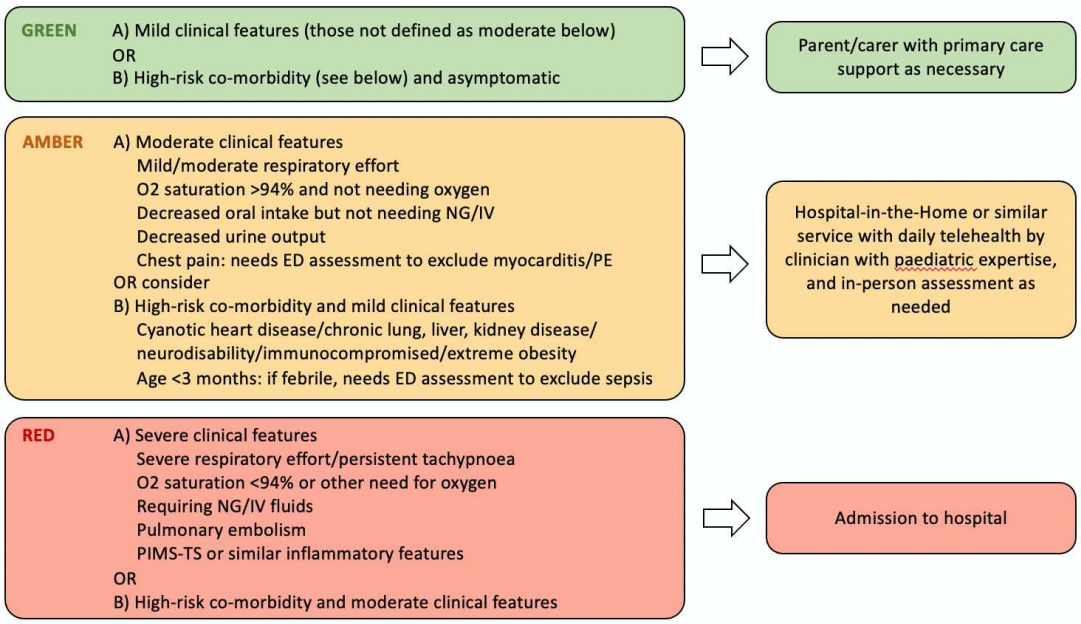
Supplementary material

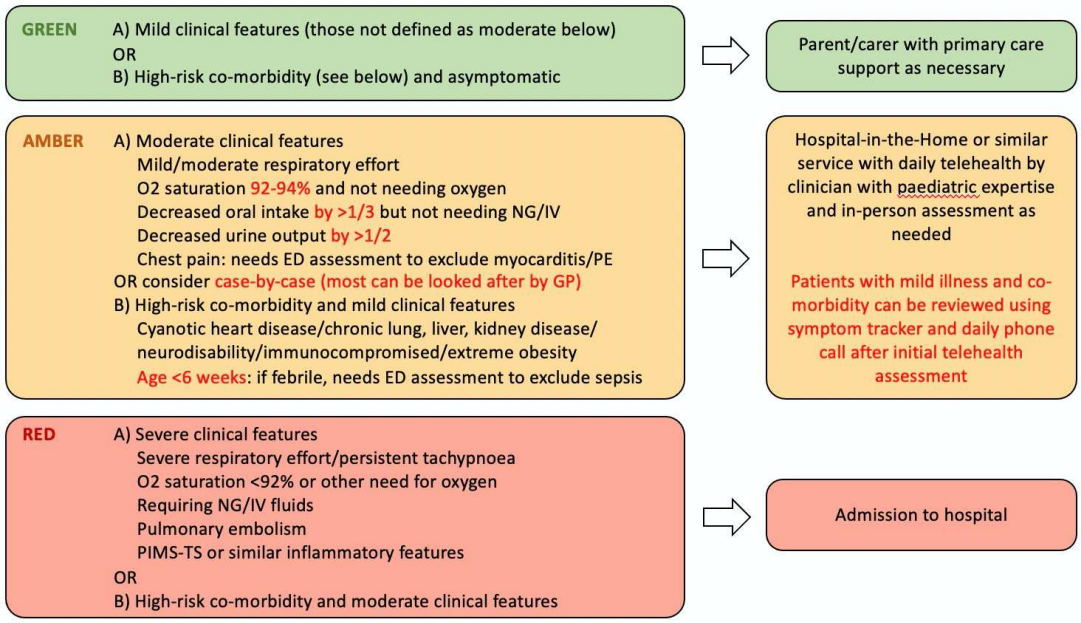
Figure

Evolution of the RCH HITH COVID-19 guideline (new changes highlighted in red text for each iteration)

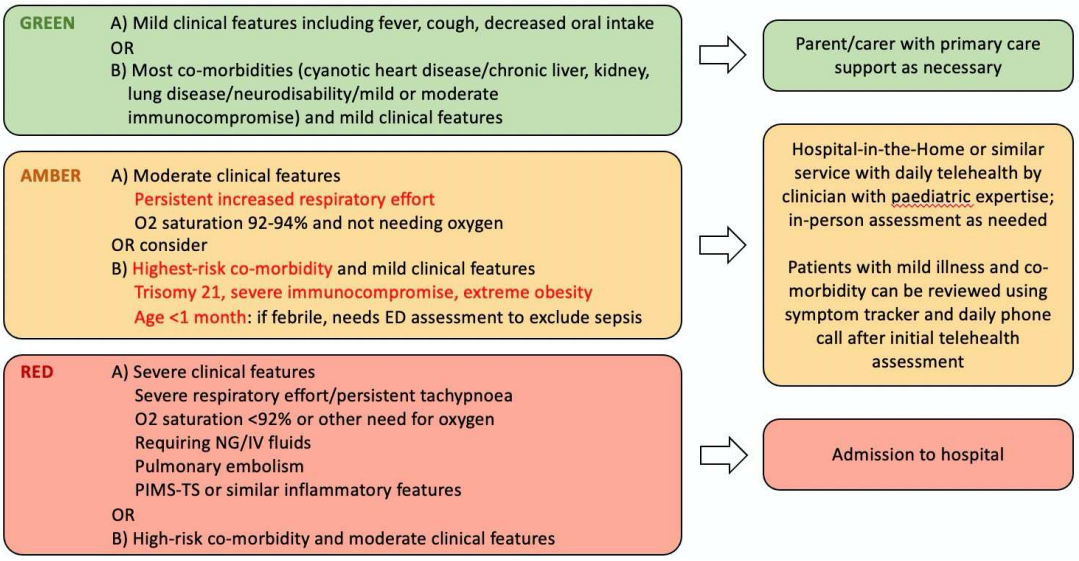
A) Original guideline March 2020



B) Guideline changes in response to delta wave October 2021



C) Guideline changes in response to omicron wave March 2022



Tables

Table A. Telehealth use on HITH pre- and during COVID

	Pre-COVID		During COVID		OR, 95% CI	P value
	In person No. (%)*	**Telehealth** No. (%)*	**In person** No. (%)*	**Telehealth** No. (%)*		
Nursing						
Registered nurse	25,425 (98)	471 (2)	27,107 (95)	1,286 (5)	2.6, 2.3-2.9	<0.001
Medical						
Fellow/registrar	237 (85)	41 (15)	118 (14)	725 (86)	35, 24-52	<0.001
Allied health						
Physiotherapist	3,613 (76)	1,115 (24)	2,927 (65)	1,608 (35)	1.8, 1.6-1.9	<0.001
Dietitian	611 (81)	141 (19)	309 (50)	313 (50)	4.4, 3.4-5.6	<0.001
Speech therapist	412 (93)	32 (7)	294 (55)	239 (45)	10, 7-16	<0.001
Occupational therapist	76 (100)	0 (0)	66 (86)	11 (14)	N/A	<0.001
Total	32,174 (94)	1,800 (6)	35,126 (88)	4,182 (12)	2.3, 2.2-2.4	<0.001

*Percentage of visits provided by that practitioner group
Clinical co-ordination of externally outsourced patients not included

Table B. Telehealth use on HITH during the COVID-19 variants: original and alpha, delta and omicron

	Original & alpha Telehealth/total visits (%)	**Delta variant** Telehealth/total visits (%)	**Omicron variant** Telehealth/total visits (%)
Nursing			
Registered nurse	363/16,600 (2)	416/8,028 (5)	507/3,886 (13)
Medical			
Fellow/registrar	44/100 (44)	417/451 (93)	259/272 (95)
Allied health			
Physiotherapist	1,030/2,819 (37)	406/1,181 (34)	172/535 (32)
Dietitian	183/439 (42)	80/119 (67)	50/64 (78)
Speech therapist	3/42 (7)	110/179 (62)	48/67 (72)
Occupational therapist	0/76 (0)	8/30 (27)	0/5 (0)
Total	1,705/20,298 (8)	1,439/9,995 (14)	1,038/4,833 (21)