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Original Research Article

TO ASSESS THE PULSE OXIMETRIC SATURATION TO FRACTION OF INSPIRED OXYGEN [SPO2/ FIO2] RATIO AS A PREDICTOR OF HFNC THERAPY OUTCOME IN CHILDREN

Bhagyalakshmi S[1], A. Sathiyanandan[1], A. Uma[1], Irudaya Merlin Y[2]

[1]Assistant Professor, Department of Pediatrics, Madras Medical College, Tamilnadu, India
[2]Assistant Surgeon, Department of Pediatrics, Government Upgraded Primary Health Centre, Vairavikulam, Tirunelveli, Tamilnadu, India

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Corresponding Author:
Dr. Irudaya Merlin Y,
Email: irudayamerlin@gmail.com

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Abstract

Background: Acute respiratory illness, including bronchiolitis, pneumonia, and acute respiratory distress syndrome, affects 30–64% of children admitted to intensive care units. It is a major cause of morbidity and mortality in children. HFNC is a safe and effective method; however, early predictors are needed for success. This study aimed to assess the efficacy of HFNC therapy in children with respiratory distress and the ability of pulse oximetric saturation to a fraction of the inspired oxygen ratio as an early predictor of HFNC outcomes. **Materials and Methods:** This prospective study included 139 children in the Department of Pediatrics, Institute of Child Health, Madras Medical College, Chennai, from September 2020 to September 2021. The pulse oximetric saturation to the fraction of inspired oxygen supplied through the HFNC ratio was calculated at 0, 2, 4, 6, and 12 h. The study group was followed for 14 days after the initiation of HFNC. **Result:** This study showed that age, nutritional status, breathlessness, altered level of consciousness, and diseases in children were significantly associated with SPO2/FiO2 ratio. There was no significant difference in the SPO2/FiO2 ratio between gender and fever (p=0.655 and p=0.688, respectively). The heart rate, respiratory rate, and work of breathing of the children at intervals of 2, 4, 6, and 12 h were significantly associated with the SPO2/FiO2 ratio (p=0.001). **Conclusion:** Our study shows that pulse oximetric saturation to the fraction of inspired oxygen ratio can be a reliable, effective, and non-invasive early predictor of HFNC therapy outcomes.

INTRODUCTION

Acute respiratory illness is a major cause of morbidity and mortality in children. Bronchiolitis, pneumonia, wheezer and acute respiratory distress syndrome (ARDS) are among the most important disorders for which children may require respiratory support. Approximately 30% to 64% of all children admitted to paediatric intensive care units require respiratory support.[1] The respiratory support required for children may vary from non-invasive supports such as facemask oxygen and high-flow nasal cannula therapy to invasive forms of ventilation such as invasive mechanical ventilation or high-frequency oscillatory ventilation. High-flow nasal cannula (HFNC), also sometimes called heated humidified high-flow nasal cannula (HHHFNC) oxygen therapy, is a technique in which heated and humidified oxygen is delivered to the nose at high flow rates and has recently attracted attention as a new oxygen therapy. In the Cochrane review from 2014, HFNC in children was defined as heated, humidified and blended air/oxygen delivered via nasal cannula at different flow rates ≥ 2 L/min, delivering both high concentrations of oxygen and potentially continuous distending pressure.[2]

HFNC is a safe and well-tolerated method for delivering oxygen to children, with few reported adverse events. Its mechanisms, including nasopharyngeal dead space washout and increased pulmonary compliance, make it effective against respiratory distress. It has become an alternative to CPAP ventilation, reducing intubation and mortality rates. However, evidence of the efficacy and early predictors of successful outcomes is limited. Identifying such predictors can reduce delayed intubation, mortality, and length of hospital stay. Non-invasive and cost-effective predictors are needed, especially in nonsophisticated hospital settings.

Children in paediatric intensive care units are continuously monitored using multichannel monitors, including pulse oximetry saturation, arterial blood gas analysis, and arterial blood pressure

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monitoring. The PF ratio, derived from arterial blood gas measurements, is utilized to diagnose and monitor the course of acute respiratory distress syndrome.[3]

Aim

This study aimed to assess the efficacy of HFNC therapy in children with respiratory distress and the ability of pulse oximetric saturation to a fraction of the inspired oxygen ratio as an early predictor of HFNC outcomes.

MATERIALS AND METHODS

This prospective study included 139 children in the Department of Pediatrics, Institute of Child Health, Madras Medical College, Chennai, from September 2020 to September 2021. The study was approved by the institutional ethics committee (EC Reg. No: ECR/270/Inst/TN/2013/RR-16) before initiation, and informed consent was obtained from all the patients.

Inclusion Criteria

All children aged > 1 month and < 12 years who had been admitted to the PICU, started HFNC ventilation for respiratory support, and provided informed and written consent were included.

Exclusion Criteria

Children with congenital cyanotic cardiac disease, chronic lung disease, or those who did not provide consent for the study were excluded.

Methods: Demographic and clinical data, oxygen requirement data, and pulse oximetric saturation data were collected from the study groups. The HFNC machine used was FISHER & PAYKEL – AIRVO 2. Pulse oximetric saturation was measured using MASIMO RADICAL 7. The pulse oximetric saturation to the fraction of inspired oxygen supplied through the HFNC ratio was calculated at 0, 2, 4, 6, and 12 h. The study group was followed for 14 days after the initiation of HFNC.

Statistical Analysis: All data were entered into a Microsoft Excel spreadsheet and analysed using SPSS Software version 20.0. The primary outcome was expressed as a proportion. The chi-square test was used to determine the association between the outcome and dependent variables. Statistical significance was set at $p < 0.05$.

RESULTS

In this study, the majority of the children were between 1 and 5 years of age, accounting for 43.89% (61 children). There were more males (55.4%) than females (44.6%). Most children had nutritional status appropriate for their age (68.35%). A total of 42.45% experienced breathlessness for less than one day. Most children (36.69%) had no history of fever. An altered level of consciousness was present in 33.09% of the children. The most common disease type was wheezer, affecting 41 children, followed by bronchiolitis, affecting 39 children. Most children stayed in the hospital for up to 7 days (68.35%). Mechanical ventilation was absent in 79.86% of the children. The death rate among the children was 5.7% [Table 1].

At the onset of monitoring (0 h), all children exhibited tachycardia and tachypnoea. However, over time, there was a gradual decrease in both parameters. By 12 h, tachycardia had decreased to 29.5%, while tachypnoea had decreased to 38.85%. The percentage of children with normal heart and respiratory rates increased steadily over the monitoring intervals, reaching 70.5% and 61.15%, respectively, by the 12-hour mark. Within the initial 6 h, 76.26% of the patients exhibited normal work of breathing. The work of breathing decreased from 100% at 0 h to 23.74% at 12 h. Most patients (41.73%) had an SPO2/FiO2 ratio between 100 and 149.9 at 0 hours. Over time, there was a decrease in the number of patients with higher ratios (>250), with 40.29% observed at 12 h [Table 2].

The SPO2/FiO2 ratio at different levels at 6-hour intervals was compared with age, gender, nutritional status, breathlessness, fever, altered level of consciousness, and disease in the sample children. Age, nutritional status, breathlessness, altered level of consciousness, and disease were significantly associated with the SPO2/FiO2 ratio ($p<0.05$). There was no significant association between the SPO2/FiO2 ratio and gender, fever ($p=0.6547$, $p=0.6817$) [Table 3].

At the beginning of monitoring (0 h), all children with tachycardia had SPO2/FiO2 ratios predominantly within the range of 200–250 and above 250. As time progressed (2 h), a shift occurred towards higher SPO2/FiO2 ratios, with more children showing normal heart rates and higher ratios exceeding 250. The proportion of children with tachycardia decreased across all SPO2/FiO2 ratio intervals. The heart rate of children at different intervals of 2, 4, 6, and 12 h was significantly associated with the SPO2/FiO2 ratio ($p=0.001$) [Table 4].

At the time of admission, all the children had tachypnoea. At 2 h, the maximum population of children with tachypnoea (21.92%) had an SPO2/FiO2 ratio of < 100 and the minimum population with tachypnoea (17.81%) had a ratio of > 250. The respiratory rate of children at 2, 4, 6, and 12 h had a significant relationship with the SPO2/FiO2 ratio ($p=0.001$) [Table 5].

All children showed increased work of breathing at the time of hospital admission. By 2 h, there was a shift towards higher SPO2/FiO2 ratios among children with both normal and increased work of breathing, with a notable increase in those with normal work of breathing showing ratios above 250. The proportion of children with increased breathing work decreased across all SPO2/FiO2 ratio intervals. The work of breathing of sample children at different intervals of 2, 4, 6, and 12 h was significantly associated with the SPO2/FiO2 ratio ($p=0.001$) [Table 6].

Among the study population, for stay up to 7 days, the majority of children had ratios above 200, with

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fewer requiring mechanical ventilation. For stays longer than 14 days, a significant portion of children had ratios below 200, and there was a higher prevalence of mechanical ventilation. The length of hospital stay, requirement of mechanical ventilation, and outcome of the sample children were significantly associated with the SPO2/FiO2 ratio (p=0.001, p=0.001, p=0.007) [Table 7].

Table 1: Demographic details of the study.

		Frequency
Age in years	Up to 1	50 (35.97%)
	1-5	61 (43.89%)
	6-12	28 (20.14%)
Gender	Male	77 (55.4%)
	Female	62 (44.6%)
Nutritional status	Appropriate for age	95 (68.35%)
	Under Nourished	28 (20.14%)
	Over Nourished	16 (11.51%)
Breathlessness	<1 day	59 (42.45%)
	1-3 days	51 (36.69%)
	>3 days	29 (20.86%)
Fever	No History	51 (36.69%)
	<1 day	11 (7.91%)
	1-3 days	43 (30.94%)
	> 3 days	34 (24.46%)
Altered level of consciousness	Absent	93 (66.91%)
	Present	46 (33.09%)
Disease type	Bronchiolitis	39 (28.06%)
	Wheezer	41 (29.5%)
	Sepsis	12 (8.63%)
	Pneumonia	28 (20.14%)
	Others	19 (13.67%)
Length of stay in days	Up to 7	95 (68.35%)
	7-14	31 (22.3%)
	> 14	13 (9.35%)
Mechanical ventilation	Absent	111 (79.86%)
	Present	28 (20.14%)
Outcome	Improved	131 (94.2%)
	Death	8 (5.7%)

Table 2: Heart rate, respiratory rate, work of breathing, SPO2/FiO2 ratio at different intervals

		Interval				
		0 hour	**2 hours**	**4 hours**	**6 hours**	**12 hours**
Heart rate	Normal	0	63 (45.32%)	81 (58.27%)	92 (66.19%)	98 (70.5%)
	Tachycardia	139 (100%)	76 (54.68%)	58 (41.73%)	47 (33.81%)	41 (29.5%)
Respiratory rate	Normal	0	66 (47.48%)	79 (56.83%)	76 (54.68%)	85 (61.15%)
	Tachypnoea	139 (100%)	73 (52.52%)	60 (43.17%)	63 (45.32%)	54 (38.85%)
Work of breathing	Normal	0	72 (51.8%)	85 (61.15%)	97 (69.78%)	106 (76.26%)
	Increased	139 (100%)	67 (48.2%)	54 (38.85%)	42 (30.22%)	33 (23.74%)
SPO2/FiO2 ratio	>100	27 (19.42%)	24 (17.27%)	21 (15.11%)	18 (12.95%)	11 (7.91%)
	100 – 149.9	58 (41.73%)	43 (30.94%)	32 (23.02%)	23 (16.55%)	14 (10.07%)
	150 – 199.9	54 (38.85%)	47 (33.81%)	38 (27.34%)	29 (20.86%)	18 (12.95%)
	200 – 250	0 (0%)	14 (10.07%)	23 (16.55%)	32 (25.02%)	40 (28.78%)
	>250	0 (0%)	11 (7.91%)	25 (17.99%)	37 (26.62%)	56 (40.29%)

Table 3: Comparative analysis of various parameters between SPO2/Fio2 ratio

		SPO2/FiO2 Ratio					P value
		< 100	**100 - 149.9**	**150 - 199.9**	**200 - 250**	**>250**	
Age in years	Up to 1	13 (26%)	15 (30%)	10 (20%)	8 (16%)	4 (8%)	0.0012
	1 – 5	4 (6.56%)	5 (8.2%)	14 (22.95%)	16 (26.23%)	22 (36.07%)	7
	6 – 12	1 (3.57%)	3 (10.71%)	5 (17.86%)	8 (28.57%)	11 (39.29%)	
Gender	Male	11 (14.28%)	14 (18.18%)	18 (23.38%)	17 (22.08%)	17 (22.08%)	0.6547
	Female	7 (11.29%)	9 (14.52%)	11 (17.74%)	15 (24.19%)	20 (32.26%)	
Nutritional status	Appropriate for age	2 (2.10%)	4 (4.21%)	25 (26.32%)	29 (30.53%)	35 (36.84%)	0.001
	Undernourished	12 (42.86%)	11 (39.29%)	2 (7.14%)	2 (7.14%)	1 (3.57%)	
	Over nourished	4 (25%)	8 (50%)	2 (12.5%)	1 (6.25%)	1 (6.25%)	
Breathlessness	> 1 day	1 (1.7%)	5 (8.47%)	8 (13.56%)	21 (35.59%)	24 (40.68%)	0.001
	1-3 days	4 (7.84%)	12 (23.53%)	16 (31.37%)	8 (15.69%)	11 (21.57%)	
	> 3 days	13 (44.83%)	6 (20.69%)	5 (17.24%)	3 (10.34%)	2 (6.90%)	
Fever	No History	7 (13.72%)	11 (21.57%)	13 (25.49%)	12 (23.53%)	8 (15.69%)	0.6817
	> 1 day	2 (18.18%)	3 (27.27%)	1 (9.09%)	2 (18.18%)	3 (27.27%)	
	1-3 days	5 (11.63%)	6 (13.95%)	7 (16.28%)	11 (25.58%)	14 (33%)	
	> 3 days	4 (11.76%)	3 (8.82%)	8 (23.53%)	7 (20.59%)	12 (35%)	

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Altered level of consciousness	Absent	3 (3.23%)	10 (10.75%)	20 (21.5%)	26 (27.96%)	34 (36.56%)	0.001
	Present	15 (32.61%)	13 (28.26%)	9 (19.57%)	6 (13.04%)	3 (6.52%)	
Disease	Bronchiolitis	3 (7.69%)	3 (7.69%)	9 (23.08%)	9 (23.08%)	15 (38.46%)	0.0364
	Wheezer	4 (9.76%)	6 (14.63%)	10 (24.39%)	11 (26.83%)	10 (24.39%)	
	Sepsis	5 (41.67%)	3 (25%)	2 (16.67%)	1 (8.33%)	1 (8.33%)	
	Pneumonia	5 (17.86%)	9 (32.14%)	5 (17.86%)	6 (21.43%)	3 (10.71%)	
	Others	1 (5.26%)	2 (10.52%)	3 (15.79%)	5 (26.32%)	8 (42.11%)	

Table 4: Comparative analysis of heart rate at different intervals between SPO2/FiO2 ratio

Interval	Heart rate	SPO2/FiO2 Ratio					P value
		< 100	100-149.9	150-199.9	200 - 250	>250	
0 hour	Normal	0	0	0	0	0	-
	Tachycardia	18 (12.95%)	23 (16.55%)	29 (20.86%)	32 (25.02%)	37 (26.62%)	
2 hours	Normal	1 (1.59%)	7 (11.11%)	14 (22.22%)	17 (26.98%)	24 (38.10%)	0.0047
	Tachycardia	17 (22.37%)	16 (21.05%)	15 (19.74%)	15 (19.74%)	13 (17.11%)	
4 hours	Normal	2 (2.47%)	8 (9.88%)	16 (19.75%)	23 (28.4%)	32 (39.51%)	0.001
	Tachycardia	16 (27.59%)	15 (25.86%)	13 (22.41%)	9 (15.52%)	5 (8.62%)	
6 hours	Normal	4 (4.35%)	11 (11.96%)	19 (20.65%)	24 (26.09%)	34 (36.96%)	0.001
	Tachycardia	14 (29.79%)	12 (25.53%)	10 (21.28%)	8 (17.02%)	3 (6.38%)	
12 hours	Normal	3 (3.06%)	10 (10.20%)	20 (20.41%)	29 (29.59%)	36 (36.74%)	0.001
	Tachycardia	15 (36.59%)	13 (31.71%)	9 (21.95%)	3 (7.32%)	1 (2.44%)	

Table 5: Comparative analysis of the respiratory rate at different intervals between SPO2/FiO2 ratio

Interval	Respiratory rate	SPO2/FiO2 Ratio					P value
		< 100	100-149.9	150-199.9	200 - 250	>250	
0 hour	Normal	0	0	0	0	0	-
	Tachypnea	18 (12.95%)	23 (16.55%)	29 (20.86%)	32 (25.02%)	37 (26.62%)	
2 hours	Normal	2 (3.03%)	8 (12.12%)	14 (21.21%)	18 (27.27%)	24 (36.36%)	0.0024
	Tachypnea	16 (21.92%)	15 (20.55%)	15 (20.55%)	14 (19.18%)	13 (17.81)	
4 hours	Normal	3 (3.80%)	9 (11.39%)	17 (21.52%)	22 (27.85%)	28 (35.44%)	0.0019
	Tachypnea	15 (25%)	14 (23.33%)	12 (20%)	10(16.67%)	9 (15%)	
6 hours	Normal	1 (1.32%)	9 (11.84%_	16 (21.05%)	21 (27.63%)	29 (38.16%)	0.001
	Tachypnea	17 (26.98%)	14 (22.22%)	13 (20.63%)	11 (17.46%)	8 (12.7%)	
12 hours	Normal	4 (4.71%)	10 (11.76%)	18 (21.18%)	23 (27.06%)	30 (35.29%)	0.001
	Tachypnea	14 (25.93%)	13 (24.07%)	11 (20.37%)	9 (16.67%)	7 (12.96%)	

Table 6: Comparative analysis of work of breathing at different intervals between SPO2/FiO2 ratio

Interval	Work of breathing	SPO2/FiO2 Ratio					P value
		< 100	100-149.9	150-199.9	200 - 250	>250	
0 hour	Normal	0	0	0	0	0	-
	Increased	18 (12.95%)	23 (16.55%)	29 (20.86%)	32 (25.02%)	37 (26.62%)	
2 hours	Normal	1 (1.39%)	7 (9.72%)	14 (19.44%)	21 (29.17%)	29 (40.28%)	0.001
	Increased	17 (25.37%)	16 (23.88%)	15 (22.39%)	11 (16.42%)	8 (11.94%)	
4 hours	Normal	2 (2.35%)	8 (9.41%)	19 (22.35%)	23 (27.06%)	33 (38.83%)	0.001
	Increased	16 (29.63%)	15 (27.78%)	10 (18.52%)	9 (16.67%)	4 (7.41%)	
6 hours	Normal	4 (4.12%)	10 (10.31%)	21 (21.65%)	28 (28.87%)	34 (35.05%)	0.001
	Increased	14 (33.33%)	13 (30.95%)	8 (19.05%)	4 (9.52%)	3 (7.14%)	
12 hours	Normal	3 (2.83%)	14 (13.21%)	25 (23.58%)	29 (27.36%)	35 (33.02%)	0.001
	Increased	15 (45.46%)	9 (27.27%)	4 (12.12%)	3 (9.09%)	2 (6.06%)	

Table 7: Comparative analysis of length of stay, mechanical ventilation, and outcome between SPO2/FiO2 ratio

		SPO2/FiO2 Ratio					P value
		< 100	100 - 149.9	150 - 199.9	200 - 250	>250	
Length of stay (days)	Up to 7	3 (3.16%)	8 (8.42%)	23 (24.21%)	28 (29.47%)	33 (34.74%)	0.001
	7-14	9 (29.03%)	12 (38.71%)	4 (12.9%)	3 (9.68%)	3 (9.68%)	
	> 14	6 (46.15%)	3 (23.08%)	2 (15.39%)	1 (7.69%)	1 (7.69%)	
Mechanical ventilation	Absent	2 (1.8%)	18 (16.22%)	25 (22.52%)	30 (27.03%)	36 (32.43%)	0.001
	Present	16 (57.14%)	5 (17.86%)	4 (14.29%)	2 (7.14%)	1 (3.57%)	
Outcome	Improved	13 (9.92%)	22 (16.79%)	28 (21.38%)	31 (23.67%)	37 (28.24%)	0.0072
	Death	5 (62.5%)	1 (12.5%)	1 (12.5%)	1 (12.5%)	0 (0%)	

DISCUSSION

Our study included 139 children, with 43.89% aged < 1 year, 35.97% aged 1–5 years, and 20.14% aged 6–12 years. Regarding nutritional status, 68.35%, 20.14%, and 11.51% of participants were appropriate for age, undernourished, and overnourished, respectively. Among the children on HFNC, 29.50% had wheezing, 28.06% had bronchiolitis, 20.14% had pneumonia, 13.67% had other infections, and 8.63% had sepsis. The spectrum of diagnoses in our children covered various systems, with 29.50% presenting with wheezing, the most common cause of PICU admission for HFNC. This aligns with Kristen et al. (2017), who found that the primary diagnoses for HFNC use were status asthmaticus and bronchiolitis,

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often as a post-extubation therapy.[4] In contrast, an Egyptian study by Rady et al. (2016) identified pneumonia as the most common cause of HFNC therapy in patients in the PICU.[5] Chang et al. (2021) suggest HFNC as first-line therapy for hypoxia-related acute respiratory distress across all age groups.[6] Baudin et al. (2016) found HFNC to be well-tolerated by paediatric ICU patients.[7]

In our study, all children exhibited tachycardia, tachypnoea, and increased work of breathing upon admission. Tachycardia decreased to 54.68%, 41.73%, 33.81%, and 29.50% at 2, 4, 6, and 12-hour intervals respectively. Tachypnoea decreased to 52.52%, 43.32%, 43.17%, and 38.25% at the same intervals. Bressan et al. (2013) concluded that HFNC therapy decreased respiratory distress in the first 4 hours of initiating therapy and improved the oxygenation status of infants.[8]

In our study, the length of hospital stay, requirement of mechanical ventilation, and outcomes among the children were significantly associated with the SPO2/FiO2 ratio. The maximum number of children who stayed in the hospital for > 14 days (46.15%) had an SPO2/FiO2 ratio < 100. The maximum number of children escalated to mechanical ventilation (57.14%) had an SPO2/FiO2 ratio of < 100. The maximum population of children with improved outcomes (28.24%) had an SPO2/FiO2 ratio of > 250, the maximum death rate (62.50%) was observed in children with an SPO2/FiO2 ratio of < 100, and there were no deaths in children with an SPO2/FiO2 ratio of > 250. Milani et al. observed that the need for oxygen was decreased in the HFNC group and also the duration of hospital stay decreased in the paediatric population who were started on HFNC therapy for bronchiolitis.[9]

Wing et al. (2012) proposed that early initiation of HFNC therapy in emergency departments decreased the intubation rate.[10] Mckieman et al. (2010) also documented a fall in intubation rate from 23% to 9% after the introduction of HFNC.[11] Koyauchi et al. (2020) concluded that Spo2/Fio2 ratio at 24 hrs after initiating HFNC was a good predictor of successful HFNC treatment in adults with ILD.[12]

CONCLUSION

Our study shows that pulse oximetric saturation to the fraction of inspired oxygen ratio can be a reliable, effective, and non-invasive early predictor of HFNC therapy outcomes. Failure to raise the SF ratio after initiation of HFNC therapy indicates a need for escalation of the mode of ventilation. This non-invasive and early predictor could decrease the rate of delayed intubation in the emerging era, where HFNC is the preferred mode of ventilation in most paediatric intensive units.

Limitations: This study had several limitations, including that the SP ratio was measured only in children, and the corresponding PF ratio, the most accurate marker of effective ventilation, was not measured. Only the SP ratio values at 6 h were considered, without tracking the trend throughout ventilation, and a specific SP ratio cutoff was not established; only the range of SP ratios was used as a prognostic marker. The SP ratio values were broad and not disease-specific, limiting their effectiveness. This study did not account for the influence of antibiotics and microbial toxaemia on the recovery of children, and the broad age group with a small number of cases may have limited the findings.

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