Observational Study

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Can a pulse oxygen saturation of 95% to 96% help predict further vital sign destabilization in school-aged children?

A retrospective observational study

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Abstract

To determine whether a peripheral capillary oxygen saturation (SpO_2) of 95% to 96% should be considered "nonurgent" in school-aged children, as suggested by the Canadian Emergency Department Triage and Acuity Scale.

School-aged children (6–12 years old) with a normal body temperature (36.5–37.4°C) who visited our department between September, 2014 and August, 2015 (n = 4556) were divided into 4 groups based on SpO_2: group A: 99% to 100%; group B: 97% to 98%; group C: 95% to 96%; and group D: ≤94%. The heart rate (HR), respiratory rate (RR), and hospitalization rate were compared among the groups, and also between children with SpO_2 95% to 96% and matched controls with SpO_2 ≥97% (n = 280 each).

Among 4556 eligible patients, groups A, B, C, and D comprised 2700 patients (59.3%), 1534 patients (33.6%), 280 patients (6.2%), and 42 patients (0.9%), respectively. The median (interquartile range [IQR]) RR significantly increased with decreasing SpO_2 (23 [20–25], 24 [20–26], 24 [23–30], and 30 [24–40] breaths/min in groups A–D, respectively; $P < .001$). Similarly, the median (IQR) HR significantly increased with decreasing SpO_2 (93 [83–104], 98 [87–110], 107 [93–119], and 121 [109–137] bpm, groups A-D, respectively; $P < .001$). Group D had the highest annual hospital admission rate (18 cases/42 patients, 42.9%). Further, the HR and RR differed significantly between the cases (107 [93–119] bpm; 24 [23–30] breaths/min) and controls (96 [86–106] bpm; 24 [20–28] breaths/min, respectively) ($P < .001$ and $P = .02$, respectively).

An SpO_2 of 95% to 96% among school-aged children should not be considered "nonurgent," but rather a significant clinical situation that requires early review of HR and RR. Prompt interventions among this group of children will help prevent further destabilization of vital signs, which will, in turn, contribute to decreased healthcare costs.

Abbreviations: 95% CI = 95% confidence interval, CTAS = Canadian Emergency Department Triage and Acuity Scale, HR = heart rate, IQR = interquartile range, PEWS = Pediatric Early Warning System, RR = respiratory rate.

Keywords: Canadian Triage and Acuity Scale, heart rate, respiratory rate, school-aged population, SpO_2

1. Introduction

Peripheral capillary oxygen saturation (SpO_2) is widely used to assess urgency during pediatric care, and is generally included in a child's vital sign assessment.[1] The criterion of SpO_2 is included in some triage systems, including the Canadian Emergency Department Triage and Acuity Scale (CTAS), Emergency Severity Index, Australian Triage Scale, and Manchester Triage System.[2] The 5-level Pediatric CTAS triage system (level I, resuscitate; level II, emergent; level III, urgent; level IV, less emergent; and level V, nonurgent) is based on presenting complaints and medical conditions of children and has been used in the pediatric emergency setting of leading Japanese healthcare institutes for over 10 years.

Although an SpO_2 <95% is considered abnormal in the CTAS and in most asthma and pneumonia guidelines, there is no description of the standard value.[2] Furthermore, although conventional wisdom states that pulse oximetry levels ≥95% should be considered normal, data from previous studies suggest that the normal oxygen saturation range should lie between 97% and 100%.[1–7] Therefore, oxygen saturation levels of 95% and 96% in school-aged children may correlate with an increased risk of an underlying clinical disease.[3] If oxygen saturation levels of 95% to 96% can be used to predict the development of vital sign instability and other medical conditions in children, the current CTAS definition of a "nonurgent" medical condition within an emergency setting may need to be modified. Thus, this study aimed to clarify whether oxygen saturation levels of 95% to 96% in patients visiting pediatric clinical departments constitutes a "nonurgent" situation.

2. Methods

This retrospective, population-based, observational study was conducted in the Pediatric Emergency Center of Kitakyushu

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Municipal Yahata Hospital, Japan, using data obtained from September, 2014 through to August, 2015. The hospital is a tertiary referral center for the community pediatric department and is located 19 m above sea level. The reporting guidelines for STROBE were used in the design and implementation of our research. Patient data were collected from electronic medical charts.

For the survey target population, school-aged children who undergo consultation in the general hospital for intrinsic or extrinsic reasons were targeted.[8]

Of the patients who underwent triage by the Pediatric Early Warning System (PEWS)[9–11] in our hospital during the study period, we included school-aged children (6–12 years old) with a normal body temperature (36.5–37.4°C). The children were divided into 4 groups based on their SpO_2 level: group A—99% to 100%; group B—97% to 98%; group C—95% to 96%; and group D—≤94%.

The primary outcomes were differences in heart rate (HR), respiratory rate (RR), and hospitalization rate between the groups. The HR, RR, and SpO_2 were measured concomitantly. The Kruskal–Wallis test was used to compare the median values of continuous variables (such as age) and the proportions of categorical variables between groups. Data for nonparametric continuous variables were expressed as the median ± interquartile range (IQR). In addition, differences in the hospitalization rates were calculated using the chi-square test. For comparison between children with an SpO_2 of 95% to 96% and a control group of age and sex-matched children with an SpO_2 ≥97%, the control group was selected from among 4234 cases of SpO_2 ≥97%. As a total of 280 patients had an SpO_2 of 95% to 96%, a matching cohort of 280 patients was selected as the control group. To compare these 2 groups, the Mann–Whitney *U* test was used for all analyses except for the hospitalization rate, which was calculated using the chi-square test. The results were analyzed using PRISM software (version 7; GraphPad, San Diego, CA). The threshold for significance was $P < .05$.

Study approval was obtained from the Institutional Review Board of the Pediatric Emergency Center at the Kitakyushu Municipal Yahata Hospital. As the study data were anonymous, the requirement for informed consent was waived.

3. Results

Of the total 41,512 patients who underwent triage during the study period, children who were ≤5 years old or ≥13 years old were excluded (n = 31,814) along with those who had errors in their medical records regarding SpO_2 (n = 12). After applying the exclusion criteria, 4556 children aged 6– to 12 years with a normal body temperature were included (Fig. 1). Of these, 2700 (59.3%), 1534 (33.6%), 280 (6.2%), and 42 (0.9%) patients were classified as groups A (SpO_2, 99%–100%), B (SpO_2, 97%–98%), C (SpO_2, 95%–96%), and D (SpO_2, ≤94%), respectively.

The median (IQR) RR increased significantly as the SpO_2 decreased: group A, 23/min (20–25/min); group B, 24/min (20–26/min); group C, 24/min (23–30/min); and group D, 30/min (24–40/min) ($P \leq .01$) (Fig. 2A). Similarly, the median (IQR) HR increased significantly as the SpO_2 decreased: group A, 93 beats per minute (bpm) (83–104 bpm); group B, 98 bpm (87–110 bpm); group C, 107 bpm (93–119 bpm); and group D, 121 bpm (109–137 bpm) ($P < .001$) (Fig. 2B). The hospitalization rate showed a significant rise with decreasing SpO_2: group A, 3.8% (95% confidence interval [CI] 3.1%–4.5%); group B, 4.9% (95% CI 3.7%–5.8%); group C, 10.7% (95% CI 7.1%–14.3%); and Group D, 42.9% (95% CI 27.9%–57.8%) ($P < .001$).

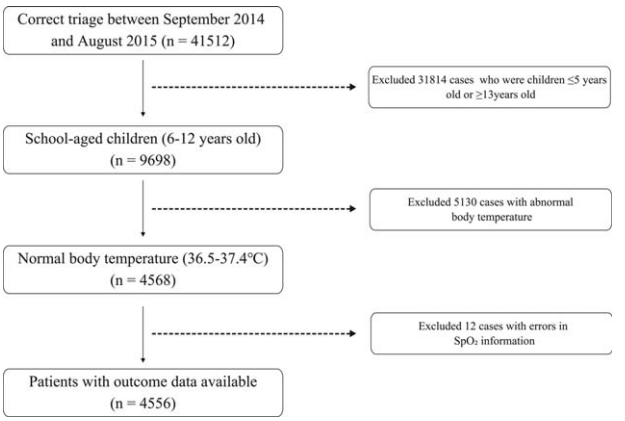

Figure 1. Study flow for participant inclusion. Patients who were 6 to 12 years in age and who had a clear description of their SpO_2 in their medical chart were eligible for enrollment in the study. Children aged 5 years or younger or those older than 13 years were excluded. All children who had unclear SpO_2 descriptions were also excluded.

The median (IQR) HRs and RRs were significantly different between cases (107 bpm [93–119 bpm] and 24/min [23–30/min], respectively; $P < .001$) and controls, (96 bpm [86–106 bpm] and 24/min [20–28/min], respectively; $P = .02$) (Table 1). The hospitalization rate was significantly higher for the case group (n = 30, 11%) compared with the matched control group (n = 12, 4%; $P = .006$; Table 1). Asthma-related diseases were present in 38% and 9% of the case group and control group, respectively.

Finally, we performed subgroup analyses of the differences in the HR, RR, and hospitalization rate between the 2 groups among children with asthma (30/200 cases in each group). This showed that the HR was significantly different, at 105 bpm versus 97 bpm ($P < .001$) in cases versus controls. However, the RR did not differ between the 2 groups ($P = .50$), whereas the hospitalization rate tended to be higher in the 95% to 96% group compared with the 97% to 100% group (20% vs 10%; $P = .06$).

4. Discussion

In the present study, RR, HR, and hospitalization rate were significantly higher in school-aged children with an SpO_2 of 95% to 96% compared with those with an SpO_2 of 97% to 100%. Further, the observed increase in heart rate among the 95% to 96% saturation group caused the PEWS score to rise by 2 points, and in patients with a saturation of ≤94%, the PEWS score went up by 3 or more points. Moreover, when considering the HR increase in the 95% to 96% group, the patient presentation was at level 3 or 4 rather than level 5 according to the CTAS.

Although the hospitalization rate of group C (SpO_2, 95%–96%) was only 10%, this hospitalization rate was 2.2 times higher than that of group B (SpO_2, 97%–98%), and 2.8 times higher than that of group A (SpO_2, 99%–100%). In addition, the hospitalization rate in group D (SpO_2, ≤94%) was approximately 40%, which was 4 times higher than that in group C. Taken together, these findings suggest that a patient's oxygen saturation may help predict the severity of a condition, and also underscore a need for closer patient observation. Accordingly, if a patient is not living at a high altitude, an SpO_2 of 95% to 96%

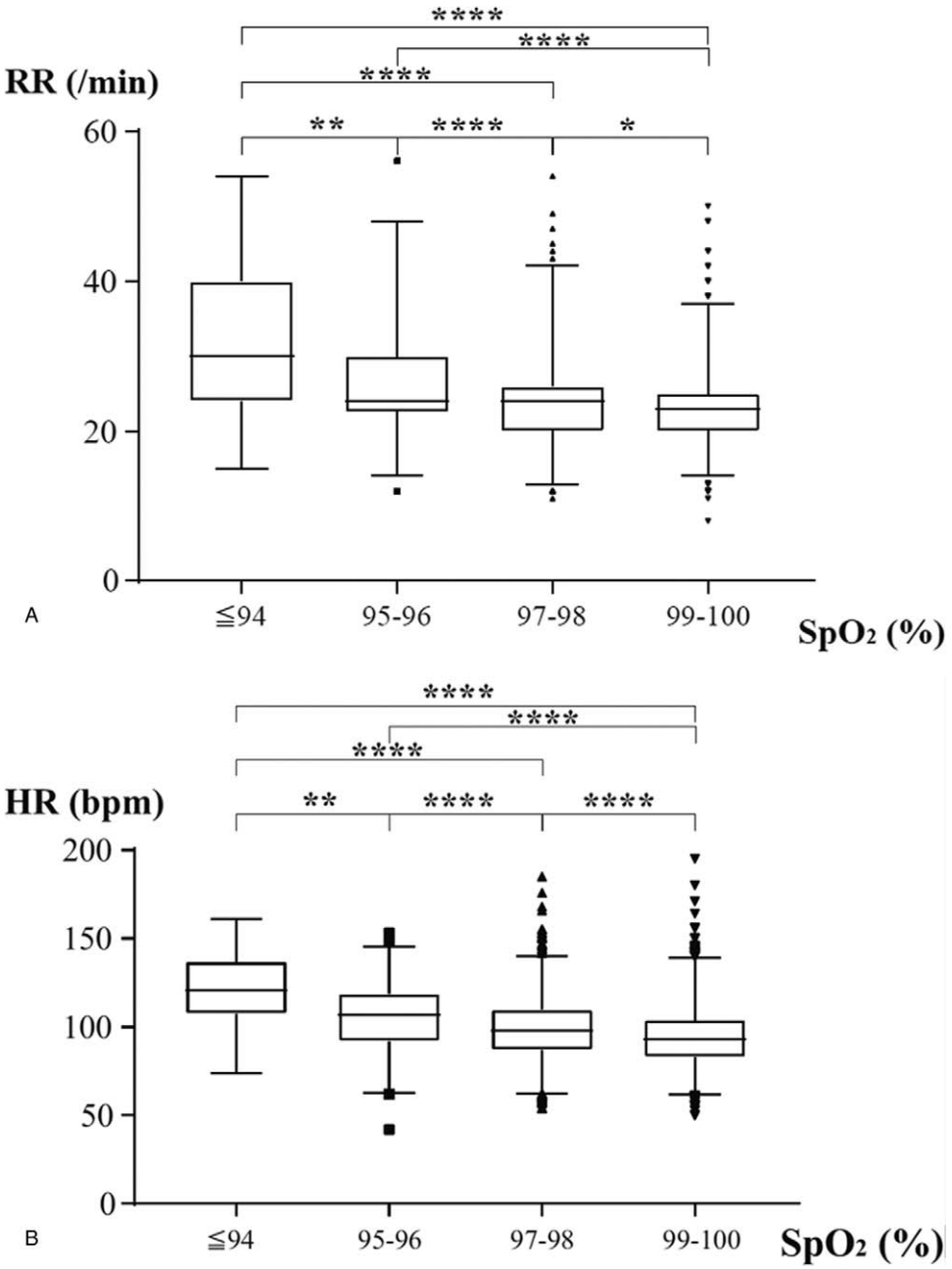

Figure 2. (A) Distribution of respiratory rate (RR) values in children aged 6 to 12 years (n = 4556) according to the peripheral capillary oxygen saturation (SpO_2) groups. (B) Distribution of heart rate (HR) values in children aged 6 to 12 years (n = 4556) according to the SpO_2 groups. The horizontal line through the center of each box represents the median value, the top of the vertical bar going through the box is the maximum value of the 1st to 99th percentile, and the bottom end of the vertical bar going through the box is the minimum value of the 1st and 99th percentile. *P = .035, **P = .005, ****P < .001.

should not be dismissed as "nonurgent" in the setting of pediatric emergencies. Of note, in this study, although there was a statistically significant difference in the RR, there was no clinically significant difference in the RR between the groups with SpO_2 95% to 96% and 97% to 100%. In contrast, the HR in the group with SpO_2 95% to 96% was significantly higher than in the group with SpO_2 97% to 100%, both statistically and clinically.

A recent retrospective cohort study reported that oxygen saturation of 95% to 96% is adequate for children who are admitted in hospital; however, it was reported that these values are associated with respiratory infection of the airway, pulmonary, or cardiovascular systems.[12] The same was also considered from the ratio of diseases hospitalized in the 95% to 96% group in this study. Previous reports have suggested that an SpO_2 $\leq$95% is abnormal and requires intervention, particularly in patients with pneumonia or asthma.[1,4] Moreover, 1 study suggested that an SpO_2 $\geq$97% is common in healthy school-aged children.[3] Despite these reports, a global standard value for SpO_2 in children has not been established.[1] Normal values for SpO_2 have recently been reported in various populations.[1,5–7] An SpO_2 $\geq$97% was reportedly normal in a study performed in

Table 1

Comparison between patients 6 and 12 years of age with an oxygen saturation of 95% to 96% and matched controls with an oxygen saturation of 97% to 100%.

	Cases (n = 280)	Control (n = 280)	*P*
Variables			
Age, y	8 (7–10)	8 (6–9)	
Sex, males	183 (65)	195 (70)	
Females	97 (35)	85 (30)	
Body temperature, °C	36.9 (36.7–37.1)	36.9 (36.7–37.1)	
Respiratory rate, breaths/min	24 (23–30)	24 (20–28)	.023
Heart rate, bpm	107 (93–119)	96 (86–106)	<.001
Hospitalization	32 (11)	14 (5)	.0058
Disease			
Neurological disorders	20 (7)	26 (9)	
Upper respiratory infection	47 (17)	60 (21)	
Pneumonia, atelectasis	18 (6)	11 (4)	
Asthma, asthmatic bronchitis	106 (38)	26 (9)	
Gastroenteritis	25 (9)	32 (11)	
Trauma, extrinsic disease	17 (6)	32 (11)	
Allergy and rash	10 (4)	19 (7)	
Other	37 (13)	74 (26)	
Reason for hospitalization			
Neurological disorder	1 (3)		
Upper respiratory infection	1 (3)	1 (7)	
Pneumonia, atelectasis	5 (15)		
Asthma, asthmatic bronchitis	16 (50)		
Gastroenteritis	2 (6)	7 (50)	
Allergy and rash	1 (3)		
Other	6 (19)	6 (42)	

Data are reported as n (%) or median (interquartile range).
bpm = beats per minute.

Hawaii,[5] whereas an SpO_2 of 98.5% was considered the reference value for children aged 1 month to 5 years in India.[6] In Papua New Guinea, the median SpO_2 was 98% (95% CI 97.5%–98.0%) for 5-year-old children.[7] In the United States, the mean SpO_2 was 98.7% (95% CI 98.6%–99.8%) for children aged 5 to 15 years old.[1] Therefore, an SpO_2 of 95% to 96% in school-aged children living at sea level should not be dismissed as a "nonurgent" presentation, but instead understood as a condition that has clinical significance for the pediatric emergency care setting. There have been some documented reports demonstrating a decrease in mean oxygen saturation and HR with increasing altitude.[13,14] For this reason, the findings of the present study are relevant only at sea level.

The present study has some limitations. First, this was a retrospective study conducted in a single center. Therefore, selection bias could be present. Moreover, because our hospital is an emergency hospital, treatment and hospital bias could also exist. Second, it is difficult to evaluate vital signs in children due to their tendency of becoming emotional and restless, both of which can result in HR and RR fluctuations. Therefore, standardized measurement methods are needed, and also future prospective studies to record and analyze the response and time to response for saturation level. Finally, we did not study relationships between saturation and specific disease types or compare these with changes in HR and RR. Therefore, future studies are warranted to evaluate these potential relationships.

This is the first known study of the relationship between oxygen saturation levels and adverse events in pediatric emergency patients with normal body temperature at sea level. We demonstrated that the RR, HR, and hospitalization rate were significantly higher in school-aged children with an SpO_2 of 95% to 96% compared with those with an SpO_2 of 97% to 100%. These results suggest that an SpO_2 of 95% to 96% should not be dismissed as nonurgent. Instead, careful review of HR and RR should be conducted to facilitate timely assessments and interventions, thereby decreasing the associated healthcare costs. Furthermore, by understanding early signs of vital sign destabilization among school-aged children, the quality of triage decision-making could be improved.

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Author contributions

MK and SF conceived the study and its design; MK, SF, KT, and JK collected the data; SF, KT, JK, and KI managed, analyzed, and interpreted the data. All authors have read and approved the final manuscript. This manuscript has not been published or presented elsewhere in part or in entirety and is not under consideration by another journal.

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