

# Admission predictability of children with acute asthma

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## Abstract:

**OBJECTIVES:** We aimed to evaluate the seasonal variations of acute asthma presentation in children and the utility of the pediatric asthma score (PAS) and its components in early admission prediction.

**METHODS:** As part of a randomized controlled trial addressing the clinical efficacy of budesonide nebulization in the treatment of acute asthma in children, the PAS was measured at baseline, 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup>, and 4<sup>th</sup> h from the start of medications. Decision of admission was taken at or beyond the 2<sup>nd</sup> h.

**RESULTS:** Out of a total 906 emergency department (ED) visits with moderate-to-severe acute asthma, 157 children were admitted. June to September had the lowest number of visits. The admission-to-discharge ratio varied throughout the year. During the ED stay, between baseline and 3<sup>rd</sup> h, admission predictability of the total score improved progressively with a small difference between the 2<sup>nd</sup> and 3<sup>rd</sup> h. The total score remained the strongest predictor of admission at every time point compared to its individual components. The drop of PAS from baseline to the 2<sup>nd</sup> h was not a good predictor of admission. Oxygen saturation (OS) and respiratory rate (RR) had relatively higher predictability than other components.

**CONCLUSIONS:** Decision of admission could be made to many children with moderate-to-severe acute asthma at the 2<sup>nd</sup> h of ED stay based on their total PAS. OS and RR should be part of any scoring system to evaluate acute asthma in children.

## Keywords:

Acute asthma, admission, children, emergency, exacerbation

Asthma is the most prevalent chronic illness of childhood, and acute asthma is one of the most common complications of the disease that contributes significantly to health-care burden. Acute asthma has been defined as “episodes of progressive increase in shortness of breath, cough, wheezing, or chest tightness or some combination of these symptoms.”<sup>[1,2]</sup> More recently, a group of experts proposed a definition of “a worsening of asthma requiring the use of systemic corticosteroids to prevent a serious outcome.”<sup>[3]</sup> In the US, 2.3% of all emergency department (ED) visits and about 5.6% of all hospitalizations among children were attributed to acute asthma.<sup>[4]</sup> In Saudi Arabia, one center reported that over 1 year, an average of 5.7% of all ED visits were secondary to acute asthma.<sup>[5]</sup>

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This ratio can rise to 13.7% during the winter season as reported by another study from a different hospital.<sup>[6]</sup>

A proportion of children presenting to the ED with acute asthma are eventually admitted to the hospital with an estimated rate ranging from 7% to 23%.<sup>[7,8]</sup> This is determined by several variables including age, sex, the baseline severity of exacerbation,<sup>[9]</sup> early response to treatment in the ED (within the 1<sup>st</sup> h),<sup>[10]</sup> and the level of control of asthma symptoms in the past.<sup>[11]</sup> The severity of acute asthma is determined based on symptoms and signs such as respiratory rate (RR), wheezing, retractions, and oxygen saturation (OS). In addition, direct indicators of bronchoconstriction such as peak expiratory flow rate or forced expiratory volume in the first second (FEV<sub>1</sub>) are very useful tools for assessing asthma severity when applicable.<sup>[12]</sup>

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There are several scores used in research and sometimes in clinical practice to evaluate the severity of acute asthma in a more standardized and accurate way. These scores vary considerably in the parameters they use and in the grading of each parameter. In this study, we aimed to evaluate the utility of the pediatric asthma score (PAS) in predicting admission to the hospital at different time points and the contribution of each of its components in this regard by utilizing data from a cohort of patients composed of all children presenting with moderate-to-severe acute asthma to the ED of a major children's hospital in Riyadh, Saudi Arabia, over 17 months' duration as part of a clinical trial.<sup>[13]</sup>

## Methods

### Study design and population

Children 2–12 years of age who are presenting to the ED with acute asthma exacerbation were screened using the PAS<sup>[14]</sup> [Table 1]. The diagnosis of asthma was determined based on history of physician-diagnosed asthma or previous episode of shortness of breath that responded well to  $\beta$ 2-agonist. The data were collected as part of a clinical trial on the efficacy of budesonide 500 mcg given 3 times in the 1<sup>st</sup> h of treatment mixed with  $\beta$ 2-agonist and ipratropium bromide by nebulization to children presenting with moderate or severe asthma exacerbation (score >7). Another control group received normal saline placebo instead of budesonide. Prednisone or prednisolone 2 mg/kg (maximum 60 mg) was given at the beginning of treatment to all patients. Additional doses of  $\beta$ 2-agonist were given at the discretion of the treating physician but maximally one dose every 30 min. More information was taken including family history, triggers of exacerbation, past history, and past use of rescue and prophylactic medications. Patients who were critically ill, had heart or chronic lung disease, or received systemic steroids within the past 7 days were excluded from the study.

PAS was measured at baseline (screening), 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup>, and 4<sup>th</sup> h from the start of medications. Decision for admission was taken at 2, 3, or 4 h if the patient did not show satisfactory improvement. Patients who showed improvement but were not fit for discharge were kept in the ED to receive additional doses of albuterol. Discharge criteria were no accessory muscle use, minimal or completely resolved wheezing, and OS >92%. At the 4<sup>th</sup> h time point, a decision to either admit or discharge had to be finally made.

### Statistical analysis

Receiver operator characteristic (ROC) curves were drawn by comparing and contrasting the scores of the eventually discharged and admitted patients at baseline, 1<sup>st</sup>, 2<sup>nd</sup>, and 3<sup>rd</sup> h. The sensitivity and specificity of the total PAS and each of its components was calculated at different points to calculate the area under the curve (AUC), which was utilized as a measure of predicting admission to the hospital. All data were analyzed using GraphPad Prism version 6 (GraphPad Software, San Diego, CA, USA).

## Results

### Frequency of admission and discharge

Within a 17 months' study period, from November 2010 to March 2012, 906 visits by children with moderate-to-severe acute asthma were made to the ED. Out of which, 157 resulted in admission. March had the highest number of ED visits within the year. A number of visits during January, February, April, May, October, November, and December were high and comparable while June, July, August, and to some extent, September had relatively low number of visits [Figure 1]. The ratio of admission to discharge varied throughout the year. The main characteristics of patients who were admitted or discharged are shown in Table 2. The two groups did not differ in their demographic and prehospital treatment features. Children were not admitted or discharged at

**Table 1: Pediatric asthma score**

Variable	Asthma score		
	1 point	2 points	3 points
Respiratory rate (breaths/min)			
2-3 years	≤34	35-39	≥40
4-5 years	≤30	31-35	≥36
6-12 years	≤26	27-30	≥31
>12 years	≤23	24-27	≥28
Oxygen saturation (%)	>95 with room air	90-95 with room air	<90 with room air or supplemental oxygen
Auscultation	Normal breathing or end-expiratory wheezing	Expiratory wheezing	Inspiratory and expiratory wheezing, diminished breath sounds, or both
Retractions	None or intercostal	Intercostal and substernal	Intercostal, substernal, and supraclavicular
Dyspnea	Speaks in sentences or coos and babbles	Speaks in partial sentences or utters short cries	Speaks in single words or short phrases or grunts

baseline or 1<sup>st</sup> h, but at the 2<sup>nd</sup> h, 446 were discharged and only 6 children were admitted. The rest of the patients had their data available for analysis at the 3<sup>rd</sup> h.

**Predictability of admission**

The ability of the total score and each of its components to predict admission was assessed at baseline, 1<sup>st</sup> h, 2<sup>nd</sup> h, and 3<sup>rd</sup> h using the AUC of ROC curves [Figure 2a-d]. The magnitude of drop of the score from baseline to 2<sup>nd</sup> h, representing clinical improvement during that time, was also evaluated [Figure 2d]. The ability of the total score to predict admission at the 3<sup>rd</sup> h was highest followed by the 2<sup>nd</sup> h with only small difference (0.03) in

the AUC and intersecting confidence intervals [Table 3]. However, there was a greater difference between the 2<sup>nd</sup> and 1<sup>st</sup> h (0.06) and even more difference between the 1<sup>st</sup> h and baseline (0.11) with no shared values in the confidence intervals [Table 3]. Predictability of the total score was also higher than each individual component at each time point. Among the PAS components, RR and OS had more weight than other parameters at the 2<sup>nd</sup> and 3<sup>rd</sup> h but not as baseline or 1<sup>st</sup> h. On the other hand, the AUC of the drop of the total score from baseline to 2<sup>nd</sup> h was less than the AUC of the total score at baseline and interestingly less than AUC of the drop in RR at the 2<sup>nd</sup> h [Figure 2e].

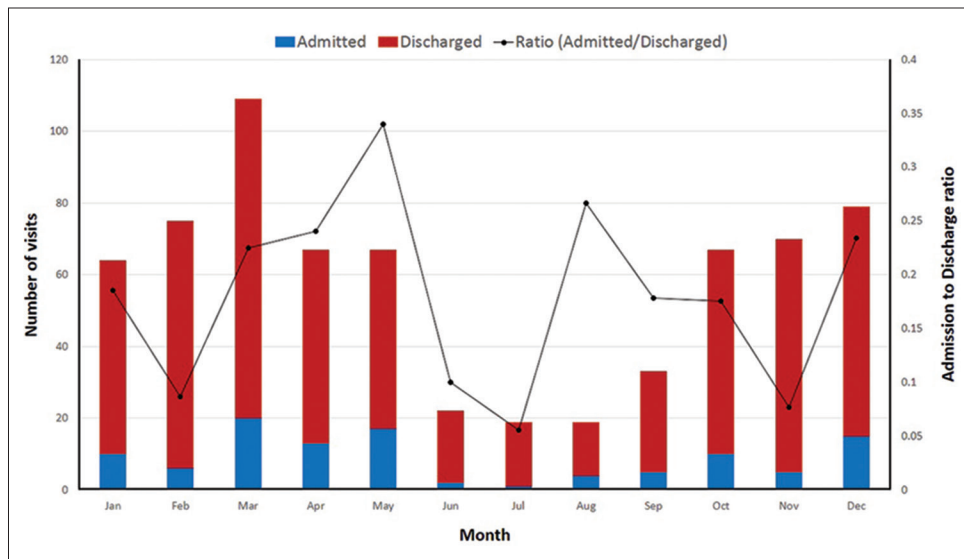


Figure 1: Frequency chart showing the distribution of admitted and discharged children with acute asthma and their ratio from the emergency department over 1 year

**Table 2: Characteristics of admitted and discharged patients**

	Admitted (n=157), n (%)	Discharged (n=749), n (%)	Total (n=906), n (%)
Gender (female)	62 (39.5)	255 (33)	317 (35)
2-6 years old	108 (68.8)	507 (67.7)	615 (67.9)
7-12 years old	49 (31.2)	242 (32.3)	291 (32.1)
Smokers at home	33 (21)	137 (18.3)	170 (18.8)
Pets at home	13 (8.2)	55 (7.3)	68 (8)
Previous ED visits	146 (92.9)	699 (93.3)	845 (93)
Use of β2-agonists	137 (87.3)	565 (75.4)	702 (77.5)
Use of inhaled corticosteroids	54 (36.3)	183 (24.4)	273 (30)

ED=Emergency department

**Table 3: Area under the curve of receiver operator characteristic curves for each score parameter and total scores at every time point**

PAS parameter	AUC (95% CI)			
	Baseline	1 h	2 h	3 h
Respiratory rate	0.56 (0.51-0.6)	0.7 (0.66-0.75)	0.78 (0.74-0.82)	0.83 (0.79-0.87)
Oxygen saturation	0.67 (0.62-0.72)	0.76 (0.7-0.8)	0.80 (0.76-0.84)	0.80 (0.76-0.85)
Auscultation	0.64 (0.58-0.68)	0.7 (0.65-0.75)	0.72 (0.67-0.77)	0.72 (0.67-0.78)
Retraction	0.64 (0.59-0.69)	0.7 (0.65-0.75)	0.72 (0.67-0.77)	0.71 (0.65-0.77)
Dyspnea	0.65 (0.6-0.7)	0.65 (0.59-0.7)	0.60 (0.53-0.65)	0.56 (0.50-0.62)
Total score	0.74 (0.7-0.79)	0.85 (0.82-0.88)	0.91 (0.89-0.93)	0.94 (0.91-0.96)

AUC=Area under the curve, CI=Confidence interval, PAS=Pediatric asthma score

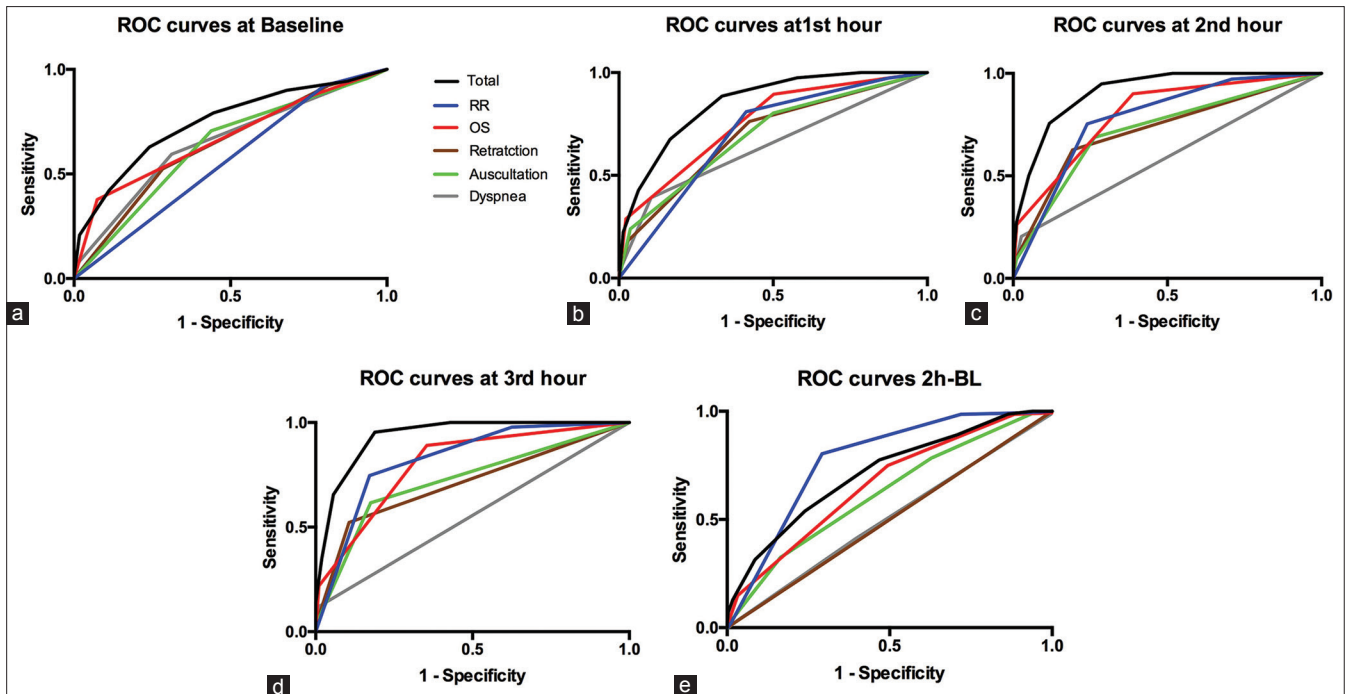


Figure 2: Receiver operator characteristic curves of the acute asthma scores at (a) baseline, (b) 1<sup>st</sup> h, (c) 2<sup>nd</sup> h, (d) 3<sup>rd</sup> h, and (e) the difference in score between the 2<sup>nd</sup> h and baseline. RR: Respiratory rate, OS: Oxygen saturation

## Discussion

During June, July, August, and September the number of children presented to the ED dropped markedly. This is mainly attributed to the decrement in the incidence of upper respiratory tract infections.<sup>[15,16]</sup> Another possible factor is that many city residents travel abroad during the summer vacation, especially in July and August. The increased number of children with acute asthma presenting to the ED and subsequently the increased number of admission during March of that year is likely to be due by the unusual occurrence of several thunderstorms during that month in 2011. Thunderstorms are known to substantially increase the number and severity of asthma exacerbations.<sup>[17]</sup> Seasonal variation was also observed in other studies that were done in different geographical areas. For instance, two different studies, one in Toronto and another from 117 EDs in Korea, showed that the highest number of pediatric ED visits due to acute asthma was during winter.<sup>[18,19]</sup> In contrast, June was reported to have a higher number of admissions of asthmatic children in the Caribbean island of Trinidad, and this was attributed to the wave of the Saharan dust cloud during that month.<sup>[20]</sup>

The ROC curve analysis showed that the ability of PAS to predict admission improves with time during the first 3 h in the ED after starting treatment. The small difference in the AUC between the 2<sup>nd</sup> and 3<sup>rd</sup> h suggests that more patients could possibly be admitted earlier at the 2<sup>nd</sup> h. Studies should be conducted to assess the appropriate

score above which children with acute asthma should be admitted at that time point. This may be very helpful in an overcrowded ED. On the other hand, the response to therapy at the 2<sup>nd</sup> h as judged by the improvement in asthma score from baseline was a much weaker predictor of admission compared to the total asthma score even at baseline and therefore should not be used to predict admission.

Assessing each component of the PAS separately showed variable results. OS had relatively high predictability at all-time points while RR showed improved predictability as time progressed, and dyspnea was overall the weakest predicting parameter and showed weaker predictability with time but still had some added value. Moderate predictability was seen with auscultation and retraction. The total score, however, remained the strongest predictor of admission at every time point. Surprisingly, improvement in RR at the 2<sup>nd</sup> h from baseline was a better predictor than the drop of the total score. This is interesting, especially that the RR was not among the discharge criteria in the original study.<sup>[13]</sup> Furthermore, in the original study, it was noted that a drop of a single point at the lower scale of the score has a much less influence on the likelihood of admission than a drop of a single point at the higher end of the score scale. This has to be taken in consideration when making modifications to the PAS in the future with more weight needs to be given to the RR and OS than to other parameters to make it more accurate. Other recent studies concurred that OS is a major predictor of admission in children with acute asthma<sup>[21]</sup> and that RR is a reliable

physical sign of respiratory distress and correlates well with measures of lung function such as FEV<sub>1</sub>.<sup>[22]</sup>

Several different scoring systems are utilized to assess patients with acute asthma. For example, hourly measurements of the Pediatric Respiratory Assessment Measure (PRAM)<sup>[23]</sup> score showed that predicting the need of hospitalization of acute asthma patients improves with time in the ED, consistent with our findings. It is worth noting that some acute asthma severity scores, such as pulmonary index score,<sup>[24]</sup> respiratory clinical score,<sup>[25]</sup> and Pediatric Asthma Severity Score,<sup>[26]</sup> do not include OS. On the other hand, PRAM and the modified Woods–Downes asthma scores do not include the RR. This may reduce the accuracy of these scores. In addition, although not evaluated in this study, adding the effect of high-risk asthma indicators such as previous ED visits could strengthen the predictability of hospitalization.<sup>[27]</sup>

### Limitations

The study was conducted in a single center; this may limit the generalizability of the results. In addition, other factors that may influence patients' admission and were included in other scores were not taken into account in the PAS such as inspiratory/expiratory ratio, air entry, and mental status and therefore were not possible to evaluate.

### Conclusions

Admitting more children with acute asthma earlier based on their asthma score, especially when ED beds are on very high demand, could save a lot of valuable time and money. The decision to admit patients with acute asthma should not solely be made on any individual component of the asthma score. There is a great need to have a standardized acute asthma severity score that includes all the important clinical determinants of acute asthma and gives each one an appropriate weight. This will help advance the medical care of acute asthma patients as well as research.

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- The manuscript has been read and approved by all the authors, the requirements for authorship have been met, and each author believes that the manuscript represents honest work
- An abstract was presented at the Saudi Pediatrics Association meeting in Riyadh on 7–9 February 2017.

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### Conflicts of interest

There are no conflicts of interest.

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