Development of the Siriraj Clinical Asthma Score

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Summary

Introduction: **Acute asthmatic attack in children commonly occurs despite the introduction of effective controllers such as inhaled corticosteroids and leukotriene modifiers. Treatment of acute asthmatic attack requires proper evaluation of attack severity and appropriate selection of medical therapy. In children, measurement of lung function is difficult during acute attack and thus clinical asthma scoring may aid physician in making further decision regarding treatment and admission.**

Methods: **We enrolled 70 children with acute asthmatic attack with age range from 1 to 12 years (mean ± SD = 51.5 ± 31.8 months) into the study. Twelve selected asthma severity items were assessed by 2 independent observers prior to administration of salbutamol nebulization (up to 3 doses at 20 minutes interval). Decision for further therapy and admission was made by emergency department physician. Three different scoring systems were constructed from items with best validity. Sensitivity, specificity and accuracy of these scores were assessed. Inter-rater reliability was assessed for each score. Review of previous scoring systems was also conducted and reported.**

Results: **Three severity items had poor validity, i.e., cyanosis, depressed cerebral function, and I:E ratio ($p > 0.05$). Three items had poor inter-rater reliability, i.e., breath sound quality, air entry, and I:E ratio. These items were omitted and three new clinical scores were constructed from the remaining items. Clinical scoring system comprised retractions, dyspnea, O_2 saturation, respiratory rate and wheezing (range of score 0-10) gave the best accuracy and inter-rater variability and were chosen for clinical use – Siriraj Clinical Asthma Score (SCAS).**

Conclusion: **A Clinical Asthma Score that is simple, relatively easy to administer and with good validity and variability is essential for treatment of acute asthma in children. Several good candidate scores have been introduced in the past. We described the development of the Siriraj Clinical Asthma Score (SCAS) in this report and reviewed the literature on the development of clinical asthma score for use in children.** ***(Asian Pac J Allergy Immunol 2013;31:210-6)***

Key words: *asthma, acute asthmatic attack, clinical asthma score, children*

Abbreviation:

CAS	=	Clinical asthma score
CAES	=	Clinical Asthma Evaluation Score
ED	=	Emergency department
I:E ratio	=	Inspiratory:expiratory time ratio
PASS	=	Pediatric Asthma Severity Score
PEFR	=	Peak expiratory flow rate
PI	=	Pulmonary Index score
PRAM	=	Preschool Respiratory Assessment Measure
RDAI	=	Respiratory Distress Assessment Index
SCAS	=	Siriraj Clinical Asthma Score

Introduction

Asthma is the most common chronic disease in children affecting approximately 10% of childhood population worldwide.[1] Up to 50% of children will wheeze prior to the age of 6 years.[2] However, only less than 20% of these children will continue to wheeze into late childhood and will be diagnosed as having asthma.[3] Despite recent introductions of effective 'controllers', such as new inhaled corticosteroids and leukotriene modifiers, asthma exacerbations continue to occur and several patients will require emergency department (ED) visits and

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in-hospital treatment for acute asthmatic attacks.[4] It is clear that ascertainment of severity of acute attack is essential for decision making in choosing further medications and for deciding when admission is needed. In the Global Initiative for Asthma (GINA) and the National Asthma Education and Prevention Program (NAEPP), clinical assessment for severity of acute attack was emphasized; however both guidelines did not provide precise recommendations which can be easily administered in clinical circumstances.[5,6] In an emergency situation, it is unlikely that physicians will be carrying a table containing such severity items or be able to memorize such details. Moreover, failure to record these severity items into medical records will lead to inconsistency and inter-rater variability in clinical assessment, particularly during shift changes in the emergency settings.

Recognizing these short-comings, attempts have been made to create clinical asthma scores for use in treating acute asthma in children. Wood and Downes et al, were the pioneers in creating a scoring system for use in treating children requiring admission to intensive care unit with acute attack.[7] This score had good correlation with PaO_2 and $PaCO_2$. However, with earlier intervention with corticosteroids, items in the Wood and Downes's score such as cyanosis and altered cerebral function are rarely observed in modern days of asthma therapy. Recognizing such limitations, scores such as the Respiratory Distress Assessment Instrument – RDAI[8] and a Clinical Asthma Score – CAS by Parkin, et al.[9] were designed to evaluate common presenting symptoms and signs observed in acute attack, particularly among preschoolers. Further refinements of such scores were undertaken by several groups of investigators resulting in more effective scores aiming to provide better validity and reliability particularly in predicting future admission. Examples of these scores are the Preschool Respiratory Assessment Measure – PRAM[10] and the Pediatric Asthma Severity Score – PASS.[11]

During the past 20 years, our group has been interested in this development and has established the 'Siriraj Clinical Asthma Score - SCAS' almost during the same period that the PRAM and PASS were developed. In this report, we describe our work in arriving at such a scoring system in our continuing care for asthmatic patients at our institution. In addition, we review the currently available literature on the development of clinical asthma scoring systems for use in children and highlight the weaknesses and strengths of these scoring systems in clinical use.

The Siriraj Clinical Asthma Score (SCAS)

Between May 2002 and April 2003, we enrolled 70 asthmatic children (48 boys and 22 girls) with acute asthmatic attack and who were treated at the ED at Siriraj Hospital into the observational study. Their mean ages were 51.5 ±31.8 months (range 1-12 years). Thirty-eight children were in the younger age group (range 1-5 years, mean age 29.6 ± 8.5 months) and 32 were in the older group (range 5-12 years, mean age 92.5 ± 21.6 months). They were given 5% nebulized salbutamol (0.03 cc/kg) up to 3 doses at 20 minutes interval. Necessary doses of nebulization and the decisions to admit or discharge the patients were made by ED physicians. Prior to each nebulization, 12 items of asthma severity score were assessed by 2 independent investigators not involved in the treatment. Sources of these items were derived from scoring systems evaluated in the past – see discussion.[7,9,10] Table 1 shows these 12 items along with their severity description in categorical orders from 0-2. Some items represent the same measurements (i.e. quality of breath sound and air entry, retractions and the use of accessory muscles). We, however, chose to include both item pairs in our evaluation since they were all described as such in previous investigations.

Table 1. Asthma severity assessment items (12) evaluated for validity in this study

Items	Severity scale		
	0	1	2
1. Respiratory rate (breath/min)	< 40	40-60	>60
2. Wheezing	None	Expiration	Expiration/ inspiration
3. Expiratory wheezing - degree	None	Moderate	Marked
4. Retractions	None	1 site	>1 sites
5. Dyspnea	None	Mild	Marked
6. Degree of air entry	Normal	Decreased	Absent
7. Breath sound quality	Normal	Unequal	Decreased
8. O_2 saturation	>95%	92-94%	<91%
9. Presence of cyanosis	None	In room air	In 40%O_2
10. Use of accessory muscles	None	Moderate	Marked
11. Inspiratory:expiratory ratio (I:E ratio)	I>E	I=E	I<E
12. Cerebral function	Normal	Depressed	Coma

These 12 items comprised independent variables, whereas the dependent variables (outcome variables) are (1) frequency of salbumatol nebulization needed and (2) admission vs discharge. The validity of independent variables upon the two outcome variables (dependent) was assessed by the Mantel-Haenzel linear-by-linear association test.

Independent variables were then constructed into 2 previously described composite scores, i.e., (a) the Wood and Downes's score and (b) the Clinical Asthma Score (CAS). In addition, 3 new composite categories were constructed, i.e., (c) Clinical Asthma Score with air entry (CAS) (d) Clinical Asthma Score with O_2 sat (CAS-O_2), and (e) Clinical Asthma Score with O_2 and air entry (CAS-air-O_2). Details of the first two asthma scores are shown in Table 3. In the 3 new scores, we chose to substitute I:E ratio (which showed poor validity and inter-rater variability) with air entry (CAS-air) or O_2 sat (CAS-O_2) or both (CAS-air and O_2 sat). Degree of accessory muscle use was substituted by retractions in the three new scores.

Sensitivity, specificity, accuracy and ROC (receptor operative curve) were generated for each composite score using admission/discharge as an outcome variable. Inter-rater correlation (reliability) for 12 independent variables and for each composite score was calculated using Kappa statistics and interclass correlation (ICC) accordingly. All statistics were performed using SPSS version 10 statistical package.

Results

Among the 70 patients enrolled, varying doses of salbutamol nebulizations were administered as follows: 1 dose – 20 patients (28%), 2 doses – 25 patients (35%) and 3 doses – 25 patients (35%). Ten were admitted to the hospital (14.2%, 4 in the younger group and 6 in the older group). Concomitant allergic rhinitis was observed in 42 patients (60%) and atopic dermatitis in 24 patients (34%). 72.9% had at least 1 positive skin prick test to common aeroallergens.

Three out the 12 variables (cyanosis, depressed cerebral function, and I:E ratio) showed poor validity ($p > 0.05$) while the remaining 8 variables had good validity ($p < 0.001$). Breath sound quality, air entry, and I:E ratio had poor Kappa values between the two investigators (0.63, 0.78 and 0,28, respectively). The best sensitivity, specificity and accuracy for each of the 5 composite scores (at decision scores as shown), using admission/discharge as outcome variable, are tabulated in Table 2.

Table 2. Sensitivity, specificity and accuracy of 5 asthma severity composite scores evaluated in this study

	Sensitivity	Specificity	Accuracy
1. Wood and Downes's score at ≥ 6/10	95%	80%	0.92
2. CAS at ≥ 8/10	88.3%	100%	0.96
3. CAS-air at ≥ 8/10	95%	100%	0.96
4. CAS-O_2 at ≥ 9/10	98%	100%	0.98
5. CAS-air-O_2 at ≥ 10/12	98.3%	100%	0.98

Interclass correlations of the 5 scores were as follows: (a) Wood and Downes's score = 0.93 (b) CAS = 0.92 (c) CAS-air = 0.99 (d) CAS-O_2 = 1 and (e) CAS-air-O_2 = 0.99. Figure 1 showed a plot of CAS-O_2 correlation between the two investigators (complete correlation).

Discussion

We have demonstrated in this study that some severity assessment items used in the past had poor validity (cyanosis, depressed cerebral function and I:E ratio) and some had poor inter-rater variability (air entry, I:E ratio and breath sound quality). This confirmed our past experience with the use of CAS that the I:E ratio was difficult to replicate even with the same assessor. We therefore substituted this item with air entry and O_2 saturation in the three new scores since these items were shown to have good validity in some studies as well in ours.[10] It was

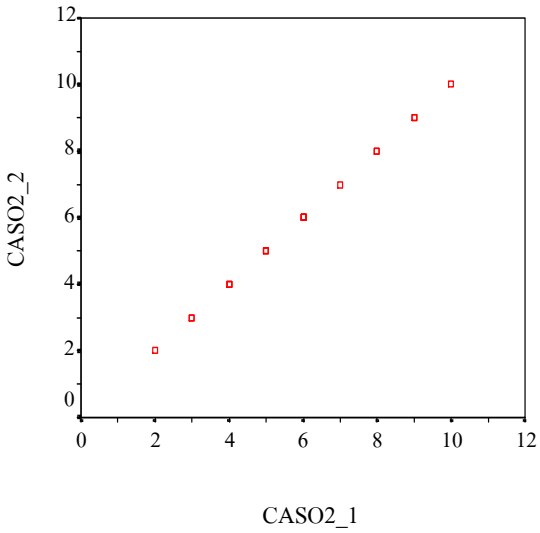

Figure 1. Plot of interclass correlation coefficient of CAS-O_2 score (CAS-$O_2$1 and CAS-$O_2$2 – observation from investigator #1 and #2, ICC = 1)

apparent from Table 2 that sensitivity, specificity and accuracy of these 3 new scores improved compared to the two reference scores. With a complete linear reliability correlation in CAS-O_2 score, we have therefore chosen this score to be used at the Siriraj Hospital since 2004 and thus named the score – the Siriraj Clinical Asthma Score (SCAS). This score has been used in our clinical practice guidelines for treating acute asthma ever since.

Review of the literature

Accurate measurement of acute asthma severity is important both for decision making and for evaluation of treatment effectiveness. Pulmonary function tests, such as spirometry and peak expiratory flow rate (PEFR), provide objective data on the severity of airway obstruction, but these tests are difficult to perform in young children because of their lack of coordination and comprehension, particularly during asthma attacks. Given that pulmonary function tests are often not feasible or reliable in young children, several clinical scores of asthma severity have been develop.[12,13] (Table 3)

The Wood and Downes's Clinical Asthma Score was one of the first asthma severity scores developed (1972). It was developed to predict impending respiratory failure in childhood status asthmaticus and for the purpose of determining needs for intensive care unit admission. The Wood and Downes's Clinical Asthma Score, therefore, had significant correlation with $PaCO_2$ ($r = 0.69$, $p < 0.001$) and PaO_2 ($r = -0.44$, $p < 0.05$).[7] However, the responsiveness and reliability of this score was not assessed. Moreover, some items such as arterial oxygen tension, cyanosis and cerebral function are difficult to evaluate objectively in children and are infrequently observed in the modern era of asthma therapy.

In 1984, Becker and colleagues introduced Pulmonary Index (PI) developed for assessing severity of acute asthma in children presenting to the ED and to predict admission to the hospital.[14] PI had good correlation with pulmonary function test ($p < 0.01$) and admission to the hospital ($p < 0.01$). PI also had very good internal consistency (Cronbach's $\alpha = 0.835$) and correlated well with the

Table 3. Characteristics of clinical asthma severity scores

Characteristics (ref no)	Wood's (7)	PI (14, 15)	CSGS (16)	RDAI (8)	CAES (17)	CAS (9)	PRAM (10, 19)	PASS (11)	SCAS
Population	Age ? n=18	6-17 yr, n=40 1-12 yr, n=65	0-2 yr, n=10	0-2 yr, n=30	0-5 yr, n=32	1-5 yr, n=30	3-6 yr, n=217 2-17yr, n=782	1-18 yr, n=1,221	1-12 yr, n=70
Setting	ED	ED	IP	ED	ED	IP	ED	ED	ED
Items									
Accessory muscle use	✓	✓	✓	✓	-	✓	✓	✓	✓
Air entry	✓	-	✓	-	-	-	✓	-	-
Anxiety	-	-	✓	-	-	-	-	-	-
Arterial oxygen tension(PaO_2)	✓	-	-	-	-	-	-	-	-
Cyanosis	✓	-	✓	-	✓	-	-	-	-
Dyspnea	-	-	-	-	✓	✓	-	-	✓
Fatigue	-	-	✓	-	-	-	-	-	-
I:E ratio	-	✓	-	-	-	✓	-	✓	-
Level of consciousness	✓	-	✓	-	✓	-	-	-	-
Oxygen saturation	-	-	-	-	-	-	✓	-	✓
Rales	-	-	-	-	✓	-	-	-	-
Respiratory rate	-	✓	✓	-	-	✓	-	-	✓
Rhonchi	-	-	✓	-	-	-	-	-	-
Speech impairment	-	-	-	-	✓	-	-	-	-
Wheezing	✓	✓	✓	✓	✓	✓	✓	✓	✓

ED = emergency department, IP = inpatient, I:E ratio = inspiratory:expiratory ratio

National Asthma Council Guidelines (NACG), with significant difference in median PI values across different NACG severity categories (sensitivity 88% and specificity 77% for severe asthma).[15] However, inter-rater reliability has not been assessed. Moreover, concerns are the difficulty in distinguishing various I:E ratio, such as 5:2 and 5:3 in a child breathing 50 times a minute; this would be too difficult to consistently reproduce. Our study confirms this difficulty with the fact that with the even easier description of I:E ratio in this report, poor validity and inter-rater reliability was observed. With this reason, we have decided to delete I:E ratio from our current scoring system.

The Clinical Symptom Grading System (CSGS) was introduced to monitor the acute asthmatic attack in hospitalized children less than two years old during the same time period as the PI.[16] The CSGS had good correlation with transcutaneous $PaCO_2$ and PaO_2, but the correlation coefficients, reliability and responsiveness were not reported. In addition, items in the CGSG, such as fatigue, anxiety, cyanosis and level of consciousness, are difficult to evaluate objectively in children.

In 1987, Lowell and his group evaluated the response to epinephrine among children less than two years of age presenting to the ED with wheezing and respiratory distress. In this report the Respiratory Distress Assessment Instrument (RDAI) was developed and utilized as a tool for assessment.[8] The RDAI had good inter-rater reliability between a pediatrician and a nurse ($\kappa = 0.9$ for wheezing score, $\kappa = 0.64$ for retraction score). In addition, it had a good responsiveness to identify change occurring after treatment ($p < 0.01$). Despite being quite a popular score in research in the ED, the RDAI has not been adequately validated with standard measure. Moreover, the RDAI consists of only two severity items (wheezing and accessory muscle use) which do not accurately reflect the severity of acute asthma.

In the 1990's two scoring systems were introduced for evaluating acute asthma severity in children less than 5 years of age. The Clinical Asthma Evaluation Score (CAES) was developed for use in children less than 5 years old presenting to the ED.[17] Although it had good correlation with $PaCO_2$ ($r = 0.75$, $p < 0.0005$) and PaO_2 ($r = -0.67$, $p < 0.0005$), the reliability and responsiveness of this score has not been assessed. Moreover, several items such as dyspnea, cyanosis, speech impairment and mental status are difficult to discern objectively in young children. Parkin et al, reported the utility of the Clinical Asthma Score (CAS) for evaluating acute asthma severity among hospitalized asthmatic children between 1 and 5 years old.[9] The CAS had good correlation with length of hospital stay ($r = 0.47$, $p < 0.05$) and drug dosing interval ($r = 0.58$, $p < 0.01$). Also, it demonstrated essential characteristics for assessment tool, i.e., good internal consistency (Cronbach's $\alpha = 0.86$), good inter-rater reliability between the two pediatricians ($\kappa = 0.82$) and between a pediatrician and a nurse ($\kappa = 0.89$), good discriminative ability (Ferguson's $\delta = 0.92$), and good responsiveness to identify change in score from admission to discharge ($p < 0.01$). However, the CAS was specially developed for, and was validated among hospitalized children between the ages of 1 and 5 years. Therefore, the usefulness of this score in older asthmatic children and in emergency care setting has to be assessed. CAS was used in our ED settings for several years prior to our evaluation. Again, I:E ratio was proven to be too difficult to reproduce in young children with fast respiratory rates in our investigation.

The Preschool Respiratory Assessment Measure (PRAM) is the one best acute asthma severity scores ever devised with good measurement properties in children.[13] The investigators evaluated the validity of severity items and later added four items with highest validity to construct the PRAM (accessory muscle use, air entry, O_2 saturation and wheezing). The main difference of PRAM from CAS was the deletion of I:E ratio and dyspnea and the addition of air entry and O_2 saturation to the PRAM (Table 3). PRAM was developed and was validated against respiratory resistance and was proven to be discriminative and responsive to severity change among children aged 2 to 17 years. PRAM had good correlation with health professional assessment of severity ($r = 0.5$-0.54),[10,18] respiratory resistance ($r = 0.22$-0.36)[10] and admission rate ($r = 0.4$-0.5, $p < 0.0001$).[19] In addition, it also had good internal consistency (Cronbach's $\alpha = 0.71$), inter-rater reliability between physician and nurse ($\kappa = 0.78$), responsiveness to identify change resulting after initial bronchodilator (Guyatt's coefficient = 0.7, effect size = 1.1), and significant discriminative ability to predict admission (AUC = 0.86).[18,19] However, PRAM was developed for use only in the ED. Other variables such as length of stay, the rate of discharge, and revisits for the hospitalized patients were therefore not assessed. CAS and PRAM are very good scoring systems and formed the basis of the construction of

Siriraj Clinical Asthma Score (SCAS). As noted in the result, we chose to include O_2 saturation rather than air entry in our scoring system since air entry did not have good validity and reliability in our trial. Thus, the Siriraj Clinical Asthma Score (SCAS) combines the best items from PRAM and CAS.

In addition, the Pediatric Asthma Severity Score (PASS) was another two-stage, carefully devised scoring system similar to ours. It is comprised of three items, i.e., wheezing, work of breathing and prolongation of expiratory phase with total score of 6. Respiratory rate was omitted since the investigators felt that ranges of normal rates for ages would be too difficult to assess. PASS was proven to be a valid, reliable and responsive score to change in children aged 1 to 18 years. The PASS had good correlation with PEFR (r = 0.27-0.37), pulse oximetry (r = 0.29-0.41), and health professional assessment of severity (r = 0.55).[18] PASS also had good inter-rater reliability between the two respiratory therapists (κ = 0.72-0.83), discriminative ability to predict admission (ROC 0.82-0.86),[11,18] and responsiveness to the treatments provided in the ED (48% relative increase in score from start to end of treatment, effect size = 0.62).[11] However, the PASS consists of only three items with a relatively narrow overall range. Some physicians may be uncomfortable relying on such a small subgroup of clinical findings.

In Thailand, the Siriraj Clinical Asthma Score (SCAS) was developed to evaluate acute asthmatic attack in pediatric patients whereas the Ramathibodi's acute asthma predictive score was developed to help the attending physicians decide on a safe discharge of an acute asthmatic adult patient from the ED.[20] The Ramathibodi's score consists of inability to lie down at presentation, wheezing after last nebulization, and PEFR after last nebulization.[20] Using a cutoff score of 2, the acute asthma score showed a sensitivity of 60%, a specificity of 67.4%, a positive predictive value of 5.7%, and a negative predictive value of 98.1%.[21] However, this score was developed and validated for use in only adult patients; PEFR is difficult to perform in young children.

In conclusion, we have developed the Siriraj Clinical Asthma Score (SCAS) for use in treating acute asthma in children. Items in this scoring system had good validity and inter-rater reliability. The cut-off point for determining admission for this score was 9. It is quite obvious from our review that all clinical asthma severity scores had both strong points (good reliability, validity, discriminatory and responsive) and weak points (some with too few items and some with items that have poor repeatability). Most of the scores were designed to help physicians in making decisions whether to admit or discharge patients. However, the use of clinical asthma scores can be extended for the assessment and monitoring of acute asthma in the hospital as well as in the ED. Clinical asthma scores that are simple, valid, and reliable are indispensable for managing acute asthma.

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