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The Buddhasothorn Asthma Severity Score (BASS): A practical screening tool for predicting severe asthma exacerbations for pediatric patients

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Abstract
Background and aim: A precise scaling system of acute asthma leads to an accurate assessment of disease severity. This study aimed to compare the accuracy of the Buddhasothorn Asthma Severity Score (BASS) with the Wood-Downes-Ferrés Scale (WDFS) to recognize the severity level of acute asthma.
Materials and methods: A cross-sectional study was conducted comprising Thai children aged 2-15 years with acute asthma. The BASS and WFDS were rated once in the emergency department. The degree of severity was determined by frequency and type of nebulized bronchodilator administrations at the time of initial treatment. The optimum cutoff points for the area under the curve (AUC) were established to predict severe asthma exacerbations.
Results: All 73 episodes of asthma exacerbations (EAEs) in 35 participants were analyzed. Fifty-nine (80.8%) EAEs were classified as severe. Both scales had good significance to recognize the selection of nebulized bronchodilator treatments by AUC of 0.815 (95% Confidence Interval [CI]: 0.680-0.950) in case of BASS, and AUC of 0.822 (95% CI: 0.70-0.944) in case of WDFS. Cutoff points of BASS ≥ 8 had sensitivity 72.9%, specificity 64.3%, positive predictive value (PPV) 89.6%, negative predictive value (NPV) 36.0% at an AUC of 0.718 (95% CI: 0.563-0.873) for severe exacerbations. These results were consistent for cutoff points of WDFS ≥ 5 with sensitivity 78.0%, specificity 50.0%, PPV 86.8%, NPV 35.0% at an AUC of 0.768 (95% CI: 0.650-0.886) for predicting severe exacerbations. There was no significant difference between the AUCs of both scales.
Conclusions: Both the BASS and WDFS were good and accurate scales and effective screening tools for predicting severe asthma exacerbations in pediatric patients by optimal cutoff points.

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Introduction

Currently, several pediatric asthma severity scores have been validated for evaluating the degree of severity, predicting hospitalization rates in children with acute asthma, and frequently for conducting medical research.[1] These scoring systems use many clinical parameters, including criteria for identifying accessory muscle of respiration contraction, rate of respiration, breathing sound on auscultation, pulse rate, level of mental status, and measurement of oxygen saturation, as presented in the Wood–Downes-Ferrés Scale (WDFS),[2] the Pediatric Asthma Severity Score (PASS),[3] the Preschool Respiratory Assessment Measure (PRAM) score,[4] the Pulmonary Index Score (PIS),[5] the Respiratory rate-Accessory muscle use-Decreased breath sounds (RAD) score,[6] etc.

The international and national asthma management guidelines for children frequently implemented in Thailand are Global Initiative for Asthma (GINA) guidelines,[7] and the acute asthma guidelines for Thai children.[8] However, these guidelines do not mention using any severity scoring systems for assessing the severity of acute asthma in emergency department (ED).

The validated WDFS[2] is widely used for accessing severity and evaluating response to treatment. The purpose of this score is to identify children who have impending or existing respiratory failure because of status asthmaticus. This score is required to evaluate adventitious and inspiratory flow on auscultation of the lungs. Although this method is easy to use and available on the bedside,[9] healthcare personnel (HCP) who have to assess these clinical parameters must have adequate training and experience and may spend prolonged contact time with patients with respiratory illness. Moreover, the parameters required to determine the location of accessory respiratory muscle contractions contained in WDFS were documented in less than 20% of surveyed hospitals.[10]

Therefore, we developed the Buddhasothorn Asthma Severity Score (BASS) using some parameters that were consistent with clinical practice guidelines. The main objectives of this study were to compare the accuracy of BASS with WDFS for recognizing the options of initial bronchodilator treatments and to determine cutoff points to predict severe exacerbations of asthma.

Materials and Methods

Study design and subjects

This cross-sectional study enrolled asthmatic children aged 2–15 years who presented with asthma exacerbations in the ED of Buddhasothorn Hospital between January 2020 and November 2021. In order to determine their composite scores, the patients enrolled in the study had to have a complete and clear record of all items of clinical parameters of BASS and WDFS.

The diagnosing of acute asthma exacerbations, defined by GINA guidelines,[7] was determined by the abrupt onset of respiratory symptoms (shortness of breath, cough, wheezing, or chest tightness) and alteration of pulmonary functions from their baselines in patients who were able to assess the effectiveness of peak expiratory flow (PEF) measurement. Patients suffering from upper respiratory tract infection (URTI) had a fever (body temperature > 37.5°C) and were diagnosed with nasopharyngitis (common cold), sinusitis, pharyngitis, laryngitis, or laryngotracheitis.[11] Patients presenting with fever, cough, or difficulty in breathing and having confirmed pneumonia, bronchiolitis, or bronchitis as interpreted by a chest X-ray were categorized as lower respiratory tract infection (LRTI).[12]

For diagnosis of asthma in pediatric patients aged 5 years and younger, we enrolled children who had recurrent episodes of wheezing (more than three episodes per year) and evident response to bronchodilators, as assessed by a physician, accompanied by any of the following symptoms suggestive of asthma: (1) cough, wheezing, and difficulty in breathing for more than 10 days during a respiratory tract infection; (2) symptoms triggered by exercise, laughing, crying, or exposure to air pollution, especially in the apparent absence of respiratory tract infection; (3) recurrent or persistent nonproductive cough, which may worsen at night or at the time of awakening; or (4) having risk factors for developing asthma, such as family history of asthma in one or more first-degree relatives, or personal history of food allergy or atopic dermatitis.[7]

Additionally, we enrolled patients older than 5 years who were able to evaluate their pulmonary function test to effectively confirm the diagnosis of asthma as well as those with a history of respiratory symptoms of asthma (wheezing, shortness of breath, chest tightness, and cough) responsive to bronchodilators. These symptoms usually got worse at night or at the time of waking up, and were triggered by exercise, laughter, allergens, and cold air. They appeared or worsened with respiratory tract infections. Variable expiratory airflow limitation was confirmed using spirometer or PEF measurements as diagnostic criteria of asthma according to GINA recommendations.[7]

We excluded viral-induced wheezing illnesses found in early childhood, namely, in preschool children who had recurrent episodes of wheezing (more than three episodes per year), typically associated with URTI. Such pediatric patients, in the absence of URTI or after exercise, had no symptoms (wheezing, shortness of breath, chest tightness, or cough) suggestive of asthma, or risk factors for developing asthma.[7]

Moreover, we also excluded the children who had underlying chronic diseases, that is, bronchopulmonary dysplasia, interstitial lung disease, congenital heart disease, or congenital anomalies, and pediatric patients who needed continuous nebulization by short-acting beta-agonist (SABA) therapy. Further, to eliminate anti-inflammatory effects of chronic systemic corticosteroids in patients with severe or persistent asthma, participants who had received systemic corticosteroids within 7 days before each episode of acute asthma were also excluded from the study.[13]

The study was registered on Thai Clinical Trials Registry (study ID: TCTR20210820003). The written informed consent was obtained from the parents of all participants prior to their participation in the study. The study was approved by the ethical committee of Buddhasothorn Hospital (approval No. BSH-IRB 019/2561).

Acute asthma severity assessment scores and data collection

All physicians who had been routinely attending pediatric patients with asthma were trained twice a year at a one-day workshop on how to accurately rate BASS and WDFS (both scales are shown in Supplementary Tables S1 and S2, respectively) by a group of general pediatricians and a pediatric allergist. These scales were rated for episodes of asthma exacerbations (EAEs) by a pool of physicians on duty in ED. A comparison of the characteristics of both clinical asthma severity scores is shown in Supplementary Table S3.

In the case of BASS, item 6 was divided into two categories for purpose of assessment (sub-item 6.1 and sub-item 6.2 as shown in Table S1) by a rater who selected one of these two sub-items. The PEF was evaluated for patients aged more than 5 years who were able to measure PEF (sub-item 6.1) effectively, and if they had limitations or were not available for PEF measurement, then persistence of central cyanosis (sub-item 6.2) was assessed.[14]

The composite score range was 6–12 for BASS and 0–14 for WDFS. Higher scores indicated a higher degree of severity for asthma exacerbations. Patients with acute asthma were administered with the suggested drug dosing guide of inhaled bronchodilators and systemic or high-dose inhaled corticosteroids based on the recommendations of GINA guidelines or national guidelines for acute asthma management in children.[7,8] However, the decision regarding management of acute asthma was at the discretion of attending physicians, and investigators did not attempt to prescribe any treatment.

We collected data, including patients' demographics, history of management of acute asthmatic episodes, current influenza vaccination and asthma medications, and any bronchodilator treatment before arrival at triage. Then, an initial assessment was prepared at the first presentation in ED regarding the level of consciousness, degree of dyspnea by examination of accessory muscle retraction, characteristics of breathing sounds and wheezing by chest auscultation, respiratory rate, pulse rate, percentage of oxygen saturation at room air, central cyanosis, and PEF measurement.

Outcome measurement

We compared accuracy between BASS and WDFS regarding initial management options for acute asthma in terms of frequency and type of nebulized bronchodilator selected. These options were classified into the following two outcomes: outcome 1 included patients who received two or more than two doses of nebulized SABAs, and outcome 2 included patients who received two or more than two doses of nebulized SABAs combined with at least one dose of ipratropium bromide. The investigators classified outcome 2 patients as severe asthma exacerbations, and patients whose condition did not require this treatment were classified as outcome 1, mild-to-moderate, patients (Supplementary Table S4).

We examined the accuracy of our outcomes by comparing area under curve (AUC) for both scales. The diagnostic tests for sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were analyzed by establishing new cutoff points for predicting severe asthma exacerbations. Furthermore, we also characterized pediatric patients with acute asthma by comparing severe and non-severe EAEs.

Statistical analysis

We calculated the sample size using the accuracy of WDFS for assessing severe bronchiolitis as analyzed by Rivas-Juesas et al.,[15] who reported that the estimation of proportion by 79% and a confidence level which was determined by 95%. The degree of precision was sought by 10% of the estimated proportion. This study assumed that the incomplete data were 20%, and the required sample size was 80 EAEs.

The raw data were analyzed by using the SPSS software (version 21 for Windows; SPSS Inc. Chicago, IL, USA). The categorical variables were shown as numbers and percentage values. Median with inter-quartile range (IQR) was reported for non-normal distributions of variables. For comparison of parameters between groups, Pearson's Chi-square test and Mann–Whitney U test were used for qualitative and quantitative data, respectively. Receiver operator characteristic (ROC) curves for outcomes1 and 2 were plotted to compare the association between BASS and WDFS. Sensitivity, specificity, PPV, NPV, and accuracy of both scales were calculated at the optimal cutoff points of AUC utilized for predicting severe exacerbations of asthma. The 95% confidence intervals (95% CI) for two outcome groups were also calculated, and $P < 0.05$ was considered as statistically significant.

Results

All 87 EAEs from 38 patients met the inclusion criteria. We excluded seven EAEs of three patients with underlying bronchopulmonary dysplasia, Down's syndrome, and atrial septal defect. Seven EAEs were excluded because oral corticosteroids had been administered to them within 7 days prior to this study. Finally, 73 EAEs from 35 patients were enrolled in this study, and most of them were males (25; 71.4%). Allergic rhinitis was reported as a major co-morbidity by 29 (82.8%) patients and in six (17.1%) of patients, it was found in their first-degree relatives. Thirteen (37.1%) patients had exposure to household smoking, and two (5.7%) of them had current influenza vaccination. The majority of patients (77.1%) developed acute asthma for one to two times during the study period. The median (IQR) age at the first presentation of symptoms and diagnosis of asthma was 31.0 (12.0–74.5) months and 37.5 (22.3–72.5) months, respectively. The baseline characteristics of study patients are shown in Table 1.

The distribution of composite scores from rating each clinical parameter for EAEs establishing the median (IQR) of BASS and WDFS were 8.0 (7.0–8.0) and 6.0 (4.0–6.5), respectively (Figures 1A and B). A significant discrimination for option of treatment was discovered in BASS (AUC = 0.815, 95% CI: 0.680–0.950) and WDFS (AUC = 0.822, 95% CI: 0.70–0.944) in outcome 1 (Figure 2A), and so does BASS (AUC = 0.718, 95% CI: 0.563–0.873) and WDFS (AUC = 0.768, 95% CI: 0.650–0.886) of outcome 2 (Figure 2B). Differences between the AUC of BASS and WDFS in outcomes 1 and 2

Table 1 The baseline characteristics of pediatric patients with asthma

Patient characteristics	N = 35	%
Gender		
Males	25	71.4
Females	10	28.6
Number of siblings		
0-1	31	88.6
2-3	4	11.4
Underlying allergic conditions		
Allergic rhinitis	29	82.8
Habitual snoring	1	2.9
None	5	14.3
Family history of allergic diseases		
Allergic rhinitis	6	17.1
Asthma	4	11.4
Allergic rhinitis and asthma	1	2.9
None	19	54.3
Unknown	5	14.3
Environment		
Household smoking exposure	13	37.1
Cat	3	8.6
Dog	3	8.6
Current influenza vaccination	2	5.7
Episodes of asthma exacerbations		
1-2	27	77.1
3-4	5	14.3
at least 5	3	8.6
Age at the first presentation of clinical symptoms of asthma (months)	31.0 (12.0-74.5)[a]	
Age at asthma diagnosis (months)	37.5 (22.3-72.5)[a]	

[a]Median (IQR).

were not significant at 0.007 (95% CI: −0.162-0.177, P = 0.934) and 0.050 (95% CI: −0.110-0.210, P = 0.538), respectively.

Comparison of patients with mild-to-moderate and severe EAEs is demonstrated in Table 2. Fifty-nine (80.8%) EAEs developed severe asthma exacerbations and 68.5% of them had an attack of symptoms between the age of 2 and 4 years. There were no significant differences for history, precipitation by respiratory infections, and current medications for asthma between the two groups of severity. We found infectious manifestations correlating with acute asthma in 28.8% of EAEs. Asthmatic patients who were precipitated with LRTI had a higher prevalence of severe EAEs than mild-to-moderate EAEs (16.9% versus 7.1%, P = 0.651). Moreover, the PEF measurement was applied for only 13.0% of patients with severe EAEs.

Chest radiography was significantly a higher level of investigation expended in patients with severe EAEs than mild-to-moderate EAEs (21.4% vs. 64.4%, P = 0.004). The median of composite scores for severe EAEs in case of BASS was significantly higher than those in mild-to-moderate EAEs by 8.0 (7.0-8.0) versus 7.0 (6.8-8.0), P = 0.007. Similarly, WDFS showed that the median of composite scores for severe EAEs was also significantly higher than mild-to-moderate EAEs by 4.5 (4.0-5.0) versus 6.0 (5.0-7.0), P = 0.001 (Table 2).

The ROC curves for BASS and WDFS for predicting severe acute asthma exacerbations are shown in Figure 2B. We established the cutoff points at the ROC curves of both scales for outcome 2 treatment. Cutoff points of BASS ≥ 8 at triage had sensitivity 72.9%, specificity 64.3%, PPV 89.6%, NPV 36.0%, and accuracy 71.2%. Similar trends were observed for cutoff points of WDFS ≥ 5 at triage with sensitivity 78.0%, specificity 50.0%, PPV 86.8%, NPV 35.0%, and accuracy 72.6% (Table 3).

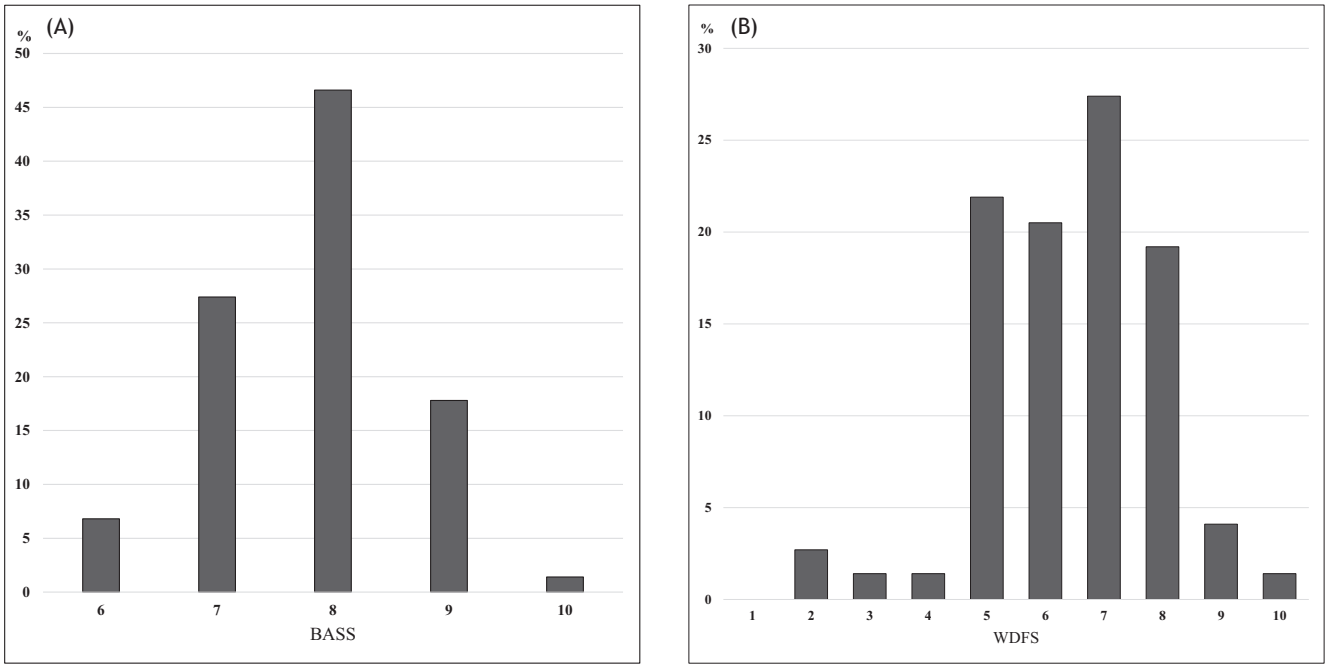

Figure 1 (A) Distribution of patients with rated Buddhasothorn Asthma Severity Score, and (B) Wood-Downes-Ferrés Scale, for episodes of asthma exacerbations.

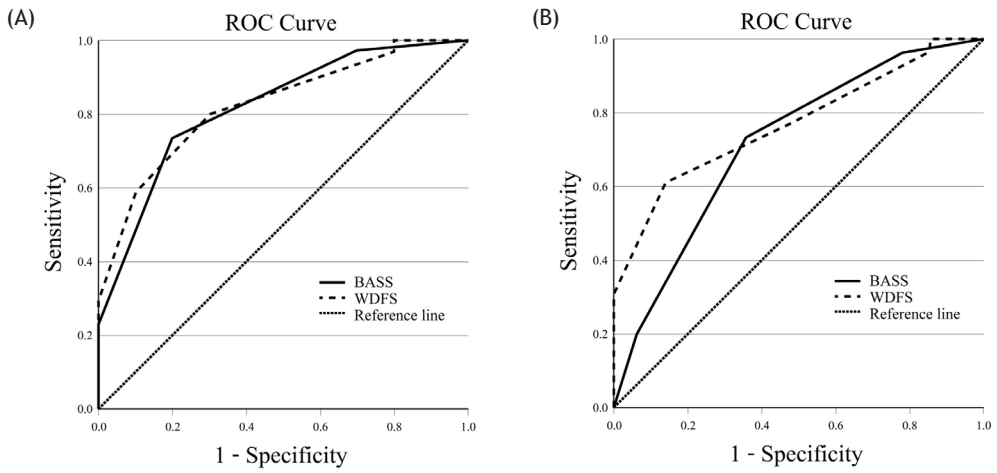

Figure 2 Comparison of ROC curve for BASS and WDFS in (A) outcome 1, and (B) outcome 2, of treatment. BASS: Buddhasothorn Asthma Severity Score; ROC: receiver operator characteristic curve; WDFS: Wood–Downes–Ferrés Scale.

Table 2 Characteristics of patients visiting for EAEs compared by level of severity.

			Degree of severity				
	Total		Mild-to-moderate		Severe		
Characteristics of patients for EAEs	**N = 73**	**(%)**	**N = 14**	**(%)**	**N = 59**	**(%)**	**P-value**
Age at acute episodes of asthma							0.602
2–4 years	50	(68.5)	10	(71.4)	40	(67.8)	
5–11 years	19	(26.0)	4	(28.6)	15	(25.4)	
12–15 years	4	(5.5)	0		4	(6.8)	
Past history of acute asthma events							
Ever intubation for asthma	1	(1.4)	0		1	(1.7)	0.624
ED or unscheduled OPD visit for asthma in the past year	58	(79.5)	11	(78.6)	47	(79.7)	0.928
Hospitalization for asthma in the past year	39	(53.4)	5	(35.7)	34	(57.6)	0.266
Revisited ED within 28 days after acute asthma	18	(24.7)	5	(35.7)	13	22.0	0.286
Concomitant infections							
None	52	(71.2)	11	(78.6)	41	(69.5)	0.651
Upper respiratory tract infection	10	(13.7)	2	(14.3)	8	(13.6)	
Lower respiratory tract infection	11	(15.1)	1	(7.1)	10	(16.9)	
Current medications and investigations for asthma in ED							
Currently prescribed SABAs by physicians	56	(76.7)	10	(71.4)	46	(78.0)	0.603
Current use of inhaled corticosteroids	53	(72.6)	8	(57.1)	45	(76.3)	0.149
Current use of leukotriene receptor antagonists	29	(39.7)	4	(28.6)	25	(42.4)	0.343
Inhaled bronchodilators administration before arrival at triage	46	(63.0)	7	(50.0)	39	(66.1)	0.262
PEF measurement	3[a]	(13.0)	0	0	3[a]	(13.0)	0.389
Chest X-ray examination	41	(56.2)	3	(21.4)	38	(64.4)	0.004
Asthma severity scores at triage							
Buddhasothorn Asthma Severity Score[b]	8.0	(7.0–8.0)	7.0	(6.8–8.0)	8.0	(7.0–8.0)	0.007
Wood–Downes–Ferrés Scale[b]	6.0	(4.0–6.5)	4.5	(4.0–5.0)	6.0	(5.0–7.0)	0.001

EAEs: episodes of asthma exacerbations; ED: Emergency department; IQR: inter-quartile range; OPD: outpatient department; PEF: peak expiratory flow; SABAs: short-acting beta 2 agonists; N: number of EAEs.
[a]Total of 23 EAEs from patients aged ≥5 years.
[b]Median (IQR).

Discussion

Our study proved that BASS has significant positive precision similar to the validated WDFS by remaining a good discriminator through the two outcomes of treatment options. The asthmatic patients who had severe acute exacerbations were often treated with multiple doses of bronchodilators, especially SABAs combination with ipratropium bromide according to the recommendations of GINA guidelines.[7] We, therefore, classified our patients for EAEs in outcome 2 of treatment for severe asthma exacerbations.

In Thailand, WDFS was applied as a clinical tool for assessing severity of the disease and helping to determine whether hospitalization was necessary for pediatric patients

Table 3 Analysis of sensitivity, specificity, PPV, NPV, and accuracy of BASS and WDFS by optimum cutoff points.

Asthma severity scores	Sensitivity	Specificity	PPV	NPV	Accuracy	Area under the ROC curve
BASS ≥ 8[a]	72.9 (59.73–83.64)	64.3 (35.14–87.24)	89.6 (80.72–94.64)	36.0 (24.09–49.92)	71.2 (59.45–81.23)	0.718 (0.563–0.873)
WDFS ≥ 5[b]	78.0 (65.27–87.71)	50.0 (23.04–76.96)	86.8 (79.28–91.86)	35.0 (20.92–52.28)	72.6 (60.91–82.39)	0.768 (0.650–0.886)

NPV: negative predictive value; PPV: positive predictive value; ROC: receiver operator characteristic curve.
[a]Score of ≥8 indicates severe, and score of <8 indicates mild-to-moderate asthma exacerbations. [b]Score of ≥5 indicates severe, and score of <5 indicates mild-to-moderate asthma exacerbations.
Data are presented as 95% Confidence Intervals.

with acute asthma.[16,17] The respiratory and cardiovascular systems (adventitious sounds and quality of inspiratory breath sounds, accessory muscles in use, cyanosis, respiratory and heart rates) were assessed for scaling WDFS (Table S2).

WDFS ≥ 8, defined as severe acute bronchiolitis, was probably a high false-negative value using original cutoff points. There was a study that adjusted lower cutoff points at WDFS > 5, and was more applicable with sensitivity of 92.3% and specificity of 54.8% for diagnosing infant patients with severe bronchiolitis.[15] This was consistent with a study conducted in Thailand which reported that WDFS ≥ 4 at triage was effective to predict the likelihood of hospitalization with sensitivity 82.6%, specificity 96.5%, PPV 90.5%, and NPV 93.2%.[17] However, the cited study did not describe the procedure of initial treatment that strongly influenced potential factors to reduce the rate of hospitalization.[17]

We, therefore, determined a new cutoff value that was lower than the original one. Our study demonstrated that BASS ≥ 8 had higher PPV than WDFS ≥ 5 PPV by 89.6% and 86.8%, respectively. However, both BASS and WDFS were significantly discriminating for options of initial bronchodilator treatments with good accuracy in outcome 1 of treatment, and remained accurate for higher severity in outcome 2 of treatment. There was no statistically significant difference between the AUC of BASS and WDFS for all primary outcomes, suggesting that both scales could be applied as screening tools with standard pediatric asthma guidelines for severity score at triage. BASS ≥ 8 indicated that pediatric patients had severe asthma exacerbations based on outcomes of initial treatment with nebulized bronchodilators as recommended by GINA guidelines.[7] Physicians may consider certain clinical items of BASS to assess severity for emergency management of these patients even if the composite of BASS does not reach the suggested cutoff point.

Moreover, WDFS has limitations for assessing severity of the disease, determining treatment parameters, and assessing response to treatment, especially in case of asthmatic patients associated with respiratory tract infections. This is because WDFS needs clinical parameters essential for assessing these conditions. Clinical manifestations of hypoxemia are often assessed in asthmatic patients. Clinical features and investigations suggestive of shock, metabolic acidosis, arterial blood gas analysis, radiographic findings, and patients' comorbidities must be evaluated. These are carried out in pediatric patients with community-acquired pneumonia to determine whether mechanical ventilation, initial management with vasoactive medications, or fluid resuscitation is necessary.[18,19]

Our study found that the median of composite scores of BASS and WDFS for asthmatic patients, precipitated with both infection and without infection, did not reach level of statistical significance. This was because both scores lacked clinical parameters required to recognize the severity of diseases in asthmatic patients associated with respiratory infections. However, some clinical and laboratory criteria are recommended for assessing the severity of community-acquired pneumonia in children, in addition to routine assessment in asthmatic patients with acute exacerbation. For example, age, fever, dehydration, shock, grunting respiration, capillary refill time, inability to eat food, and procalcitonin are effective factors for assessing severity of the disease.[20,21] This is consistent with the study conducted by Chang et al.,[22] who reported that there was no difference in acute asthma score at presentation between groups with and without viral respiratory illness precipitating exacerbations in non-hospitalized asthmatic children.[23]

A systematic review done by Chacko et al.,[10] which surveyed 17 pediatric asthma severity scores, reported that parameters needed to determine the location of respiratory muscle contractions, especially supraclavicular contraction and scalene muscle retraction, were rarely verified in surveyed hospitals. These features were also disseminated in WDFS,[2] PRAM score,[4] PIS,[5] Pulmonary Score (PS),[24] and Hospital Asthma Severity Score (HASS).[25] However, these are not quite practical to determine, especially in the community hospitals of Thailand where registered nurses are mostly responsible for managing acute asthma at triage.

History of bronchodilator use during the onset of acute dyspnea is a subjective factor, and is less reliable than the presenting symptoms of asthma for assessing the severity of exacerbations. However, asthma patients enrolled in this study were monitored for the presence of bronchodilators, and they were advised to use these medications regularly in an asthma clinic for follow-up treatment. We found that nearly 70% of EAEs had self-administered inhaled or nebulized bronchodilators before arriving at triage to alleviate their symptoms following physician's instructions written in the asthma action plan. It is possible that the patients had a worsening of their symptoms, which indicated that they were progressively developing high severity. Hence, such a history would encourage HCP to select appropriate treatment for the severity of the disease in patients having acute asthma. It also assists physicians to early consider multiple doses (three or more doses) of nebulized SABAs in combination with ipratropium bromide for improving lung function and lower hospitalization of patients having moderate to severe asthma exacerbations.[26] Further, the history taking of current reliever and controller medications is an important aspect

recommended by GINA guidelines for the management of asthma exacerbations in primary care.[7]

In clinical practice, BASS encourages PEF measurement to assess airflow obstruction. However, we recognized that in younger patients, or in most of the children aged more than 5 years, PEF was often not measured effectively. We observed that only a few peak flow meters were found in EDs of community hospitals. This indicated that peak flow meters were used rarely. Similarly, in Japan, 57% of hospitals had peak flow meters but were used for only 9% of asthmatic assessments.[27] Alternatively, to provide a faster assessment of acute asthma, HCP must consider evaluating the clinical parameter of central cyanosis. Moreover, Fábregas et al.[14] reported that the clinical parameter of cyanosis was more reliable to assess degree of airway obstruction than the assessment of use of respiratory muscles, pulse rate, or respiratory rate. The authors confirmed the condition of respiratory insufficiency by investigating the partial pressure of oxygen (PaO_2), which was significantly reduced in patients with PEF $< 50\%$. At present, GINA guidelines recommend cutoff points of PEF $\leq 50\%$ predicted or best to categorize severe asthma exacerbations.[7]

Additionally, in order to reduce the number of high scores and to simplify ratings, BASS uses the score of 1 for milder clinical symptoms and the score of 2 for more severe manifestations, and this increases its validity and utility.[1] The clinical parameters of BASS are easier for HCP to assess asthma severity because they are not required to evaluate adventitious auscultation of the lungs or specify details of accessory muscle contractions.

Moreover, the clinical parameter of BASS that we have considered reduces the contact time between patients and HCP. We avoid clinical parameters obtained through close physical examination, or parameters that require HCP to have training and experience, such as the evaluation of adventitious and inspiratory flow on auscultation of the lungs. Although PEF measurement requires prolonged contact time with patients, it could be applied through video conferencing or telemedicine while the patient is in the isolation room of ED or negative pressure room. This reduces the chance of infection spreading to HCP in COVID-19, because the majority of infected children are often asymptomatic compared to adult patients.[28] Older children can rate BASS by themselves and provide all information to HCP through video conferencing.

History taking of bronchodilator treatment before arriving at triage, spot oxygen saturation (SpO_2), pulse rate values monitored by pulse oximeter, degree of airflow obstruction from PEF, retraction of respiratory muscles, including skin and mucosal color, for recognizing central cyanosis can be achieved remotely through video conferencing.

Chest radiography was performed for more than half of EAEs. Likewise, in our study, there was a significantly increased radiography investigation rate in patients with severe asthma exacerbations.[29] Moreover, chest radiography was performed for patients with acute asthma exacerbations having fever, oxygen saturation of $\leq 92\%$ in room air, younger age group (≤ 4 years of age), and for those who complain chest pain.[30,31] Certainly, physicians must confirm the diagnosis of pneumonia, pneumothorax, or pneumomediastinum to assist decision-making for treating acute asthmatic patients presented with such positive findings.

The first limitation of our study was that most clinical scales, including BASS, were not confirmed for significant validity and reliability to assess the severity of acute asthmatic patients. However, considering the quality criteria adopted in the previous study,[1] BASS demonstrated good face validity because of the following items used as representatives for measuring dyspnea: mental status, retraction or use of accessory muscles, pulse rate, oxygen saturation, and central cyanosis. Moreover, allergy specialists and pediatricians verified and taught the contents and descriptions of each selected item to the target HCP.

Second, we did not exclude asthmatic patients with concomitant infections, one of the most important factors for worsening of asthma symptoms, that were commonly discovered in the real-life practice. However, there was no significant difference between the two levels of severity.

The number of doses of inhaled or nebulized bronchodilators in 24 h before arrival at triage was not identified and its oral forms were not included. This could have influenced the selection of subsequent medications and responses to different treatments. However, most patients had initial self-management procedures of acute asthma as suggested by their physicians. Therefore, the oral route of bronchodilators was not recommended in our settings because of slower onset of action and increased risk of adverse effects, compared to inhalations,[32] and preventing aspiration in younger patients with severe respiratory distress.

Finally, BASS had limitations in determining treatment response and hospitalization decisions because of the recommended national standard asthma guidelines, considering the clinical parameters of airflow, retraction of respiratory muscles, percentage of oxygen saturation of room air, and PEF measurement.[8]

Conclusion

We developed practical BASS for HCP, adding a new clinical parameter, as a utility to evaluate acute asthmatic patients more accurately and safely. We suggested this basic cognitive tool for assessing the degree of severity and generating the optimal cutoff point of at least 8 for predicting pediatric patients with severe asthma exacerbations in ED. However, further studies are required to determine the implementation of BASS in concordance with standardized acute asthma management guidelines for achieving the overall goal of asthma treatments.

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Supplementary

Table S1 Buddhasothorn Asthma Severity Score.

Items		Clinical parameters	Descriptions	Grading scores	
				1	2
1		History of using inhaled or nebulized SABAs alone (or in combination with ipratropium bromide) or budesonide/formoterol as SMART regimen	Administration as a reliever treatment for acute asthmatic episodes within 24 h before arrival at triage	No	Yes
2		Talks or consciousness	If any child cannot talk according to developmental milestones, consider the level of consciousness instead	Phrases or not agitated	Words or agitated
3		Any retraction or accessory muscles in use	Not necessary to identify type of accessory muscles	No	Yes
4		Pulse rate/min			
		1–5 years		≤180	>180
		6–15 years		≤120	>120
5		Room air SpO_2 (%)		≥92	<92
6	6.1	Peak expiratory flow (% predicted or best)	For children over 5 years of age with effective PEF measurement	>50	≤50
	6.2	Central cyanosis	For children under 5 years of age, or for those who have limitations of PEF measurement	No	Yes

PEF: peak expiratory flow; SABAs: short-acting beta 2 agonists; SMART: single maintenance and reliever therapy; SpO_2: spot oxygen saturation.

Table S2 Wood–Downes–Ferrés Scale.

Items	Clinical parameters	Grading scores			
		0	1	2	3
1	Wheezing	No	End of expiration	Throughout expiration	Inspiration and expiration
2	Retractions	No	Subcostal + inferior intercostal	Previous + supraclavicular	Previous + superior intercostal + suprasternal
3	Air inflow	Good, symmetrical	Regular, symmetrical	Greatly diminished	Silent thorax (no wheezing)
4	Cyanosis	No	Yes		
5	Respiratory rate (breaths/min)	<30	31–45	46–60	>60
6	Heart rate (beats/min)	<120	>120		

Table S3 Comparison of the characteristics of clinical asthma severity scores.

Items	Clinical parameters	BASS	WDFS
1	Cyanosis	+	+
2	Retractions or accessory muscles in use	+	+
3	Heart rate	+	+
4	History of using inhaled or nebulized bronchodilators in 24 h before arrival at triage	+	-
5	Ability to speak or mental status	+	-
6	Oxygen saturation	+	-
7	Peak expiratory flow	+	-
8	Air entry	-	+
9	Wheezing	-	+
10	Respiratory rate	-	+

BASS: Buddhasothorn Asthma Severity Score; WDFS: Wood—Downes—Ferrés Scale.

Table S4 Establishing the outcome of nebulized bronchodilator administration, and classifying the severity level of asthma exacerbations.

Nebulized bronchodilators as initial treatment				Outcome of treatment		
Frequency dose(s)	Type of medication			Outcome 1	Outcome 2	Severity level of acute asthma
1	SABAs	-	-	N	N	Mild-to-moderate
1	S + IBr	-	-	N	N	Mild-to-moderate
2	SABAs	SABAs	-	Y	N	Mild-to-moderate
3	SABAs	SABAs	SABAs	Y	N	Mild-to-moderate
3	SABAs	SABAs	S + IBr	Y	Y	Severe
3	SABAs	S + IBr	S + IBr	Y	Y	Severe
2	S + IBr	S + IBr	-	Y	Y	Severe
3	S + IBr	S + IBr	S + IBr	Y	Y	Severe

N: No; Y: Yes; S + IBr: short-acting beta 2 agonists combined with ipratropium bromide; SABAs: short-acting beta 2 agonists.