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CLINICAL SCORES FOR ACUTE ASTHMA IN PRE-SCHOOL CHILDREN. A REVIEW OF THE LITERATURE

DANIËLLE A. W. M. VAN DER WINDT,^{1*} AD F. NAGELKERKE,²
LEX M. BOUTER,^{1,3} JEANNETTE E. DANKERT-ROELSE² and ANJO J. P. VEERMAN²

¹Institute for Research in Extramural Medicine, Faculty of Medicine, Vrije Universiteit,

²Department of Pediatric Medicine, University Hospital, Vrije Universiteit and

³Department of Epidemiology and Biostatistics, Faculty of Medicine, Vrije Universiteit, Amsterdam, The Netherlands

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Abstract—The objective of this paper was to evaluate the applicability in research and clinical practice of clinical scores for acute asthma in pre-school children. All instruments were reviewed according to a standardized set of criteria: purpose of the score, suitability for use in children, inter-observer agreement, validity and responsiveness. A Medline literature research resulted in 16 different clinical asthma scores, which have been developed to assess the severity of acute asthma, to predict the outcome of an attack, or to evaluate the response to treatment. Most asthma scores could be easily obtained in children. Three scores have been modified to facilitate application in a younger age-category. Inter-observer agreement has received little attention, although all scores contained items that require subjective judgement. The predictive validity was insufficient to justify the application of clinical scores as a decision rule for the admission or discharge of children with acute asthma. Asthma scores seem to be useful for assessing the severity of an attack and evaluating the response to therapy, but as yet there is insufficient information on the performance of the scores to justify a preference. Wheezing and retractions appear to be important items of any useful score for acute asthma.

Childhood asthma Asthma score Clinical signs Inter-observer agreement
Validity Responsiveness

INTRODUCTION

The prevalence of childhood asthma is reported to be between 5 and 20% in Western countries [1, 2]. As the disease often starts before the age of 2 years, a considerable number of children who are treated for exacerbations of asthma are younger than 5 years old [3]. In order to provide adequate treat-

ment, it is necessary to assess the severity of an asthma attack. However, measuring the severity of airways obstruction in children is difficult.

Pulmonary function tests can provide objective evidence regarding the severity of airways obstruction, but routine measurements of peak expiratory flow rate and spirometry require active co-operation of the patient, and are thus not suitable for young children [4]. Physicians use clinical signs to assess the severity of an exacerbation of asthma and to decide on treatment strategies. Investigators frequently use

*All correspondence should be addressed to: Ms D. A. W. M. van der Windt, Institute for Research in Extramural Medicine, Vrije Universiteit, Van der Boechorststraat 7, 1081 BT Amsterdam, The Netherlands.

clinical signs to evaluate treatment efficacy in clinical trials. According to McFadden [5], the validity of clinical signs for assessing airways obstruction is limited. Moderate correlations with pulmonary function measurements have been described for several clinical signs, such as respiratory rate [6], respiratory pattern [7], wheezing [8], accessory muscle use [9] and pulsus paradoxus [10]. A single clinical sign will not be very indicative of asthma severity, but a combination of signs may provide more valid information, considering the complex relationship between the pathophysiological and the clinical features of asthma.

An array of multivariate clinical scores for acute asthma has been described in the literature. The use of most of these instruments has been reported once or twice, but the application of some scores, e.g. the Clinical Asthma Score (CAS) [11] and the Pulmonary Index (PI) [12], has been described more frequently. The scores have been used for several purposes: to assess asthma severity, to predict the outcome of an attack or to evaluate treatment efficacy.

The purpose of this paper was to review the clinical scores for acute asthma described in the scientific literature. In order to evaluate the applicability of these instruments in clinical practice and research, all scores were reviewed critically according to a set of criteria. Since pre-school children are often unable to perform pulmonary function tests, clinical signs will frequently be the deciding factor in the assessment of acute asthma. Therefore, this review was restricted to publications reporting the application of clinical asthma scores in this age-category.

METHODS

A Medline literature search was conducted for the period 1966–1992, using the keywords asthma, bronchial obstruction, airways obstruction, index and score. The references of selected papers were screened for additional relevant publications. Studies had to meet the following criteria to be included in the review:

- The study described the development or use of a multivariate index for the assessment of an episode of asthma.
- The study included children aged 0–5 years.
- The score has been composed of a combination of clinical signs of acute asthma. Scores of overall asthma severity which contain historical parameters, such as the number

of hospitalizations, type of medication and frequency of attacks, were not included in the review.

- The publication has been written in English, French, German or Dutch.

The clinical asthma scores were reviewed with regard to the following six criteria:

1. Purpose of the score

Clinical scores may be designed and applied for a variety of purposes, which can be summarized into three broad categories: discrimination, prediction or evaluation [13, 14]. An asthma score was categorized as a discriminative instrument or index of status [15] if it has been used to rate the severity of asthma at a single point in time. Whenever a score has been used to predict the outcome of an asthma attack, the score was categorized as a predictive (prognostic) instrument. An index was described as an evaluative instrument (index of change) when used to reflect changes of clinical signs of asthma over time, usually in the context of a clinical trial.

2. Description of the score

Several characteristics of the selected scores were evaluated, including the references of the publications reporting application of the score, the age-category in which the score has been used, the nature of the individual items of the score, the scaling of items and the calculation of the final score. Whenever the development of an asthma score was based on empirical evidence, as opposed to designing a score in an *ad hoc* manner, the methodology used for the development of the instrument was briefly summarized.

3. Suitability for use in children

To facilitate the applicability of asthma scores in paediatric practice, the items included in the scores should be easily obtainable in pre-school children. The suitability for use in this age-category was scored on an ordinal scale:

- the score either contains an item which requires invasive techniques or several items which may be difficult to obtain in small children (e.g. pulsus paradoxus, inspiratory to expiratory ratio)
- + the score contains no more than one item which may be difficult to obtain in small children
- ++ all items of the score can be obtained without difficulty in small children.

4. Inter-observer agreement

All publications on asthma scores were evaluated for data on inter-observer agreement.

5. Validity

The instruments were evaluated for construct validity: the extent to which a score is related to other measures in a way that is consistent with hypotheses concerning the concept that is being measured [13]. In this review the relationship of asthma scores to other indicators of the severity of bronchial obstruction was determined, such as oxygen saturation, pulmonary function or overall clinical judgement.

The relationship of predictive asthma scores to the outcome of an attack, usually defined as relapse, admission to hospital or successful discharge from the emergency department, provided information on predictive validity, which had been demonstrated by calculations of sensitivity, specificity or predictive values.

6. Responsiveness

Evaluative scores are concerned with longitudinal changes over time and should be tested for responsiveness: the ability to detect a minimal clinically important difference over time. The most appropriate measure of responsiveness is the ratio of a clinically important change after therapy to the within-patient variability of the score before treatment [16]. However, the majority of the selected publications did not provide sufficient information to make such a calculation possible. An indication of the responsiveness of an asthma score used for evaluative purposes was given by calculating the relative change in index values within 1–24 hr after initiation of treatment.

RESULTS

The results of the literature search have been summarized in three tables, according to the application of the instrument: discrimination, prediction or evaluation. In each table the scores are arranged alphabetically, according to the name of the first author mentioning application of the instrument.

Instruments used for discriminative purposes

The literature search resulted in 6 scores which have been used to assess the severity of acute asthma at a single point in time (Table 1). Some authors have proposed a classification of severity by grouping final scores into categories

of mild, moderate or severe asthma [10, 22]. Most scores were easily obtained and should be suitable for use in all age-categories. The Clinical Asthma Evaluation Score described by Obata *et al.* [22] seemed to be less suitable, as speech impairment is difficult to determine in infants.

No information was available on the methods used to design the asthma scores. These instruments have probably been designed in an *ad hoc* manner, on the basis of face validity only. Inter-observer agreement has not received much attention, although all scores include parameters such as retractions, wheezing and dyspnea, which require subjective judgement. The inter-observer agreement of the Asthma Severity Scale (ASS) has been studied on two occasions. Scoring of each item by two independent observers for 126 hospital admissions resulted in 11 observer differences, mainly concerning the scoring of accessory muscle use [18]. In contrast to these results, Bishop *et al.* [21] reported only moderate agreement between two independent observers ($\kappa = 0.63$).

Construct validity has been studied by calculating the relationship with other measures of asthma severity, such as arterial blood gas tension (PaO_2 , PaCO_2) or transcutaneous oxygen saturation (SaO_2). Both the Clinical Asthma Evaluation Score [22] and the Symptom Grading System [23] showed fairly strong correlations with PaO_2 and PaCO_2 . Conflicting results have been described for the performance of the ASS; the strong correlation with SaO_2 reported by Dawson [20] was not confirmed by the results of Bishop *et al.* [21].

Instruments used for predictive purposes

Three asthma scores have been used to predict the need for hospitalization or the likelihood of relapse after discharge (Table 2), one of which was originally designed for discriminative purposes (ASS [17]). The predictive qualities of the ASS were studied by Bishop *et al.* [21]. Fischl's Index [27] is a frequently cited predictive score for application in patients of at least 5 years old. Due to the inclusion of peak expiratory flow rate (PEFR), Fischl's Index is not useful in younger patients. Kerem *et al.* [28] proposed a modification of Fischl's Index which is applicable in all age-categories. The final score was standardized by expressing the number of positive values as a fraction of the total number of items measured for the patient at issue.

Table 1. Discriminative instruments

Name and description of instrument	Suitability in small children	Study reference number	Number of subjects	Age (yr)	Inter-observer agreement	Validity (association with other measures of asthma severity)
<i>Asthma Severity Scale</i>						
Design: <i>ad hoc</i>	++	[17]	110	0.8-14.4	—	—
Items: wheezing, accessory muscle use, pulse rate						
Scale: ordinal (0-3); maximum score 9		[18]	126	0.5-13	Disagreement in 3% of items scored	—
		[19]	112	?	—	—
		[20]	41	3-13	—	Correlation with SaO ₂ : $r = -0.76$ ($p < 0.0001$)
		[21]	60	0.5-17	Kappa = 0.63	Agreement with clinical judgement rate: kappa = 0.67 ($p = 0.016$)
						No correlation with SaO ₂ or PEFR
<i>Clinical Score</i>						
Design: <i>ad hoc</i>	++	[10]	12	1-15	—	Correlation with pulsus paradoxus: $r = 0.79$ ($p < 0.01$).
Items: wheezing, retractions, air exchange, anxiety						
Scale: ordinal (0-2); maximum score 8						
<i>Clinical Asthma Evaluation Score</i>						
Design: <i>ad hoc</i>	+	[22]	32	0-5	—	Correlation with PaCO ₂ : $r = 0.75$ ($p < 0.0005$)
Items: dyspnea, wheezing, rales, speech impairment, cyanosis, mental status						Correlation with PaO ₂ : $r = -0.67$ ($p < 0.0005$)
Scale: ordinal (0-3); maximum score 10						
<i>Symptom Grading System</i>						
Design: <i>ad hoc</i>	++	[23]	47	1-17	—	Correlation with PaO ₂ : $r = -0.86$ ($p < 0.001$)
Items: wheezing, dyspnea, rhonchi, accessory muscle use, anxiety						
Scale: six descriptive categories of increasing severity						
<i>Asthma Score</i>						
Design: <i>ad hoc</i>	++	[24]	391	2-17	—	No correlation with results of chest X-rays
Items: wheezing, retractions, cyanosis						
Scale: ordinal (0-4); maximum score 9						
<i>Clinical Symptom Grading System</i>						
Design: modification of Symptom Grading System [23]	++	[25]	10	0-2	—	Association with PaCO ₂ and PaO ₂
Items: respiratory rate, wheezing, rhonchi, retractions, fatigue, anxiety, cyanosis, breath sounds						—
Scale: six descriptive categories of increasing severity		[26]	101	0-2	—	

PEFR, peak expiratory flow rate; SaO₂, oxygen saturation; PaO₂, arterial oxygen tension; PaCO₂, arterial carbon dioxide tension.

Table 2. Predictive instruments

Name and description of instrument	Suitability in small children	Study Ref. No.	Number of subjects	Age (yr)	Inter-observer agreement	Validity	Predictive validity (ability to predict hospital admission)
<i>Asthma Severity Scale</i> See Table 1 for design, items and scale Decision rule: admission if final score > 3	++	[21]	60	Mean age 5.5	See Table 1	See Table 1	Prospective: sensitivity 97% specificity 50%
<i>Modification of Fischl's Index</i>	++	[28]	200	0.4-16	—	—	Prospective: sensitivity 79% specificity 80%
Design: based on empirically derived data (see text)							
Items: pulse rate, respiratory rate, pulsus paradoxus, PEFr, dyspnea, accessory muscle use, wheezing							
Modification: Fischl's Index [27] was standardized by expressing the number of positive values as a fraction of the total number of items measured for each patient. In this way it is possible to use the score in children who are not capable of performing PEFr measurements. As a consequence the final scores range between 0 and 1.		[29]	71	5-17	—	Correlation with FEV ₁ : $r = 0.72$ ($p < 0.001$) Correlation with SaO ₂ : $r = 0.70$ ($p < 0.001$)	—
Decision rule: admission if final score ≥ 0.75							
<i>Pediatric Predictor Index</i>	++	[30]	156	5-18	—	—	Retrospective: sensitivity 95% specificity 66%
Design: the index was designed according to protocol similar to that of Fischl [27]							
Items: pretreatment inspiratory breath sounds, post-treatment wheezing, and difference between pre- and post-treatment respiratory rate							
Scale: ordinal and dimensional; final score according to mathematical equation		[31]	100	0.5-17	—	—	Prospective (combination with SaO ₂): positive PV 72% negative PV 94%
Decision rule: admission if final score > 0							

SaO₂, oxygen saturation; FEV₁, forced expired volume in 1 sec; PV = predictive value.

Both Fischl's Index and the Paediatric Predictor Index (PPI) [30] have been developed on the basis of the results of physical examination, PEFr and blood gas analysis in patients with an acute episode of asthma. After treatment in the emergency department, patients were discharged or hospitalized, according to standard clinical criteria. All clinical decisions were made without prior knowledge of the results of the asthma score. The results of clinical signs and PEFr were subjected to multivariate discriminant analysis, based on stepwise addition of the items which contributed to the largest increase in predictive value of relapse or hospital admission.

Predictive validity has mainly been studied by calculating sensitivity and specificity to predict hospital admission or relapse after discharge. In Table 2, results concerning predictive validity are restricted to the prediction of hospital admission. According to Bishop *et al.* [21], the ASS showed a high sensitivity to predicting hospital admission, whereas specificity was considerably lower. Similar results were presented for the PPI, when applying this index retrospectively to the same data set used to design the PPI [30]. Predictive validity of the PPI has been studied once in a different population, including pre-school children, but results were only presented in combination with measurements of SaO_2 [31]. On the basis of the data from the latter publication, it was not possible to calculate sensitivity or specificity, but predictive values are listed in Table 2. The predictive qualities of the modification of Fischl's Index were less favourable than the results that have originally been presented by Fischl *et al.*, i.e. a sensitivity of 96% and a specificity of 97% [27]. Applying the modified index to a new population, which included small children, resulted in a lower predictive validity [28].

In addition to being used as a predictive instrument, these scores might be reflective of asthma severity at the time of assessment and therefore useful for discriminative purposes. However, apart from a fairly strong correlation of the modification of Fischl's Index with pulmonary function and oxygen saturation in children aged 5–17 years [29], little information was available on the construct validity of predictive instruments.

No information on inter-observer agreement of the predictive instruments has been presented in any of the selected publications.

Instruments used for evaluative purposes

Eight asthma scores have been primarily used as evaluative instruments in clinical trials (Table 3). To our knowledge, all evaluative instruments have been designed in an *ad hoc* manner. Use of the CAS and the PI has been reported frequently, in small children as well as in patients of at least 5 years of age. Both scores have been modified in order to facilitate application in younger age-categories. A higher respiratory rate in infants complicates the determination of inspiratory to expiratory ratio. Therefore, Tal *et al.* [35] replaced the item "inspiratory to expiratory ratio" by "cyanosis", which enabled use of the PI in infants. The item "oxygen tension", which was originally included in the CAS, has been modified or replaced by "cyanosis" by several authors in order to avoid the need for arterial puncture. The Clinical Score used by Pendergast *et al.* [43] was considered to be less suitable for use in children, because the assessment of the item "pulsus paradoxus" may also be complicated by a higher respiratory rate in infants. The other evaluative scores listed in Table 3 could be easily obtained, irrespective of the age of the patients.

Similar to our findings on discriminative and predictive instruments, little attention has been paid to the inter-observer agreement of evaluative instruments. A good agreement for wheezing scores ($\kappa = 0.9$) and a moderate agreement when scoring retractions ($\kappa = 0.64$) was reported for the Respiratory Distress Assessment Instrument [42]. Pilot studies on the inter-observer agreement of the PI [35] and the Clinical Scoring System [33] demonstrated only minor variations, but inter-observer agreement has not been studied thoroughly.

Information on construct validity, as summarized in Table 3, was largely deduced from text, tables or figures in the original articles. Most studies have included other measures to assess the response to treatment, but the relationship with improvements of asthma scores has not been presented. In general, changes in clinical asthma scores were consistent with changes in pulmonary function, SaO_2 , PaCO_2 , respiratory rate or pulse rate. In a few studies apparent improvements in clinical scores after therapy were not accompanied by changes in SaO_2 [32], blood gas values [35] or respiratory rate [40].

In order to review the responsiveness of the asthma scores, the relative change within treat-

Table 3. Evaluative instruments

Name and description of instrument		Suitability in small children	Study Ref. No.	Number of subjects	Age (yr)	Inter-observer agreement	Validity	Responsiveness*
<i>Clinical Score</i>								
Design:	<i>ad hoc</i>	++	[32]	43	0.5-2	—	—	25% improvement† after albuterol; uncontrolled study
Items:	pulse rate, respiratory rate, wheezing, accessory muscle use, dyspnea							
Scale:	binary (0-1); maximum score 5							
<i>Clinical Scoring System</i>								
Design:	<i>ad hoc</i>	++	[33]	28	0-2	perfect agreement in 6/8 patients	Changes were consistent with changes of SaO ₂	33% improvement after albuterol; RCT
Items:	pulse rate, respiratory rate, wheezing, accessory muscle use							
Scale:	ordinal (0-3); maximum score 12							
<i>Pulmonary Index</i> [12]								
Design:	<i>ad hoc</i>	++	[34]	35	1-13	—	Correlation with PEFR: $r = -0.52$ ($p < 0.02$)	52% improvement† after metaproterenol; RCT
Items:	respiratory rate, wheezing, inspiratory to expiratory ratio, accessory muscle use							
Scale:	ordinal (0-3); maximum score 12							
Modification: used by references [35-39] Cyanosis was included to replace the inspiratory to expiratory ratio, which is difficult to score in infants.								
			[36]	79	0-1	—	—	25% improvement† after ipratropium or fenoterol; RCT
			[37]	28	Mean age 0.9	—	—	18-33% improvement† after ipratropium or fenoterol; RCT
			[38]	74	0.5-5	—	—	33% improvement† after salbutamol + prednisolone; RCT
			[39]	22	0-1	—	—	60% improvement† after ipratropium; RCT

—continued overleaf

Table 3—Continued

Name and description of instrument	Suitability in small children	Study Ref. No.	Number of subjects	Age (yr)	Inter-observer agreement	Validity	Responsiveness*
<i>Clinical Rating</i> Design: <i>ad hoc</i> Items: wheezing, air entry, respiratory distress (i.e. indrawing, retractions, accessory muscle use) Scale: ordinal (0–3); maximum score 9	++	[40]	48	1.5–12	—	Changes were consistent changes of pulse rate	13–40% improvement† after fenoterol and/or ipratropium; RCT
<i>Clinical Score</i> Design: <i>ad hoc</i> Items: retraction, wheezing, aeration Scale: ordinal (0–3); maximum score 9	++	[41]	43	3–12	—	Changes were consistent with changes of PEFR, pulse rate and respiratory rate	75% improvement† after epinephrine; RCT
<i>Respiratory Distress Assessment Instrument</i> Design: <i>ad hoc</i> Items: wheezing, retractions, respiratory rate Scale: ordinal; summation of change scores	++	[42]	42	0–2	Wheezing: kappa = 0.9 Retractions: kappa = 0.64	Changes were consistent with changes of nasal flaring, inspiratory to expiratory ratio, breath sounds, response to treatment	Improvement† after epinephrine; RCT and uncontrolled study
<i>Clinical Score</i> Design: <i>ad hoc</i> Items: dyspnea, wheezing, scalene and sternomastoid contraction, retractions, thoraco-abdominal paradox, pulse rate, respiratory rate, pulsus paradoxus Scale: ordinal (1–4); results are averaged; maximum score 4	+	[43]	27	3.0–6.8	—	—	19% improvement† after terbutaline; RCT

—continued opposite

Table 3—Continued

Name and description of instrument	Suitability in small children	Study Ref. No.	Number of subjects	Age (yr)	Inter-observer agreement	Validity	Responsiveness*
<i>Clinical Asthma Score (CAS)</i> Design: <i>ad hoc</i>		[11]	18	?	Disagreement was rare	Correlation with PaCO ₂ : $r = 0.69$ ($p < 0.001$) Correlation with PaO ₂ : $r = -0.44$ ($p < 0.05$)	—
Items: PaO ₂ or cyanosis, inspiratory breath sounds, accessory muscle use, expiratory wheezing, cerebral function	— if PaO ₂ is in- cluded						
Scale: ordinal (0–2); maximum score 10		[44]	19	1.5–15	—	Changes were consistent with changes of PaCO ₂	75% improvement after iso- proterenol; uncontrolled study
		[45]	16	1.3–15	—	Changes were consistent with changes of PaCO ₂	30% improvement after iso- proterenol; historical controls
		[46]	37	0.5–16	—	Changes were consistent with changes of PaCO ₂ and pulse rate	62% improvement after iso- proterenol; uncontrolled study
<i>Modification of CAS</i> Exclusion of the item cyanosis	++	[47]	19	1–14	—	Changes were consistent with changes of PaCO ₂	28% improvement† after terbuta- line; uncontrolled study
		[48]	17	2–17	—	Changes were consistent with hormonal changes	—
		[49]	38	2–13	—	No correlation with PaO ₂ : $r = -0.15$	—
<i>Modification of CAS</i> Exclusion of the item cyanosis Inspiratory breath sounds was replaced by resp. rate; different interpretation of cyanosis	++	[50]	20	0.8–14.7	—	Changes were consistent with	50% improvement† after changes of pulse rate, respir- atory rate and PEFR

*Ability to detect a clinically important change within treatment categories.

†Indicates a statistically significant improvement ($p < 0.05$).PEFR, SaO₂, PaCO₂, PaO₂; see Table 1; FEV₁, forced expired volume in 1 sec; RCT, randomized clinical trial.

ment categories was calculated using information presented in the original publications. All clinical trials showed an improvement after treatment, varying in magnitude from 19% [43] to 75% [41, 44] (Table 3). Several studies demonstrated significantly larger improvements in asthma scores after experimental therapy than after placebo-treatment [33, 35–37, 39, 42]. The amount of improvement of the Respiratory Distress Assessment Instrument [42] could not be calculated due to the fact that data on baseline values were not available. This instrument was, in fact, the only index composed of items of change. For all other asthma scores comparisons were made between score values calculated before and after therapy.

DISCUSSION

Screening of the scientific literature resulted in the identification of 16 different clinical scoring systems for acute asthma in pre-school children. This collection may be incomplete, since authors do not always mention the use of an asthma score in the abstract, title or subject headings, and these publications may therefore be missed in the process. However, we presume that we have missed very few publications in which specific attention has been paid to design or performance of clinical asthma scores.

Little attention has been focused on the inter-observer agreement of asthma scores, although clinical signs such as cyanosis, retractions, dyspnea and wheezing require a subjective judgement. We do, of course, have no objections against the use of subjective clinical data *per se*, as long as these data can be described precisely enough to have a similar meaning for other observers [15]. The way in which asthma severity is expressed by clinical signs will differ between patients, and may also differ from one assessment to another. Multivariate scores might therefore give a more adequate reflection of asthma severity than individual signs. The Clinical Asthma Evaluation Score [22], the Symptom Grading System [23] and the ASS [17] may prove to be valid scores for the assessment of the severity of acute asthma at a single point in time, considering the moderate to strong correlations with PaO_2 , PaCO_2 or clinical judgement rate. Information on construct validity was limited, but most discriminative and evaluative asthma scores were related to other indicators of bronchial obstruction in a way that

is consistent with hypotheses concerning the concept of asthma severity.

The ability of asthma scores to predict the outcome of an episode of acute asthma appeared to be rather disappointing. Presenting symptoms and signs of an acute asthma attack do not necessarily indicate what the response to treatment will be. Decision-making in the emergency department should therefore not rely on the performance of a clinical asthma score at presentation, but on careful ongoing clinical assessment and in particular the response to treatment [5, 29]. A high performance of a predictive asthma score was usually only evident in the original data set. The validity of predictive instruments should be tested prospectively in different settings before being used in clinical practice.

In Table 3 the relative improvement after therapy has been presented in order to provide some information on the responsiveness of asthma scores. The relative change within treatment categories varied considerably between scores, as well as in the same scores between publications. The magnitude of change was probably not only dependent on the responsiveness of the instrument, but has also been influenced by the type of treatment, the severity of asthma at baseline and the timing of effect measurement. Nevertheless, the fact that asthma scores showed significant improvement after therapy in many intervention studies seems to suggest sufficient ability to detect a clinically significant change. The PI [35], the Respiratory Distress Assessment Instrument [42] and the Clinical Scoring System [33] have been successfully used in infants with asthma, showing some evidence of validity, responsiveness and inter-observer agreement. However, insufficient information was available on the performances of evaluative asthma scores to rate one instrument above another.

Nearly all instruments can be easily scored in children and, where necessary, modifications have been proposed to enable application in all age-categories. However, asthma-scoring in children may involve some other pitfalls. Respiratory rate and pulse rate will be influenced by crying and by the level of activity of the child. These items should ideally be measured when the child is completely at rest, which is a very rare situation in children during an asthma attack. The assessment of pulsus paradoxus with a sphygmomanometer may be difficult in children, but a value exceeding 15 mmHg

should be regarded as an indicator of considerable disease severity [51]. In adult patients the presence of a pulsus paradoxus larger than 15 mmHg could be detected by palpation of the radial pulse, which is a less complicated method [52]. Should this hold for pre-school children as well, pulsus paradoxus can be an important item of a clinical score for acute asthma. Most instruments have included accessory muscle use or retractions, dyspnea and wheezing, which were apparently highly relevant for the assessment of asthma severity. These items showed a stronger relationship with pulmonary function than other clinical signs [29].

Although most asthma scores appeared to contain similar items, the design of the scores has been done in an *ad hoc* manner or has been based on research in adult asthmatics and children who are capable of performing pulmonary function tests. In the future, research should be concentrated on the study of the performances of discriminative and evaluative asthma scores in children. This is particularly relevant for children who are unable to manage peak flow tests, and who account for a large number of attendances at the emergency department. Bishop *et al.* [21] evaluated the performances of the ASS, which proved to be an imprecise but reasonably valid measure of clinical judgement about the severity of an acute episode of asthma. It is advisable to evaluate other asthma scores in a similar fashion before embarking on the development of yet another asthma score.

In this review clinical scores were evaluated with regard to the purpose of the instrument, according to a framework proposed by Kirschner and Guyatt [13]. This framework turned out to be convenient for reviewing asthma scores applied in this age-category, as nearly every instrument was designed and applied for either discrimination, prediction or evaluation. Whether these asthma scores are useful for other measurement functions than the one they have been designed for, largely remains to be seen. The same holds true for the question whether the properties of these instruments allow for application in individual patients as well as in groups, which should be the main criterion for evaluating clinical measures according to Williams and Naylor [53]. This review has shown that the predictive validity of asthma scores is clearly insufficient to allow for the application of clinical scores as a decision rule for the admission or discharge of individual

patients with acute asthma. Some scores may, however, prove to be useful for monitoring the severity of asthma and the response to treatment of an individual patient.

In conclusion, clinical asthma scores seem to be useful instruments for discriminative and evaluative purposes, but as yet there is not enough information on the performances of asthma scores to justify a preference for one particular instrument. Wheezing and retractions appear to be essential elements of a useful clinical score for acute asthma in children. These (and other) items should be scored according to clearly described categories in order to minimize inter-observer variation.

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