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ORIGINAL ARTICLE

Modified Pulmonary Index Score Was Sufficiently Reliable to Assess the Severity of Acute Asthma Exacerbations in Children

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ABSTRACT

Background: The Modified Pulmonary Index Score (MPIS) was developed as an indicator of the severity of acute asthma in children. The objective of this study is to evaluate the reliability and validity of the MPIS for children with acute asthma, including those five years or younger in age.

Methods: We evaluated the inter-rater reliability and internal consistency of the MPIS by having at least two trained physicians and a nurse—each of whom was blinded to the others' scores—simultaneously examine inpatients with asthma exacerbation and rate them according to the MPIS. We also evaluated the intraclass correlation coefficient (ICC), kappa, Cronbach's α and correlations between the MPIS and other indicators associated with asthma severity.

Results: A total of 25 children (median age, five years; 13 patients were five years or younger in age) were enrolled in this study. The MPIS showed excellent inter-rater reliability (all ages: ICC = 0.95, 95% CI = 0.94-0.97; five years or younger: ICC = 0.93, 95% CI = 0.89-0.96) and good internal consistency (all ages: Cronbach's α = 0.87; five years or younger: Cronbach's α = 0.85). The MPIS showed good correlation with a visual analogue scale assessed by the physicians.

Conclusions: The MPIS was a sufficiently reliable assessment tool for children with acute asthma, including those five years or younger in age.

KEY WORDS

asthma, child, reliability, symptom assessment, validity

INTRODUCTION

Bronchial asthma is one of the most common chronic childhood disorders in the world. More than 90,000 of such patients younger than 18 years old require hospitalization annually in Japan, with a majority of them being preschool children. Appropriate objective assessment for acute asthma severity is essential, not only for evaluating the effectiveness of treatment, but also for sharing patient information among medical professionals. Although pulmonary function tests are commonly used to assess the severity of acute asthma in adults, they are difficult to perform in children, especially those who are younger than five years old.[1]

Accordingly, several clinical scores have been developed in order to evaluate the severity of asthma attacks.[2-8] Carroll *et al.*[9] developed and evaluated the Modified Pulmonary Index Score (MPIS) in 2005 based on data obtained from 30 children with a mean age of 7.6 years. They reported high inter-rater reproducibility and good correlations of the MPIS with

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Table 1 The Modified Pulmonary Index Score (MPIS)

		Score			
		0	1	2	3
Oxygen saturation, %		>95	93-95	90-92	<90
Accessory muscle use		None	Mild	Moderate	Severe
Inspiratory-to-expiratory flow ratio		2 : 1	1 : 1	1 : 2	1 : 3
Wheezing		None	End expiratory	Inspiratory and expiratory wheeze, good aeration	Inspiratory and expiratory wheeze, decreased aeration
Heart rate	<3 years old	<120	120-140	141-160	>160
	≥3 years old	<100	100-120	121-140	>140
Respiratory rate	<6 years old	≤30	31-45	46-60	>60
	≥6 years old	≤20	21-45	36-50	>50

clinical outcomes such as ICU admission. The MPIS appears to be suitable for measuring the severity of acute asthma exacerbation, and was applied as primary outcome measurement in some clinical trials.[10,11] However, its applicability to preschool children has not yet been fully elucidated. In this study, we evaluated the inter-rater reliability and internal consistency of the MPIS in a younger population, including preschool children.

METHODS

This study was approved by the Institutional Ethics Review Board, and informed consent was obtained before enrollment. Between September 2009 and February 2011, patients who were admitted to the hospital with asthma exacerbation were considered for enrollment in the study. Patients were eligible if they were one to 12 years of age and had previously been diagnosed with asthma. Patients were excluded if (1) acute conditions such as croup or pneumonia were present, (2) asthma exacerbation was severe enough to require ventilatory support, (3) altered mental status was observed, or (4) there were underlying pulmonary or cardiac conditions.

The MPIS consisted of six items: (1) oxygen saturation on room air (SpO_2), (2) accessory muscle use, (3) inspiratory-to-expiratory flow ratio (I:E ratio), (4) degree of wheezing, (5) heart rate (HR) and (6) respiratory rate (RR). For each of these items, a score of 0 to 3 is assigned based on the severity. The range of total score is 0 to 18. The higher the total score is, the more severe the condition (Table 1).

RATERS AND THEIR TRAINING

Forty-five physicians (three pediatric allergists, six pediatric hospitalists and 36 residents) and 12 nurses (all of whom were pediatric ward nurses) participated in this study as raters of the MPIS.

Before starting this study, we developed digital learning software for the MPIS that contained recorded auscultation sounds, video images and computer graphics of the asthma exacerbation with varying severity. This software was developed to standardize evaluation of the subjective MPIS items, i.e., (2) through (4), described above. All of the raters completed training with this software and evaluated their skills with 10 test cases after training.

ASSESSMENT OF THE PATIENTS

To evaluate the inter-rater reliability of the MPIS, at least two physicians and a nurse—each of whom was blinded to the other raters' scores—simultaneously assessed each inpatient's asthma using the MPIS. Patients were assessed at admission and at one or two more times subsequently, with an interval of at least eight hours.

In addition to the assessment with MPIS, physicians were required to score their subjective evaluation of the severity of asthma exacerbation with a Visual Analogue Scale (VAS) from 0 (no symptoms) to 10 (needs intubation). At the same time, with raters' evaluation, the parents were asked to score the degree of dyspnea of their child using a 10-point scale, with 10 representing the status at admission.

STATISTICAL ANALYSIS

The inter-rater reliability of the total MPIS was evaluated using the intraclass correlation coefficient (ICC). The inter-rater reliability of each item was evaluated using a weighted kappa coefficient for two evaluations: two physicians, and a physician and a nurse. Some raters evaluated the same patient sequentially, followed by the ICC of the reduction of MPIS within-rater and within-patient being calculated.

The internal consistency was evaluated as Cronbach's alpha coefficient. The correlation of the MPIS and the physicians' VAS was assessed by Pearson's correlation coefficients to explore the concurrent validity. Responsiveness was evaluated using Pearson's correlation coefficients of the reduction of average MPIS and that of VAS and the parents' evaluation. All analyses were performed for all ages group, five years or younger (younger-age group), and six years or older. Data were analyzed with SAS software ver-

Table 2 Characteristics at admission

Patients (*N* = 25)	
Age [median (range)]	5.0 (2-12)
1-5 years old [*N* (%)]	13 (52.0)
6-12 years old [*N* (%)]	12 (48.0)
MPIS at entry [median (range)]	10 (5-16)
Simultaneous evaluation (62 times)	**Frequency (%)**
Age	
1-5 years old	31 (50.0)
6-12 years old	31 (50.0)
Consciousness	
Sleep	3 (4.8)
Awake	59 (95.2)
Posture	
Sitting	42 (67.7)
Lying	20 (32.3)
Crying	
Yes	2 (3.2)
No	60 (96.8)
Physician's assessment of asthma exacerbation severity	
Mild	25 (40.3)
Moderate	25 (40.3)
Severe	12 (19.3)
Respiratory arrest imminent	0

sion 9.1 (SAS Institute, Cary, NC, USA).

RESULTS

A total of 62 simultaneous assessments for 25 patients were performed. Table 2 summarizes the admission characteristics and clinical condition of the participants.

INTER-RATER RELIABILITY

Table 3 shows the ICC of the overall MPIS and the kappa coefficients for each item score. The ICC was excellent for both the all-ages group (ICC = 0.95, 95% CI = 0.94-0.97) and the younger-age group (ICC = 0.93, 95% CI = 0.89-0.96). Kappa coefficients for each item were also high, especially for the objective items (oxygen saturation, RR and HR) and accessory muscle use. The overall MPIS scores were plotted in Figure 1 [(a) between physicians, and (b) between one physician and one nurse]. Both plots showed a positive linear trend. Pearson's correlation coefficients were R = 0.96 (95% CI = 0.93-0.97) between two physicians and R = 0.95 (95% CI = 0.90-0.98) between one physician and one nurse. The ICC of the MPIS reduction was also preferable (ICC = 0.75, 95% CI = 0.66-0.84) for the all-age group.

INTERNAL CONSISTENCY, CONCURRENT VALIDITY AND RESPONSIVENESS

With regard to construct validity, the internal consistency of the MPIS was good for the total patients (Cronbach's alpha = 0.87), and was the same for the patients of each younger and older age group (Cronbach's alpha = 0.85 and 0.89, respectively). Each of the six components contributed significantly to the overall MPIS (Table 4). With regard to concurrent validity, Pearson's correlation coefficients between the

Table 3 Inter-rater reliability of MPIS

	All ages	1-5 years	6-12 years
ICC of overall MPIS	0.95 (0.94-0.97)	0.93 (0.89-0.96)	0.97 (0.95-0.98)
Kappa coefficients between two physicians (95% confidence intervals)			
Oxygen saturation in room air	0.96 (0.91-1.00)	1.00 (1.00-1.00)	0.92 (0.82-1.00)
Accessory muscle use	0.84 (0.76-0.92)	0.88 (0.78-0.98)	0.80 (0.68-0.93)
I:E ratio	0.69 (0.57-0.82)	0.50 (0.28-0.73)	0.77 (0.62-0.92)
Degree of wheezing	0.77 (0.63-0.91)	0.76 (0.54-0.97)	0.77 (0.57-0.96)
Heart rate	0.96 (0.93-1.00)	0.93 (0.86-1.00)	0.99 (0.96-1.00)
Respiratory rate	0.85 (0.75-0.95)	0.80 (0.65-0.96)	0.88 (0.75-1.00)
Kappa coefficients between physician and nurse (95% confidence intervals)			
Oxygen saturation in room air	1.00 (1.00-1.00)	1.00 (1.00-1.00)	1.00 (1.00-1.00)
Accessory muscle use	0.77 (0.63-0.92)	0.78 (0.61-0.95)	0.67 (0.40-0.93)
I:E ratio	0.61 (0.40-0.82)	0.56 (0.32-0.80)	0.80 (0.41-1.00)
Degree of wheezing	0.77 (0.55-0.99)	0.69 (0.42-0.97)	0.75 (0.36-1.00)
Heart rate	0.92 (0.84-1.00)	0.90 (0.80-1.00)	1.00 (1.00-1.00)
Respiratory rate	0.74 (0.51-0.97)	0.54 (0.29-0.79)	0.88 (0.69-1.00)

ICC, Intraclass Correlation Coefficient.

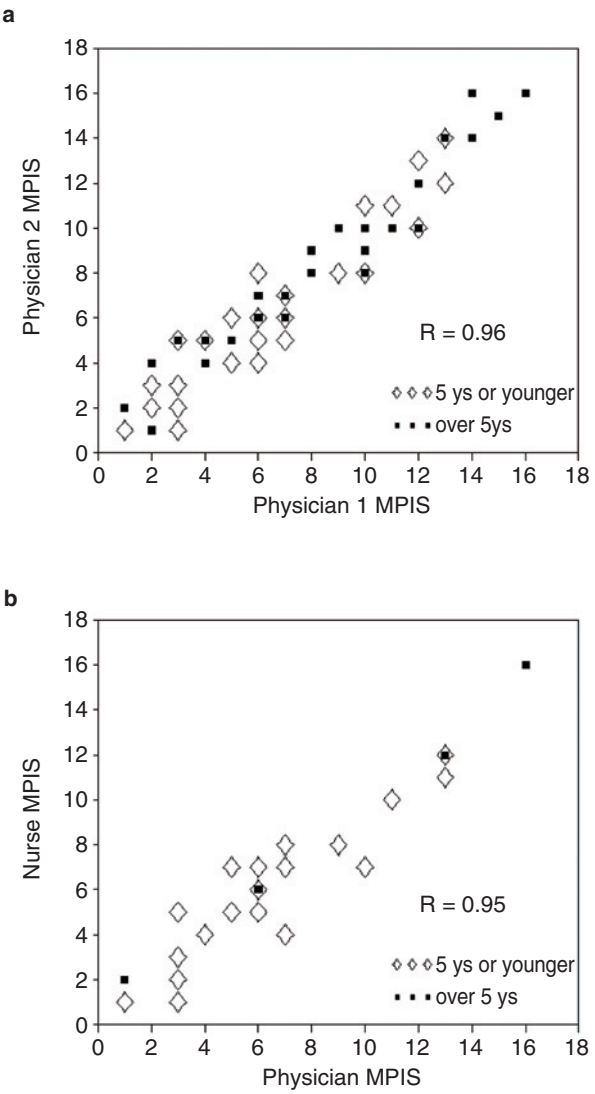

Fig. 1 (**a**) Scatter plots of the scores evaluated simultaneously between two physicians and (**b**) between a physician and a nurse. White diamonds denote children aged 1-5 years, while black dots denote children aged 6-12 years.

MPIS and the physicians' mean VAS were 0.92 (0.86-0.95) in the total patients and 0.91 (0.81-0.96) in the five-year-old and younger patients.

As for responsiveness, Pearson's correlation coefficient for the reduction in the MPIS relative to reduction in the VAS was 0.85 (0.65-0.93) in the total population, and 0.86 (0.58-0.97) in the five-year-old and younger patients. The coefficient for correlation between the reduction in the MPIS relative to the reduction in the parents' evaluated score from the 10 points at admission was 0.76 (0.47-0.89, N = 21) in the total population, and 0.69 (0.07-0.91, N = 10) in the younger-age group.

Table 4 Internal consistency of MPIS

	All ages	1-5 years	6-12 years
Cronbach's coefficient alpha	0.87	0.85	0.89
Cronbach's coefficient alpha with deletion of each item			
Oxygen saturation in room air	0.86	0.85	0.87
Accessory muscle use	0.82	0.80	0.85
I:E ratio	0.86	0.84	0.88
Degree of wheezing	0.85	0.82	0.87
Heart rate	0.85	0.82	0.86
Respiratory rate	0.86	0.83	0.88

DISCUSSION

Carroll *et al.*[9] reported the predictive validity and reproducibility of the MPIS for asthma exacerbations in 30 children with a mean age of 7.6 ± 5.5 years in 2005. Its applicability for preschool children, however, was not clearly demonstrated. This study was designed to evaluate the inter-rater reliability and internal consistency of the MPIS when used for pediatric populations including those younger than five years old. Overall, 13 of the 25 recruited children were five years old or younger, and 31 of 62 simultaneous assessments were performed for this age group.

Our simultaneous assessments were performed with the raters blinded to each other, and data were analyzed by an independent data manager and statistician. These procedures aimed at eliminating rater bias and analytical bias.

The overall inter-rater reliability of the MPIS was excellent between physicians and between a physician and a nurse; the same was observed for the younger-age group. Among the six components of the MPIS, two objective components (oxygen saturation and heart rate) and one subjective component (the degree of accessory muscle use) showed high inter-rater reliability. The kappa coefficients for the I:E ratio for patients aged 1-5 years were relatively low, indicating that higher respiratory rate in younger ages may make it difficult to standardize the evaluation of the I:E ratio.

In the absence of a gold standard measure for the severity of asthma exacerbation in younger children, we alternatively compared the physicians' evaluations of the MPIS with the VAS; strong correlations were found between them. Although the VAS is subjective, it is often used as comprehensive clinical assessment. A good correlation between the MPIS and the VAS reflects a good face validity of the MPIS.

In this study, the raters were not only those with clinical expertise, but also nurses and residents under training. Our results support the idea that the MPIS, combined with proper training for assessment, can be used widely as a shared assessment tool in clinical practice, where medical staff with different oc-

cupations or experience often work together and share patient information.

There were several limitations in this study. First, the number of assessments was relatively small. Second, there was a methodological problem whereby not all of the 62 simultaneous evaluations were independent; 37 of 62 evaluations were performed as subsequent evaluations of 25 initial evaluations. When the same rater evaluates the same patient at subsequent times, the assessment of the subjective component can be relative to the previous assessment instead of being an absolute assessment. This could lead the result in the direction of having a higher degree of correlation. Nonetheless, our results indicate that the MPIS could be used reliably in a clinical setting where the same physician evaluates the same patient at several subsequent times.

In summary, the MPIS showed good reliability and validity for children with acute asthma, including those five years and younger. The MPIS can serve as a valuable tool for assessing the severity of asthma exacerbation in those who are too young or sick to reproducibly perform pulmonary function tests, or in settings where such tests are not available.

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