
The pulmonary index score as a clinical assessment tool for acute childhood asthma

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Background: Asthma in the pediatric population imposes a significant burden on the Australian health care system. The lack of a standardized asthma assessment tool is an area that needs to be addressed.

Objective: To validate the pulmonary index score (PIS) against the National Asthma Council Guidelines (NACG) asthma assessment.

Methods: The project was approved by The Children's Hospital at Westmead Human Research Ethics Committee. Sixty-five patients aged 1 to 12 years with acute asthma were assessed independently using both the PIS and the NACG on presentation to the emergency department.

Results: These results indicate that the PIS (1) has high internal consistency (Cronbach $\alpha = .835$); (2) correlates well with the NACG, with significant differences in PIS values across different NACG severity categories; (3) predicts with good sensitivity (85% for nonmild cases and 88% for severe cases) and specificity (75% for nonmild cases and 77% for severe cases) the various categories of asthma severity according to the NACG; and (4) significantly differs between admitted (mean PIS = 8.4) and nonadmitted (mean PIS = 5.0) patients.

Conclusion: Use of the PIS may provide an objective and standardized approach to the assessment and monitoring of asthma in children.

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INTRODUCTION

Asthma is one of the most common chronic childhood disorders, especially in Australia,¹ where it affects up to 14% to 16% of children. Although the prevalence of asthma has plateaued in recent years, it remains a significant burden in emergency departments (EDs), especially in children.² Therefore, an objective and reliable measure for the assessment of asthma is needed to streamline and standardize asthma management.

The assessment of asthma is difficult in children because the objective measure of spirometry is often impractical in young children.³ In Australia, the most widely accepted acute asthma assessment measure comes from the National Asthma Council Guidelines (NACG), which groups children with acute presentations into mild, moderate, and severe/life-threatening categories based on several examination findings (Table 1).⁴ The NACG is derived from a respectable consensus group of physicians in Australia, and it has been shown to be a valid tool in assessing acute asthma in children and in predicting need for hospital admission.^{5,6} As such, it is considered the gold standard for asthma assessment. Certainly,

asthma management guidelines around Australia are primarily based on the NACG.

The pulmonary index score (PIS) is a composite of objective clinical observations that compose a score from 0 to 12 (Table 2). It can be derived quickly and has long been used as a research tool to assess clinical response to various asthma therapies.^{7–9} It was validated for use in children presenting with acute asthma against pulmonary function testing in a previous study.¹⁰ In that study, they found a significant correlation between the PIS and forced expiratory volume in 1 second/forced vital capacity, and a PIS greater than 6 was predictive of hospital admission.

Because the PIS offers the advantage of being objective and easy to derive, we sought to determine whether the PIS is a suitable tool for the assessment of asthma in children by validating the PIS against the NACG (2006) in the setting of the pediatric ED.

METHODS

The project was approved by the The Children's Hospital at Westmead Human Research Ethics Committee. This was a prospective controlled trial conducted between February 1, 2006, and February 1, 2008, at The Children's Hospital at Westmead ED. Patients were recruited nonconsecutively during peak asthma seasons in February and the winter months, depending on the availability of the main investigator. Children aged 1 to 12 years presenting to the ED with acute respiratory distress and wheeze typical of acute asthma were included. Children who did not respond to salbutamol and children with underlying pulmonary or cardiac problems were excluded. Although preschool children presenting with

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Table 1. NACG Assessment of Acute Asthma in Children (2006)

Symptom	NACG asthma severity category		
	Mild	Moderate	Severe/life-threatening
Altered consciousness	No	No	Agitated/confused/drowsy
Pulse oximetry on presentation, %	>94	90–94	<90
Talks in	Sentences	Phrases	Words/Unable to speak
Pulse rate, bpm	<100	100–200	>200
Central cyanosis	Absent	Absent	Present
Wheeze intensity	Variable	Moderate-loud	Quiet
PEFR, % of predicted	>60 or personal best	40–60 or personal best	<40 Unable to perform
FEV ₁ , % of predicted	>60	40–60	<40 Unable to perform

Abbreviations: FEV₁, forced expiratory volume in 1 second; PEFR, peak expiratory flow rate; NACG, National Asthma Council Guidelines.

a first episode of acute wheeze do not always develop subsequent asthma, they were included in the study if they were bronchodilator responsive because the acute assessment and management of these children is the same.

All staff members in the ED were familiar with the NACG acute asthma assessment. They were asked to circle an appropriate description for each of the components (consciousness, pulse oximetry, talking ability, pulse rate, presence of central cyanosis, and wheeze intensity). The pulmonary function assessment (peak expiratory flow rate [PEFR] and forced expiratory volume in 1 second) was not conducted because “these tests are usually not used in the assessment of acute asthma in children”⁴ owing to measurement inconsistencies in this group. The final category of asthma severity was then determined based on the number of component descriptions circled in each category. However, if any of the descriptions in the severe category were circled, the patient was assessed to be in the severe category, consistent with the guidelines.

Implementation of the PIS was facilitated by multiple education sessions conducted by the main investigator (P.H.). Nursing and medical staff were instructed on use of the PIS, including measurement of the respiratory rate, assessment of wheeze and accessory muscle use, and measurement of the inspiratory to expiratory ratio. Measurement of the respiratory rate was achieved by counting the rate of respiration during a 20-second period and multiplying by 3; a score of 0 to 3 was then allocated based on the rate. Wheeze was assessed by means of auscultation, and a score of 0 to 3 was designated based on the precise nature of the wheeze. The inspiratory to expiratory ratio was measured by tapping out or counting the seconds required in each of the inspiratory and

expiratory phases, and the ratio was then calculated and rated accordingly with scores of 0 to 3. Accessory muscle use was assessed by observing the work of breathing, noting the degree of intercostal and subcostal recessions and the tracheal tug. This was then rated from 0 to 3. A final composite score of 0 to 12 was obtained by summing the individual scores. All the participants were deemed competent in use of the PIS.

After informed oral consent was provided by the parents, each patient was assessed independently by a physician and a nurse at the same time, and participants were blinded to each other’s assessments. The assessment was performed before the patient’s first dose of salbutamol was administered on arrival at the ED. Physicians were allocated to assess patients using the PIS on odd days (Monday, Wednesday, Friday, and Sunday), and nurses were allocated to assess patients using the PIS on even days (Tuesday, Thursday, and Saturday) and vice versa for the NACG assessment. Data sheets were collected, and the results were analyzed.

Data were analyzed using statistical software (Stata version 10.1; StataCorp LP, College Station, Texas). Descriptive statistics were obtained on patient characteristics and are presented as either frequencies and percentages or mean and standard error. To demonstrate the random allocation of patients into odd and even days for data collection, patient characteristics were compared between odd and even days. To test for associations between patient characteristics and days, χ^2 tests were applied to categorical variables and independent *t* tests were used for continuous variables. To assess the internal consistency of the 4 different items in the PIS, the Cronbach α internal consistency coefficient was calculated, where a high value of the coefficient would indicate good

Table 2. Pulmonary Index Score (PIS)

Score	PIS components			
	Respiratory rate, bpm	Wheezing	Inspiratory to expiratory ratio	Accessory muscle use
0	<30	None	5:2	0
1	31–45	Terminal expiration with stethoscope	5:3–5:4	+/- (questionable increase)
2	46–60	Entire expiration with stethoscope	1:1	++ (apparent increase)
3	>60	Audible without stethoscope or silent chest	<1:1	+++ (maximal increase)

correlation between the different items in the score. To evaluate the properties of the PIS as an assessment tool for asthma severity, sensitivity, specificity, and area under the receiver operating characteristic (ROC) curve were also calculated, using the NACG as the gold standard. The PIS cutoff points for mild vs nonmild asthma and severe vs nonsevere asthma were calculated based on the most optimum values of sensitivity and specificity.

RESULTS

Sixty-five children were recruited for the study. There were 38 boys (58%) and 27 girls (42%), with a mean (SE) age of 5.4 (0.41) years (age range, 1–12 years). Nearly equal numbers of patients were assessed on even days ($n = 31$, 48%) and odd days ($n = 34$, 52%). Most of these asthmatic patients were classified as mild ($n = 24$, 37%) and moderate ($n = 24$, 37%), with slightly more than a quarter ($n = 17$, 26%) classified as severe according to the NACG. The mean (SE) PIS was 6.1 (0.37) (range, 0–12). Nearly one-third of the patients ($n = 21$, 32%) were admitted to the hospital. To demonstrate that patients were allocated randomly to either odd or even days, comparisons were conducted on patient characteristics between days. There were no statistically significant differences in any of these characteristics between odd and even days.

Analyses of the internal consistency of the PIS yielded a high Cronbach α of .835, suggesting that all 4 components were necessary and assessed a similar construct. The results for sensitivity, specificity, and areas under the ROC curve and their corresponding 95% confidence intervals (CIs), using the NACG as the gold standard, are summarized in Table 3, with their ROC curve graphs depicted in Figures 1 and 2. A PIS of 6 or greater had sensitivity of 85%, specificity of 75%, and an area under the ROC curve of 0.896 (95% CI, 0.822–0.970) for predicting nonmild cases. A PIS of 8 or greater had sensitivity of 88%, specificity of 77%, and an area under the ROC curve of 0.874 (95% CI, 0.792–0.957) for predicting severe cases. To further evaluate agreement between the PIS and the NACG, median PIS values were compared across different categories of asthma severity classified using the NACG. The median PIS values for the mild, moderate, and severe NACG categories were 3.0, 7.0, and 8.0, respectively.

Table 3. Sensitivity, Specificity, and Areas Under the ROC Curve for Different PIS Cutoff Values

PIS cutoff value	Sensitivity, %	Specificity, %	Area under the ROC curve (95% CI)
$\geq 6^a$	85.4	75.0	0.896 (0.822–0.970)
$\geq 8^b$	88.2	77.1	0.874 (0.792–0.957)

Abbreviations: CI, confidence interval; PIS, pulmonary index score; ROC, receiver operating characteristic.

^a Scores less than 6 indicate mild asthma and scores of 6 or greater indicate moderate and severe asthma.

^b Scores less than 8 indicate mild and moderate asthma and score of 8 or greater indicate severe asthma.

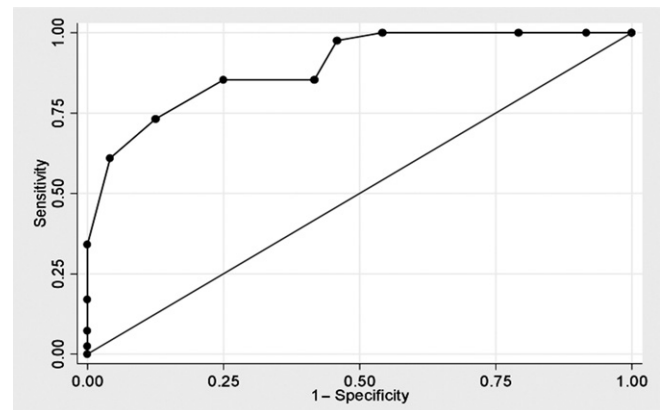


Figure 1. Plot of sensitivity against 1–specificity for use of the pulmonary index score to classify mild and nonmild cases. Area under the receiver operating characteristic curve = 0.896.

There was a significant difference in median PIS values across the 3 categories of severity ($\chi^2_2 = 34.30$, $P < .001$). Furthermore, there was a significant difference in mean PIS values between patients who were admitted to the hospital and those who were not ($t_{63} = -5.10$, $P < .001$), with mean (SD) PIS values of 8.4 (1.8) and 5.0 (2.8) for admitted and nonadmitted patients, respectively.

DISCUSSION

Although the PIS has long been used as a research tool, it is not commonly used in the clinical scenario. One reason may be the lack of data supporting its correlation with an accepted measure of asthma severity. In this study, we validated the PIS against the gold standard NACG assessment of acute asthma severity. We have shown that the PIS correlates well with the NACG, with significant differences in median PIS values across different NACG severity categories. We also showed that a PIS of 6 or greater predicts with high sensi-

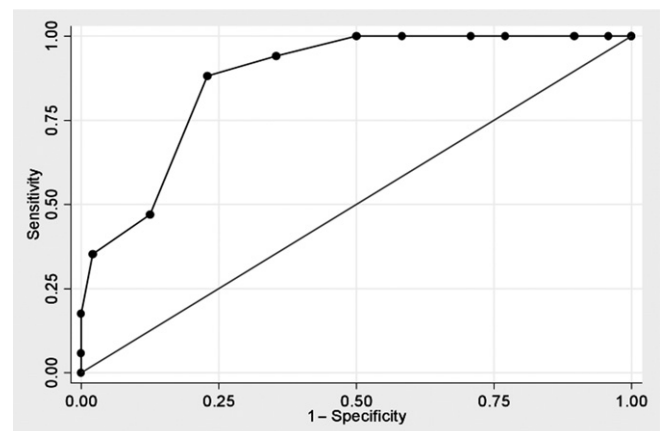


Figure 2. Plot of sensitivity against 1–specificity for use of the pulmonary index score to classify severe and nonsevere cases. Area under the receiver operating characteristic curve = 0.874.

tivity (85%) and specificity (75%) moderate and severe asthma, whereas a PIS of 8 or greater predicts severe asthma, again with relatively high sensitivity (88%) and specificity (77%). Taken together, this would mean that a PIS of less than 6 correlates with mild asthma, a PIS of 6 or 7 correlates with moderate asthma, and a PIS of 8 or greater correlates with severe asthma, according to the NACG. This is further reflected in the fact that patients admitted to the hospital for asthma had a higher PIS (mean PIS = 8.4) compared with those who were not admitted (mean PIS = 5.0). Use of the PIS would enable an objective assessment of asthma, hence facilitating a standardized approach to asthma management, including initial management, observation, and discharge planning.

Several asthma scores have been designed to assess the severity of acute asthma in children, many of which are actually modifications of the PIS. The modified PIS, for example, is essentially the PIS plus other variables, such as oxygen saturation and heart rate. One study¹¹ demonstrated that the modified PIS positively correlates with hospital admission, length of albuterol use, length of oxygen use, and need for intensive care unit admission. The pulmonary score is the PIS without the inspiratory to expiratory ratio. One study¹² showed that the pulmonary score correlated, although only moderately, with PEFR.

The clinical asthma score is another score that is composed of the 4 components of the PIS with an added component of "dyspnea" assessed by the patient's ability to speak. In this study,¹³ only moderate correlation is found between the score and oxygen saturation, length of hospital stay, and drug dosage interval. Perhaps the largest study to validate an asthma severity score comes from Wisconsin, where across 2 centers 1221 patients were recruited. In this study,¹⁴ the authors used the Paediatric Asthma Severity Score, which in effect is the PIS without the respiratory rate. Their results, however, indicated only modest correlation with PEFR, oxygen saturation, and drug dosage intervals.¹⁴

In the present study, we showed that the PIS has high internal consistency, which indicates that all 4 components of the score measure the same construct and are needed to make up a final score that is valid. This highlights the advantage of the PIS over the previously mentioned scores. Furthermore, whereas the other scores were validated against individual measures, such as PEFR or oxygen saturation, the PIS has now been validated against a composite clinical measure (NACG), demonstrating its robustness as a clinical assessment tool. There are, however, some limitations to this study. We did not have a large patient population as in the Paediatric Asthma Severity Score study, but compared with the other studies of asthma scores mentioned previously herein, the present population size of 65 patients was equivalent to or slightly more than that in these studies. Patient recruitment was only partially randomized, but patient demographics revealed that there was no significant difference between each of the groups recruited on the odd or even days. Furthermore, approximately equal numbers of physicians and

nurses assessed the patients using either the NACG or the PIS. The patients were recruited nonconsecutively across a period of time as it was thought best to recruit during the asthma peak seasons of February and winter each year. Again, this did not bias the study population, with a median age of 4 years and a male predominance, which is consistent with the literature.¹⁵

In conclusion, this study demonstrated that in children, the PIS predicts with high sensitivity and specificity the various categories of asthma severity according to the NACG. This, coupled with the fact that the PIS has also been validated against pulmonary function testing,¹⁰ suggests that the PIS can be applied as a useful clinical tool for the assessment and monitoring of asthma in children in the ED. Although in the present study we did not assess whether the PIS varies in response to treatment, various research studies⁷⁻⁹ have already used the PIS for this purpose. Nevertheless, future studies may be needed to assess this capacity of the PIS. Furthermore, although we established the validity of the PIS against the NACG, we did not formally test its reliability; this may be further tested in future studies by assessing the consistency of the PIS across different skill levels of physicians and nursing staff. We suggest that the PIS may be a useful adjunct to the current NACG with the added advantages of allowing for rapid assessment and objective monitoring of asthma in children, thus helping to streamline asthma management.

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