The *Pediatric* Respiratory Assessment Measure: A Valid Clinical Score for Assessing Acute Asthma Severity from Toddlers to Teenagers

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Objective To determine the performance characteristics of the Preschool Respiratory Assessment Measure (PRAM) in preschool and school-aged children with acute asthma.

Study design In a prospective cohort study, we examined the validity, responsiveness, and reliability of the PRAM in children aged 2 to 17 years with acute asthma. The study involved more than 100 nurses and physicians who recorded the PRAM on triage, after initial bronchodilation, and at disposition. Predictive validity and responsiveness were examined using disposition as outcome.

Results The PRAM was recorded in 81% (n = 782) of patients at triage. The PRAM at triage and after initial bronchodilation showed a strong association with admission ($r = 0.4$ and 0.5, respectively; $P < .0001$), thus supporting its ability to distinguish across severity levels. The responsiveness coefficient of 0.7 indicated good ability to identify change after bronchodilation. The PRAM showed good internal consistency (Cronbach $\alpha = 0.71$) and inter-rater reliability ($r = 0.78$) for all patients and across all age groups.

Conclusions Good performance characteristics were observed in all age groups, making the PRAM an attractive score for assessing asthma severity and response to treatment. *(J Pediatr 2008;152:476-80)*

Guidelines for the management of acute pediatric asthma hinge on the objective assessment of asthma severity, generally measured by lung function tests such as peak expiratory flow rate or spirometry.[1] Unfortunately, these lung function tests are nearly impossible to obtain in preschool-aged children because of poor coordination and in 35% to 50% of school-aged children, because of severity of illness or poor familiarity with the technique.[2-4] With preschool-aged children representing over half the patients treated for acute asthma,[5] it is estimated that three quarters of asthmatic children cannot perform standard lung function tests in the emergency setting. To enable the clinical application of asthma guidelines, it is thus crucial to find alternative ways to measure asthma severity and response to treatment, valid for children aged 2 to 17 years.

Clinical scores can serve as simple and inexpensive tools to assess asthma severity for the entire paediatric age span. More than 18 clinical scores for assessing acute asthma have been reported, many of which were developed ad hoc without formal validation,[6,7] or, like the Pulmonary Index or the Pulmonary Score, were validated only in school-aged children.[8,9] In an independent review, Birken et al[10] identified the Preschool Respiratory Assessment Measure (PRAM) as one of two acute asthma severity scores with good measurement properties in preschool-aged children: it was developed and validated against respiratory resistance and proved discriminative and responsive to change in children aged 3 to 6 years.[11] Subsequently, the Pediatric Asthma Severity Score (PASS) proved reliable, valid, and responsive to change in children aged 1 to 18 years.[4] The authors cautioned users that the 6-point PASS may not be sensitive enough to identify small but clinically important changes in status. Conversely, the PRAM had not been validated in school-aged children and lacked a formal assessment of reliability. Both the PASS and the PRAM have high face and content validity, containing items frequently assessed in asthmatic children of all ages.

PASS	Pediatric Asthma Severity Score	PRAM	Preschool Respiratory Assessment Measure

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The objectives of this study were to examine the performance characteristics of the PRAM along the dimensions of validity, responsiveness to change, and reliability in children aged 2 to 17 years presenting with acute asthma.

METHODS

In the spring of 2003, we introduced the PRAM as the standard assessment tool for all children aged 2 years and above presenting with acute asthma to our pediatric emergency department. In the fall of 2003, we introduced a clinical care pathway based on the PRAM and examined the impact of these interventions on guideline adherence and admission rate. Nested in this quality control initiative, we examined the feasibility, validity, and responsiveness to change of the PRAM in a prospective observational cohort study of all eligible children who presented between March and May 2003 and between September and November 2003. We examined the internal consistency and the inter-rater reliability in a convenience sample of patients recruited after November 2003. This quality improvement initiative was approved by both the Scientific and the Institutional Review Boards which did not recommend individual patient consent.

Children were eligible if they (1) were ages 2 to 17 years, (2) had asthma defined as two or more episodes of wheezing responsive to inhaled β2-agonist, and (3) required at least one nebulization of albuterol for the treatment of the index exacerbation. Children with chronic lung diseases such as bronchopulmonary dysplasia were excluded. Patients with repeat visits were included only once.

As per our clinical care pathway, the triage nurse assessed the patient, recorded the initial PRAM, and administered the first albuterol treatment (or, in severe asthma, a set of 3 albuterol and ipratropium bromide treatments within 1 hour), hereafter referred to as initial bronchodilation. Our pool of over 100 physicians and nurses were trained to measure the 12-point PRAM, a validated composite score comprised of oxygen saturation and four physical findings (Figure 1; available at www.jpeds.com). The training included a lecture with slides and demonstration (particularly for assessing scalene muscle contraction) followed by on-site assistance. The treating physician or nurse recorded the PRAM a second time, usually within 60 minutes of the initial bronchodilation, and every one to two hours subsequently until disposition. Within 6 hours of triage, a decision to admit or discharge home was made by the treating physician, with no specific reference to the PRAM.

Statistics

We considered construct validity under two aspects, namely, the internal consistency and predictive validity. We examined the internal consistency of the PRAM at triage to determine the degree to which each individual item contributes to the overall PRAM score, using the Cronbach α coefficient.[12] To assess the predictive validity[13] and responsiveness,[14] we selected disposition (admission or discharge) as criteria because it is a meaningful outcome for children, parents, physicians, and administrators and is equally applicable to all age groups. Predictive validity was examined by the association between admission rate and either the PRAM at triage or after initial bronchodilation using the Spearman's rank correlation with values between age groups compared with the Mann-Whitney *U*-test, and by multivariate logistic regression. We sought to identify the model that best predicted disposition with information obtained early in the course of treatment such as age, sex, PRAM at triage, and change in PRAM after initial bronchodilation, including relevant interaction terms. The adequacy of the model was reported as the area under the curve (*c* statistics).

We examined responsiveness, that is, the ability of the PRAM to detect clinically important changes over time in two ways. First, we calculated the Guyatt's responsiveness coefficient,[15] as the ratio of the change in PRAM after initial bronchodilation among patients who were subsequently discharged, over the standard deviation of the change in PRAM in those who were admitted; values of 0.5 and 0.8 are considered indicative of moderate and large effects, respectively.[16] Second, to allow comparison with the methods used to assess PASS, we computed the effect size using the method of Kazis et al,[17] as the ratio of the change in PRAM between triage and disposition to the standard deviation of the PRAM at triage; a value of 0.8 or more is considered large as it indicates a change of at least four-fifths the baseline standard deviation.[16,17]

We assessed the inter-rater agreement, defined as the degree to which a physician and a nurse obtained a similar PRAM score in the same patient, using the weighted κ statistic, reported with the 95% confidence interval; values of 0.7 or more were considered indicative of good agreement.[18] To minimize the time trend, only pairs of rating done within 30 minutes of each other with no intervening treatment were selected for analysis; we did not blind the raters from the other's score. A P value of less than .05 was considered indicative of statistical significance. The analyses were performed using SAS (version 9.01 for Windows, SAS Institute Inc, Cary, NC).

RESULTS

Of the 1039 visits made during the study period, 75 were repeat visits. Of the 964 unique patients, the PRAM was recorded at triage in 782 (81%) children; their median age was 5.8 (interquartile range, 3.5 to 9.6) years, and 63% were male. A similar proportion of preschool (20%) and school-aged (18%) children had no recorded PRAM value. They were similar in age and sex distribution as those with a recorded PRAM but required significantly less albuterol (69% vs 39% requiring $\leq$2 treatments, $P < .0001$), and fewer admissions (8% vs 21%, $P < .0001$), suggesting a lower asthma severity.

A second PRAM was recorded between 15 and 75 minutes after initial bronchodilation in 554 (57%) children, at which time they had received 1 (n = 379), 2 (n = 74), 3 (n = 94) or 4 (n = 7) albuterol treatments. Patients whose second PRAM fell outside the specified time boundaries had similar

Table I. Internal consistency for PRAM and its individual components, overall and for each age group

Age groups	All ages (n = 254)	2-6 Years (n = 158)	7-17 Years (n = 96)
Individual components			
Scalene retractions	0.71	0.69	0.74
Suprasternal retractions	0.68	0.69	0.66
Wheezing	0.6	0.59	0.62
Air entry	0.62	0.63	0.61
O_2 saturation	0.68	0.7	0.65
Overall PRAM	0.71	0.71	0.71

Values represent the Cronbach α coefficient.

sex and age distributions with a lower triage PRAM (3.5 vs 5, $P < .0001$) and admission rate (9% vs. 24%, $P < .0001$) than those with a timely assessment, again suggesting lower severity.

With regard to construct validity, the internal consistency of the initial PRAM was good for the whole age spectrum as well as across different age groups (Cronbach α coefficient: 0.71); each of the 5 components contributed significantly to the overall PRAM (Table I). Predictive validity, assessed by the association between the PRAM and the rate of admission, was strong whether based on the PRAM at triage ($r = 0.4$, $P < 0.0001$) or after initial bronchodilation ($r = 0.5$, $P < .0001$); there was no significant difference between preschool and school-aged children for either PRAM measure (Figure 2). The models that best predicted admission were the combination of PRAM at triage and change in PRAM after initial bronchodilation (c statistics: 0.86), followed by the PRAM after initial bronchodilation alone (0.84) or the PRAM at triage (0.78). Age and sex were not important predictors.

With regard to responsiveness, the Guyatt coefficient was 0.7, showing good ability of the PRAM to identify change occurring after initial bronchodilation.[16] The effect size, calculated from the change in PRAM between triage and disposition, was 1.1 for the whole cohort and increased with the PRAM at triage, irrespective of the cutoff values used to delineate the severity groups (Figure 3). In other words, the ability to detect change between triage and disposition was large, with discharged children consistently displaying a greater improvement than those admitted, irrespective of baseline severity.

A group of 254 children aged 2 to 17 years met the requirement for assessing inter-rater reliability. They were similar to the overall group, with 67% male, a median age of 5 (interquartile range, 2 to 17) years and encompassing the whole range of PRAM scores from 0 to 12. There was a high inter-rater agreement between the PRAM measured by the physician and that of the nurse ($\kappa = 0.78$); this held true across all age groups and for each of the PRAM components (Table II).

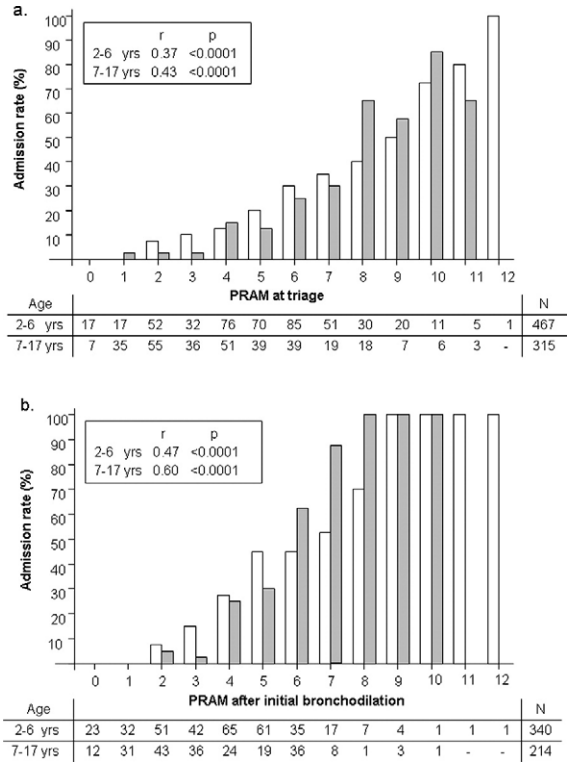

Figure 2. The rate of admission by the PRAM score at **(a)** triage and **(b)** after initial bronchodilation, in children aged 2 to 6 years *(white bars)* in which the PRAM was originally validated and in children ages 7 to 17 years *(gray bars)*.

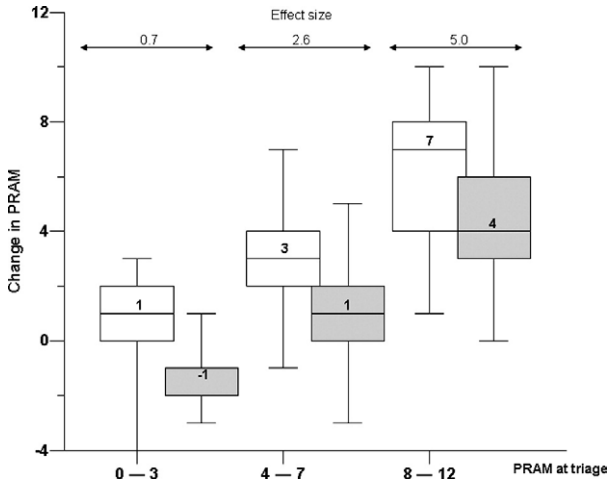

Figure 3. Box plot displaying the change in PRAM between triage and disposition depicted separately for admitted *(gray bars)* and discharged *(white bars)* patients, by baseline severity stratum. Effect sizes were calculated as the mean change in PRAM between triage and disposition over the standard deviation of the PRAM at triage.

DISCUSSION

In the real-life setting of a busy pediatric emergency department, the PRAM has good validity, responsiveness to change and inter-rater reliability, not only in preschool

Table II. Inter-rater reliability for the PRAM and its individual components, overall and for each age group

Age groups	All ages (n = 254)	2-6 Years (n = 158)	7-17 Years (n = 96)
Individual components			
Scalene muscle contraction	0.92 (0.84, 1)	0.89 (0.77, 1)	1 (1, 1)
Suprasternal retractions	0.85 (0.78, 0.91)	0.8 (0.71, 0.9)	0.89 (0.8, 0.98)
Wheezing	0.7 (0.63, 0.76)	0.64 (0.55, 0.74)	0.78 (0.69, 0.88)
Air entry	0.72 (0.65, 0.8)	0.76 (0.67, 0.85)	0.67 (0.53, 0.8)
O_2 saturation	0.81 (0.73, 0.88)	0.8 (0.71, 0.9)	0.82 (0.69, 0.94)
Overall PRAM	0.78 (0.74, 0.83)	0.76 (0.71, 0.83)	0.80 (0.74, 0.87)

Values represent the weighted κ coefficients with 95% confidence intervals.

aged children in whom it was developed but also in school-aged children and adolescents. These findings were derived from a large number of children treated by more than 100 nurses and physicians, suggesting good generalizability to similar clinical settings. The performance characteristics were stable across the entire pediatric age spectrum, making the PRAM an attractive clinical score for use in clinical as well as research settings.

The PRAM has good face validity. Three of the four signs, namely suprasternal indrawing, air entry, and wheezing, are consistently found in most pediatric asthma scores.[4,6,8] Previously associated with severe airway obstruction in preschool-aged children,[11] this study confirmed the important contribution of scalene muscle contraction to the PRAM, in both preschool and school-aged children.[19] Having been portrayed as the fifth vital sign,[20] oxygen saturation has been identified as a strong independent predictor of the need for intensive therapy or hospital admission, with 92% frequently used as cutoff value.[21-23] The high Cronbach coefficient for each of the five components further supports the construct validity of the PRAM in all age groups.

We have originally developed the PRAM by criterion validity, using respiratory resistance measured by forced oscillation in children aged 3 to 6 years.[11] With the strong association between the PRAM and admission rate, we confirm the PRAM's predictive abilities, in both preschool and school-aged children. These observations suggest that the PRAM at triage could be used as a unique score for all children to guide therapy and to apply the severity-based acute asthma guidelines. With its greater predictive ability, the PRAM measured after an hour of treatment may be used to further adjust therapy, supporting similar findings in other studies.[24,25] We would propose the following PRAM categories (0 to 3, 4 to 7, 8 to 12) for identifying children at low ($<$10%), moderate (10% to 50%), and high risk ($\geq$50%) of hospital admission, respectively.

The results demonstrate the responsiveness of the PRAM to detect change resulting from treatment. The Guyatt's statistic confirms the ability of the change after initial bronchodilation to predict disposition.[16] In absence of lung function, we were unable to confirm the previously identified change in PRAM of 3 points or more, as indicative of a clinically meaningful change.[11] Indeed, use of admission as endpoint was imprecise and confounded by severity as the greatest change in PRAM occurred in patients with higher triage PRAM, who had both the highest opportunity to change and the highest risk of admission. To provide a fair comparison with the PASS, we reported the change in PRAM between triage and disposition for all patients. Within each triage severity stratum, the change in PRAM was greater in patients discharged compared with those admitted, but only marginally so for the overall group, again suggesting confounding by severity. The overall effect size was greater for the PRAM than the PASS (1.1 vs 0.6 to 0.8) suggesting greater responsiveness, perhaps because of its larger scale (12 points vs 6 points) or other study differences.[4] The increasing effect size of the PRAM with higher baseline severity indicates that a smaller sample size would be needed to identify the same group difference in patients with moderate or severe asthma compared to those with mild airway obstruction.

The overall inter-rater reliability was very good and was sustained across each age group, despite the involvement of over a 100 different assessors. This value may have been overestimated because physicians and nurses were not blinded to each other's score. The magnitude of overestimation attributed to the absence of blinding may hover around 10%.[26] The inter-rater reliability for individual signs observed with PRAM is of similar magnitude to that observed in other scores, a reassuring finding. Nevertheless, independent confirmation of reliability with appropriate blinding would be indicated.[4,10]

The recording of the PRAM in greater than 80% of patients underlines the feasibility of this measure in the context of a busy pediatric emergency department. This value is probably an underestimation of its true feasibility because the lower severity of patients with no PRAM suggests omission, rather than measurement difficulty, as the reason for non recording. This high documentation rate of asthma severity compares favorably to the disconcerting rates of 42% previously reported in emergency settings.[27] As such documentation is associated with improved quality of care,[28] the feasibility of the PRAM represents a major advantage over spirometry for which cooperation rates hover around 0% for preschool-aged children and about 50% for school-aged children.[29]

Despite our large sample, the small number of children with PRAM scores of 10 and above resulted in instability of

admission rates, particularly for school-aged children; performance of the PRAM in a group with severe asthma, perhaps in the intensive care unit, may lead to further confirmation. One could question the use of disposition as an endpoint to assess validity and responsiveness because of the expected lower precision, compared to a continuous outcome such as lung function, and because of the variability in admission criteria across and within institutions; imprecision and variability certainly add noise to the analyses, thus reducing the strength of a true association. Despite these caveats, in large samples where the ratio of signal to noise is high, admission remains an outcome of major clinical importance for evaluating the efficacy of acute asthma management or, at the very least, for identifying patients with greater severity.[30-32] One may argue that because the admitting physician was not blinded to the PRAM values, the latter may have influenced the decision to admit, perhaps resulting in an overestimation of the ability of the PRAM to predict admission. Consequently, we evaluated the validity and responsiveness on the PRAM measured at triage and after the initial bronchodilation, which we believed were less likely to affect physician's decision several hours later. As for other clinical scores, the PRAM remains simply a means to record clinical signs in a standardized fashion, albeit with some degree of subjectivity in the ascertainment and coding of these signs.

In summary, the PRAM, originally validated in asthmatic children aged 3 to 6 years, appears as a feasible, valid, responsive, and reliable pediatric tool to determine asthma severity in children aged 2 to 17 years. The particular usefulness of the PRAM lies in its applicability for all age groups. The PRAM could serve to assess asthma severity in all patients including those too young or sick to reproducibly perform pulmonary function tests and in settings where such testing is not available. With the same acronym, the "P" in PRAM can now stand for "Pediatric" rather than "Preschool", becoming the Pediatric Respiratory Assessment Measure.

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Signs	0	1	2	3
Suprasternal retractions	Absent		Present	
Scalene muscle contraction	Absent		Present	
Air entry*	Normal	Decreased at bases	Widespread decrease	Absent/minimal
Wheezing*	Absent	Expiratory only	Inspiratory and expiratory	Audible without stethoscope/silent chest with minimal air entry
O_2 saturation	≥95%	92%-94%	<92%	

Figure 1. *If asymmetric findings between the right and left lungs, the most severe side is rated. Reprinted from The Journal of Pediatrics, Vol. 137, Issue 6. Chalut DS, Ducharme FM, Davis GM. The Preschool Respiratory Assessment Measure (PRAM): A responsive index of acute asthma severity. Pages 762-768, Copyright © 2000, with permission from Elsevier.