

PEDIATRIC ASTHMA

Utility of Portable Spirometry in a Pediatric Emergency Department in Children with Acute Exacerbation of Asthma

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Objectives. The primary purpose of this study was to determine if portable spirometers can be successfully used in an emergency department (ED) in children with an acute exacerbation of asthma. The secondary purpose of this study was to determine if a validated clinical asthma score (CAS) correlates with the spirometry results in children with an acute exacerbation of asthma. **Methods.** Children between the ages of 6 and 17 years who presented to an urban free-standing children's hospital ED with an acute exacerbation of asthma were enrolled in our study. On arrival, the CAS was recorded and then portable spirometry was performed. Attempts were continued until acceptable and reproducible flow loop measurements were obtained or until the patient was unable to perform further attempts. Outcomes included success at spirometry and correlation of spirometry with the CAS. **Results.** A total of 101 patients were enrolled in this study. Of those patients, only 35 (35%) were able to successfully perform portable spirometry. Successful spirometry attempts were associated with older age (10.4 vs. 8.9, $p = .01$), lower respiratory rates (24.8 vs. 30.2, $p = .001$), lower heart rates (110 vs. 124, $p = .004$), and lower CASs (8.4 vs. 9.7, $p = .001$). Increasing asthma severity correlated with a decreased likelihood of successfully obtaining a useful forced expiratory volume in 1 second (FEV₁) measurement ($p = .013$). Compared with cases of mild asthma, a patient with moderate asthma is 33% less likely to be able to perform spirometry, and a patient with severe asthma 93% less likely to perform spirometry. The CAS correlated poorly with the more objective measure of FEV₁% predicted in those with mild asthma. **Conclusion.** Many children are incapable of using portable spirometry for the evaluation of acute exacerbations of asthma in the ED. The clinical asthma scoring system demonstrated poor correlation with portable spirometry measurements in terms of severity classification.

Keywords acute exacerbation, asthma, children, emergency department, FEV₁, spirometry

BACKGROUND

Acute asthma exacerbations are one of the most common complaints seen in the pediatric emergency department (ED). In 2009, the National Asthma Education and Prevention Program (NAEPP) expert panel report 3 defined an exacerbation of asthma as an acute or subacute episode of progressively worsening shortness of breath, coughing, wheezing, and chest tightness or any combination thereof. The NAEPP recommends that during an acute exacerbation of asthma objective measures of lung function be obtained and monitored (1). There are various objective methods available to the ED physician in assessing the severity of an asthma exacerbation. These include clinical signs, pulse oximetry, scoring systems, peak flow meters, and spirometry.

Individual clinical signs such as heart and respiratory rates, breath sounds, accessory muscle use, skin color, mental status, and speech have shown to poorly correlate with the actual degree of small airway obstruction in children with asthma (2, 3). Pulse oximetry has been shown to be an effective noninvasive tool to assess the mild to moderate asthma exacerbation, but is unreliable in the severe asthmatic (4, 5). The clinical scoring systems are tools that attempt to quantify the degree of severity for any given asthma exacerbation and determine the therapy required

by the patient. There are a number of clinical scores that have been published to assess the acute asthma severity in children. Most of these scores are based on similar clinical findings but only a few have had good validation studies performed or interobserver reliability (6, 7).

Peak flow meters are inexpensive, portable, and readily available and give reproducible results. However, they mostly reflect flow in the large airways, are effort dependent, and can be unreliable predictors of asthma exacerbations (8, 9). The ideal method for the objective measurement of small airway obstruction is the use of spirometry. Laboratory-based spirometry is the "gold standard" for the assessment of lung function in children with chronic stable asthma, in both clinical and research protocols. Portable spirometers have become more available and can provide valid measurements that are highly comparable to those obtained from the office-based device (10–12). Although spirometry is a little more effort dependent than peak flow meters, it offers greater accuracy, more direct measurement of smaller airways as compared with larger airways, and better reproducibility (13, 14). Spirometers measure forced expiratory volume or the amount of air that can be blown out of the lungs in a single second. Patients must breathe in and seal their lips around the spirometer's mouthpiece and then blow out as hard and as fast as possible until there is absolutely no air left in the lungs. The patient must perform this maneuver several times to achieve a reproducible measurement.

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OBJECTIVE

The primary purpose of this study was to determine if portable spirometers can be successfully used in an ED in children with an acute exacerbation of asthma. The secondary purpose of this study was to determine if a validated clinical asthma score (CAS) correlates with the spirometry results in children with an acute exacerbation of asthma.

METHODS

This study was performed in a tertiary care, free-standing children's hospital ED with an annual census of 60,000. Children between the ages of 6 and 17 years who presented to the ED with a self-reported diagnosis of asthma and a chief complaint of wheezing, shortness of breath, cough, or increased work of breathing were eligible for enrollment. The protocol was approved by the Institutional Review Board and written informed consent was obtained from all patients before study entry and assent was obtained from all children older than 7 years. Children were excluded if they had a history of a chronic lung disease (e.g., cystic fibrosis), non-corrected congenital heart disease, suspected intrathoracic foreign body, clinical or radiographic evidence of pneumonia, needed immediate resuscitation, or were pregnant.

Eligible patients were identified by research assistants or the attending ED physicians. The attending ED physician made the decision regarding the severity of the asthma exacerbation based on their physical exam findings and assigned a CAS. The patient then consented and the forced expiratory volume in 1 second (FEV₁) value was recorded and calculated as a percentage of their predicted based on standardized height and weight charts. All spirometry was performed by licensed respiratory therapists trained in the use of the hand-held spirometer (Renaissance II, Puritan Bennett, Carlsbad, CA, USA). In accordance with NAEPP guidelines, an FEV₁ of greater or equal to 70% predicted was considered a mild exacerbation, 40%–69% predicted was considered a moderate exacerbation, and if less than 40% predicted, severe.

As many of the children enrolled had never performed spirometry, the respiratory therapist spent 1–2 minutes demonstrating how to use the device, performed a forced exhalation maneuver for the patient, and then coached the patient during their attempts.

A standardized, previously validated asthma score (15, 16) with good interobserver reliability and spirometry were conducted for each patient after meeting the entry criteria. The asthma score in our study is a modification of the scoring system proposed by the National Institutes of Health (17); is used extensively in our ED and inpatient units; and rates the severity of an episode based on signs, symptoms, and oxygen requirements. It is composed of five variables (respiratory rate, pulse oximetry, retractions, auscultation, and dyspnea) that can be scored from 1 to 3 resulting in a total score of 5–15. A score from 5 to 7 represented a mild exacerbation,

8 to 11 a moderate exacerbation, and 12 to 15 a severe exacerbation. Pulmonary function was conducted with a Renaissance II hand-held spirometer (Puritan Bennett), which was calibrated each day using a 3-L syringe. Pulmonary function tests were repeated until the two tests agreed within 5% of each other or until the patient was unable to tolerate further attempts because of respiratory complaints or exhaustion. The highest FEV₁ was used for analysis. All spirometry loops were analyzed according to the standards specified by the American Thoracic Society using their acceptability and reproducible criteria. All loops were analyzed by a board-certified asthma/allergy subspecialist to determine the reliability of the results for each patient. Loops were dichotomized as either adequate or inadequate. Those loops deemed inadequate were excluded from further analysis, such as the FEV₁% predicted calculations and CAS correlations.

Patients received steroids and bronchodilator treatment until the child was discharged home or the decision was made to admit the child. Once disposition was decided, the study was concluded for that patient.

Data collected included the child's age, weight, height, gender, ethnicity, pulse oximetry, heart rate, respiratory rate, CASs, spirometry FEV₁ results, and disposition from the ED.

Statistical analysis was performed using Stata 8.0 (StataCorp LP, College Station, TX, USA). Data were examined for correlation between asthma severity and FEV₁% predicted among those deemed FEV₁ capable. Summary statistics are presented as mean $\pm$ standard deviation and as percentages. Univariate analyses of baseline characteristics employed Student's *t*-test and chi-square test, or the nonparametric analogs when appropriate. Comparison of asthma severity with FEV₁% predicted was carried out by linear regression to determine correlation. Scatter plots were used to visualize the correlation. Statistical significance was defined as $\alpha = 0.05$ with two-sided alternative hypotheses.

RESULTS

All the patients who were approached to take part in this study participated. A total of 101 patients were enrolled in this study. Of those patients, only 35 (35%) were able to successfully perform portable spirometry. Study sample characteristics are summarized in Table 1. Successful spirometry attempts were associated with older age (10.4 vs. 8.9, $p = .01$), lower respiratory rates (24.8 vs. 30.2, $p = .001$), lower heart rates (110 vs. 124, $p = .004$), and lower CASs (8.4 vs. 9.7, $p = .001$).

Table 2 displays the distribution of FEV₁ capability across severity groups according to the CAS. Increasing asthma severity correlated with a decreased likelihood of successfully obtaining a useful FEV₁ measurement ($p = .013$). Compared with cases of mild asthma, a patient with moderate asthma is 33% less likely to be able to perform spirometry, and a patient with severe asthma 93% less likely to perform spirometry. An asthma score

TABLE 1.—Baseline patient characteristics.

	Spirometry capable (<i>n</i> = 35)	Spirometry incapable (<i>n</i> = 66)	All pts (<i>n</i> = 101)	<i>P</i> -value
Mean age (SD)	10.4 ± 3.1	8.9 ± 2.5	9.4 ± 2.8	.01
Males (%)	23.5	31.8	29	.387
Ethnicity (%)				
Hispanic	61.8	56.1	58	
Caucasian	11.8	16.7	15	
Black	23.5	22.7	23	.857
Other	2.9	1.5	2	
Mean height (cm) (SD)	145.8 ± 17.6	138.5 ± 15.8	140.9 ± 16.7	.039
Mean weight (kg) (SD)	48.9 ± 21.6	40.3 ± 16.7	43.2 ± 18.8	.032
Mean RR (SD)	24.8 ± 5.7	30.2 ± 1.0	28.4 ± 7.9	.001
Mean HR (SD)	110 ± 21	124.5 ± 2.8	119.9 ± 2.3	.004
Mean O ₂ saturation (SD)	95.4 ± 2.9	94.3 ± 3.4	94.7 ± 2.3	.083
Mean asthma score (SD)	8.4 ± 1.4	9.7 ± 2.1	9.3 ± 2	.001
Admitted to hospital (%)	8.6	37.9	27.7	.002

Notes. RR, respiratory rate; HR, heart rate.

TABLE 2.—Correlation between CAS severity and FEV₁ capable status.

CAS severity	FEV ₁ capable (%)
Mild	47.4
Moderate	37.5
Severe	5.9

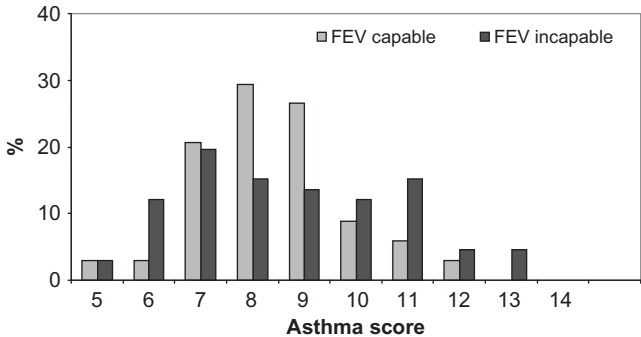


FIGURE 1.—Distribution of asthma score for FEV₁ capable status.

threshold that could be used to identify success with a hand-held spirometer could not be determined due to overlap in the distribution of FEV₁ capable across asthma severity groups (Figure 1).

The CAS correlated poorly with the more objective measure of FEV₁% predicted (Figure 2). Agreement between the two categorizations was 47.1%, with a κ value of -0.076 ($p = .729$). In Table 3, cases classified as mild by clinical assessment were assigned greater severity according to the FEV₁ measurements (67% moderate and 33% severe). Only 64% of moderate cases by clinical assessment were correctly classified as moderate by FEV₁ (24% of severe cases as per FEV₁).

DISCUSSION

Inexpensive mechanical peak flow meters that detect peak expiratory flow rates (PEFR) are commonly used in the

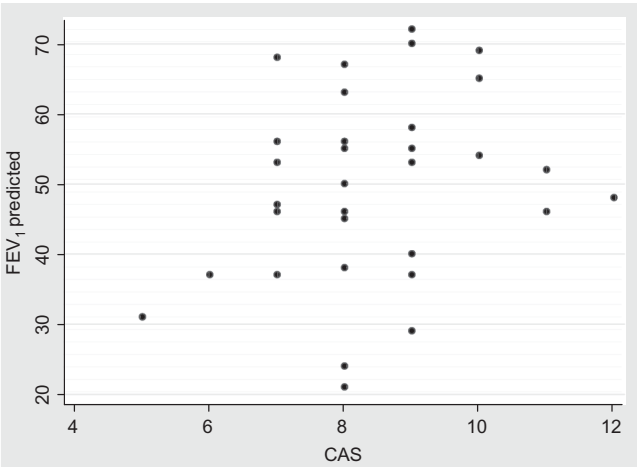


FIGURE 2.—Spirometry capable group correlation between CAS and FEV₁% predicted.

TABLE 3.—Correlation between asthma severity based on CAS and FEV₁% predicted.

<i>P</i> = .729	FEV ₁ % predicted severity		
	Mild	Moderate	Severe
Asthma score			
Mild	0	6	3
Moderate	3	16	6
Severe	0	1	0

ED setting and are used to determine an objective measurement of lung function during an exacerbation of asthma. However, the value of these measurements is limited because PEFR reflect the flows of the large airways in contrast to FEV₁ and forced expiratory flow between 25% and 75% of forced vital capacity (FVC), which characterize the flows in both the large and small airways. Also, peak flow meter recordings are not highly reproducible and can be unreliable predictors of asthma exacerbations (8, 9). The measurements of forced expiration used in the assessment of bronchospasm depend on effort and require significant cooperation by the patient. This effort and

cooperation are progressively more limited in the younger patient as well as when the severity of the asthma exacerbation intensifies. Accurate measurements unfortunately are difficult to obtain in children with acute asthma (18).

The ideal method for the objective measurement of small airway obstruction is the use of spirometry. Laboratory-based spirometry is the “gold standard” for the clinical assessment of lung function in children with chronic asthma. Portable spirometers have become more available and can provide valid measurements that are highly comparable to those obtained from the office-based device (10–12). The FEV₁ and the ratio of FEV₁ to the FVC as a measure of asthma severity have advantages compared with the PEFR. These include greater accuracy, more direct measurement of smaller airways as compared with larger airways, better reproducibility, and for some spirometers the availability of real-time graphics and quality assurance checks to confirm the reliability of the results (19, 14). Among these benefits, the accuracy is most important because it will guide the physician in the treatment and disposition of a serious disease. However, these maneuvers still depend on effort and age similar to assessment by peak flow meters. Some recent studies have shown that portable spirometry can be successfully used in the ED patient with an acute exacerbation of asthma (20, 21). This may be true in the mild asthmatic. However, in order for a hand-held portable spirometer to be useful in the ED setting, it has to also perform well when used in patients with moderate to severe asthma. After reviewing the literature, the ability of children to perform portable spirometry during the ED assessment and treatment of moderate to severe asthma has not been well studied.

In contrast to previous studies, and after receiving adequate coaching and feedback, only a third of the patients in our study were able to perform portable spirometry during an acute exacerbation. Our study agrees with a previous study that many children with an acute exacerbation of asthma are unable to perform peak flow maneuvers (18). It is well known that the ability to successfully perform spirometry is largely dependent on one’s familiarity with the device, effort, and age. Onscreen child incentives have also been implemented to improve success and reproducibility. However, in this study the patient’s ability to perform successful spirometry was largely dependent on the severity of illness. This is most likely a result of the acute inflammatory and bronchospastic phases of the illness with its associated broad severity of symptoms, especially the feeling of shortness of breath, chest tightness, tachypnea, anxiety, and respiratory fatigue. Previous studies state that children are able to perform spirometry in the clinic setting during acute exacerbations (22); however, these studies do not qualify the severity of illness. In those studies, spirometry was performed in a less stressful environment, unlike a high-volume chaotic ED. It appears that the portable spirometer may be best suited for the chronic management of asthma or for those patients with only mild acute disease.

This study is in agreement with several other studies that have demonstrated that the clinical assessments made by physicians all have underestimated the degree of obstruction (21–24). A validated CAS in our study had poor correlation with the FEV₁% predicted, misclassifying a patient to a lower severity group over 50% of the time. Nine patients had severe obstruction according to spirometry but were misclassified as mild (three patients) or moderate (six patients) per CAS. Less than half (47.4%) of the patients classified as mild were able to perform spirometry because they actually had higher severity of disease according to the gold standard FEV₁% predicted classification. The CAS and FEV₁% predicted had the greatest correlation in the moderate category (64%). This suggests that the validated CAS is not as accurate as the results from a properly performed portable spirometer. As clinicians we use our subjective findings and CASs to make treatment and disposition (admit or discharge) decisions in children with acute asthma. These may be underestimating the severity of illness. Perhaps spirometry may be most useful in the ED in determining the final disposition of those patients capable of successfully performing it, such as those borderline admit or discharge asthma patients with only mild disease after receiving treatment in the ED. In this scenario, portable spirometry may help decrease inappropriate admissions or prevent the premature discharge of a moderate to severe asthmatic whose clinical findings point only to the mild category.

Unfortunately, in many pediatric patients portable spirometry is not the “final answer,” at least not in the ED. Even though spirometry is the “gold standard” for assessing lung function in the chronic stable asthmatic, many acute asthmatic patients cannot adequately perform the maneuver. Therefore, utilizing portable spirometry as a severity measure in the acute asthmatic patient for clinical or research purposes is difficult and problematic.

LIMITATIONS

This study is limited by its relatively small size, although it is larger than most other studies and sufficiently powered to obtain our primary objective. Various clinicians and licensed respiratory therapists were involved in clinical assessments, scoring systems, and spirometry measurements creating a certain degree of interobserver variability. However, the clinical asthma scoring system and portable spirometry have already shown in previous studies to have good interobserver reliability. Clinical scores were determined before spirometry measurements to avoid bias. Also, one could argue that if more time had been spent with the patient on instruction, a larger percent of the moderate to severe patients may have been able to successfully complete spirometry. Unfortunately, this may be impractical in a busy ED as it monopolizes valuable resources, increases respiratory fatigue, and delays treatment.

CONCLUSIONS

Many children are incapable of using portable spirometry for the evaluation of acute exacerbations of asthma in the ED. The clinical asthma scoring system demonstrated poor correlation with portable spirometry measurements in terms of severity classification. Spirometry demonstrated increased severity of obstruction in patients with acute asthma exacerbations than did the clinical asthma scoring system or clinical examination. Due to the difficulties in performing the pulmonary maneuver during an acute asthma attack, the portable spirometer has limited usefulness in the ED.

DECLARATION OF INTEREST

We the authors report no conflicts of interest. We alone are responsible for the content and writing of this paper.

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