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Spirometry Use in Children Hospitalized with Asthma

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Spirometry Use in Children Hospitalized with Asthma

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Abbreviated title: Spirometry Use in Children Hospitalized with Asthma

Summary: Rationale: Asthma is the most common chronic disorder of childhood and continues to be a common cause of hospital admission. The National Asthma Education and Prevention Program Expert Panel (NAEPP) recommends spirometry to be obtained on admission, after bronchodilator during the acute phase, and at least another before discharge from the hospital. The objectives of this study were to describe the use of spirometry in children hospitalized with asthma and determine the association of pulmonary function near discharge with future exacerbations. Methods: This was a retrospective cohort study involving reviewing medical records and spirometries of children ≥ 5 years old who were admitted with asthma to Cincinnati Children's Hospital Medical Center from September 1 2009 to March 31 2011. Asthma re-exacerbation was defined as either having an emergency department (ED) visit or hospitalization for asthma that occurred within 3 months of the index hospitalization. Asthma hospitalization or ED visits were identified by the ICD-9-CM codes of having either a primary diagnosis of asthma (493), or respiratory illnesses (460-496) plus a secondary diagnosis of asthma. All spirometries were performed in a pediatric pulmonary function laboratory. Results: Among 1037 admissions (908 unique patients) included in the study, 89 (8.6%) had spirometry prior to discharge (0.3 ± 0.6 days before discharge). Fifty (56.2%) of those spirometries met American Thoracic Society's (ATS) criteria for acceptability and repeatability. Those with acceptable spirometry were significantly older than those whose spirometry did not meet ATS criteria (13 ± 4 years vs 11 ± 3 , $p=0.017$). Of these 50 children, 10 (20%) developed an asthma exacerbation within three months following discharge (mean, 32 ± 21 days). Children with re-exacerbation had significantly lower forced expiratory volume in the first second to forced vital capacity ratio (FEV_1/FVC) and forced expiratory flow at 25-75% (FEF_{25-75}) with a mean of $68.5 \pm 9.0\%$ predicted vs $76.0 \pm 9.5\%$ predicted ($p=0.038$) and $45.6 \pm 28.1\%$ vs $65.2 \pm 30.2\%$ predicted ($p=0.039$), respectively. Children who were older ($OR=1.4$; 95%CI 1.1-1.9) and those with shorter hospital stay ($OR=2.8$; 95%CI 1.1-7.4) were significantly more likely to have a re-exacerbation.

Conclusion: This study showed that few children admitted with asthma had spirometry as recommended in the NAEPP guidelines. Over half of the children over the age of five years were able to perform acceptable spirometry near discharge. Lower lung function especially FEV_1/FVC and FEF_{25-75} near discharge was associated with developing an asthma exacerbation within 3 months following the index admission. Prospective study is needed to confirm these findings.

Keywords: spirometry, asthma, children, hospitalization

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Introduction:

Asthma is a chronic disorder of the airways characterized by variable and recurring symptoms, airflow obstruction, bronchial hyperresponsiveness and underlying inflammation¹. It is the most common chronic disorder of childhood and continues to be a heavy burden to our society. In 2009, asthma prevalence among children in the United States was 9.6%, affecting 7.1 million children². Asthma exacerbations are acute or subacute episodes of progressively worsening shortness of breath, cough, wheeze, and chest tightness or some combination of these symptoms¹. The prevalence of asthma exacerbations was 4.2%, affecting four million children in 2009³. These events resulted in significant morbidity with 10.5 million school days missed³. An estimated 157,000 children with asthma exacerbations required hospitalization in 2009³. Medical expenses associated with asthma amounted to \$3259 per person per year from 2002-2007².

Studies have shown that history of prior asthma hospitalization is an independent predictor of hospital readmissions⁴⁻⁷. The rate of readmission after a recent hospitalization ranged from 16.3% to 43% per year with 11% having recurrent near-fatal exacerbations⁷⁻¹². African-American with Medicaid or no insurance are also at higher risk of readmission⁶. As part of the assessment of the severity of an asthma exacerbation, the National Asthma Education and Prevention Program through their Expert Panel Report 3 (NAEPP ERP 3) has recommended lung function to be obtained on admission and 15-20 minutes after bronchodilator during the acute phase and at least another before discharge from the hospital. Based on their expert opinion, the value of forced expiratory volume during the first second (FEV₁) of 70% predicted and above was chosen as the post treatment goal for discharge from the hospital¹.

The objectives of this study were to describe the use of spirometry in children hospitalized with asthma and determine the association of pulmonary function near discharge with future exacerbations.

Materials and Methods:

This was an exploratory retrospective cohort study involving review of medical charts and spirometries. Children aged five years and above who were admitted to Cincinnati Children's Hospital Medical Center for asthma from September 1st 2009 to March 31st 2011 were included in this study. These index hospitalizations were followed for at least three months to determine development of further asthma exacerbations. Asthma hospitalization or emergency department visits were identified by using discharge International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) codes of having either a primary diagnosis of asthma (493) or respiratory illnesses (034, 460-466, 472-475, 477-493, 495-496, 510-513, 786, 995) plus a secondary diagnosis of asthma. All identified patients' medical charts were reviewed to ensure they were treated for asthma while those who were not were excluded. Future asthma exacerbations were defined as emergency department visits or hospitalizations with asthma following discharge from the index hospitalization.

The medical records were reviewed and information including age, sex, race, body mass index (BMI), date of admission, date of discharge, level of asthma control per NAEPP guidelines¹, exposure to tobacco smoke, insurance status and whether subject was admitted to the intensive care unit or not were recorded.

All spirometries were performed in our pulmonary function lab within the institution using machines made from Viasys Healthcare Respiratory Technologies, CA according to criteria set by the American Thoracic Society (ATS)¹³. Spirometry was performed prior to bronchodilator administration and done by certified pediatric pulmonary function test technicians. Predicted values for lung function parameters

were determined by equations formulated from multiple sources according to patient's age and race.¹⁴⁻

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Descriptive statistics are provided for the frequency of spirometry being used, the proportion of children who were able to perform acceptable and repeatable spirometry according to the ATS standards¹³ and the number of children with asthma re-exacerbations. Frequencies or means ($\pm$ standard deviations) are used to describe the characteristics of the children and lung function parameters in each group. The Wilcoxon nonparametric test (for continuous variables) and either a chi-square or Fisher's test (for categorical variables) were employed to test for differences between the group of children who had spirometry with those that did; group of children who were able to perform acceptable spirometry with those who could not; and those children who had re-exacerbations with those who had not. We selected a re-exacerbation interval of three months following the index hospitalizations for our analyses since our study population developed a re-exacerbation within an average of about three months and episodes occurring more than three months post-hospitalization may be related to new triggers with seasonal changes, unrelated to prior asthma episodes. Multiple logistic regression analyses were used to study relationships between the demographic and medical factors with development of asthma re-exacerbations. We report odds-ratios with 95% confidence intervals. All statistical analyses were performed using SAS v9.2 software (SAS Institute, Cary, North Carolina, USA).

This study was reviewed and approved by the Institutional Review Boards of Cincinnati Children's Hospital Medical Center and University of Cincinnati.

Results:

A total of 1037 admissions for asthma were included in our study, made by 908 children (mean age of 9.7 ± 4.1 years) with 109 of them having multiple admissions. Spirometry was performed on 89 (8.6%) of these admissions (82 unique patients). The patient characteristics are shown in Table 1. Subjects who had spirometry were all seen by a pediatric pulmonologist or an allergist (100% vs 31%; $p < 0.0001$) and were significantly older (11.4 ± 3.7 vs 9.6 ± 4.1 years; $p = 0.0007$). The spirometries were obtained mostly during the day of discharge (0.3 ± 0.6 days to discharge). Fifty (56.2%) of the subjects who had spirometry were able to perform maneuvers achieving acceptable and repeatable criteria set by the ATS. These children were significantly older (12.7 ± 4.0 vs 10.8 ± 3.0 years; $p = 0.0169$) and were less likely to be admitted to the intensive care unit (22.00% vs 43.59%; $p = 0.0296$) (Table 2). There were no significant differences in sex, race and body mass index (BMI). The average FEV₁ near discharge was $84.1 \pm 19.1\%$ predicted; FVC was $98.1 \pm 15.3\%$ predicted; FEV₁/FVC was $74.5 \pm 9.8\%$; while FEF₂₅₋₇₅ was $61.3 \pm 30.6\%$ predicted.

In our overall population of 1037 admissions, 367 (35.4%) had a re-exacerbation within 12 months while 123 (11.9%) were associated with re-exacerbation within 3 months after discharge from the index hospitalization. The mean number of days to first re-exacerbation was 156 ± 109 days. Twenty three out of the 50 subjects who were able to perform acceptable spirometry developed future exacerbations within an average of 109 ± 85 days. Ten of those had an exacerbation within three months (mean of 32 ± 21 days from discharge). The demographic details and lung function parameters of patients with three months re-exacerbation compared to those without are shown in Table 3. Children who had an exacerbation within three months had significantly lower forced expiratory volume in the first second to forced vital capacity ratio (FEV₁/FVC) and forced expiratory flow at 25-75% (FEF₂₅₋₇₅) with a mean of $68.5 \pm 9.0\%$ predicted vs $76.0 \pm 9.5\%$ predicted ($p = 0.038$) and $45.6 \pm 28.1\%$ vs $65.2 \pm 30.2\%$ predicted

($p=0.04$), respectively. Although not meeting statistical significance, children who had an exacerbation within three months tend to be older, had higher BMI and lower forced expiratory volume in the first second (FEV_1). Multiple logistic regression analysis performed on these children showed that those who were older ($OR=1.4$; 95%CI 1.1-1.9) and children who had shorter hospital stay ($OR=2.8$; 95%CI 1.1-7.4) were significantly more likely to have an exacerbation within three months.

Discussion:

Although the National Heart, Lung and Blood Institute in their published NAEPP Expert Panel Report 3 in 2007¹ recommended spirometry to be performed during hospitalization for acute asthma, our study suggests that very few were obtained (8.6% of admissions). Study had shown that spirometry use is also low among pediatric primary care physicians in their clinics¹⁷. Patients that had spirometry in our study were all consulted by either a pediatric pulmonologist or an allergist. This low rate of spirometry use may be due to the lack of evidence showing the usefulness of spirometry in children during hospitalization. The need for an objective measure of airflow limitation apart from clinical assessments had been echoed by multiple studies¹⁸⁻²¹. Physicians often underestimate the severity of airway obstruction without spirometry^{18,21}. The use of spirometry has been shown to influence patients' treatment plans in the outpatient settings¹⁸. Studies in adults have shown that peak expiratory flow rate (PEF) can be useful in determining who will require hospitalization or can be discharged²²⁻²⁵. However, there has been no studies to our knowledge that have established levels of lung function that predict successful discharge from the emergency department or hospitalization in children.

More than half of our subjects were able to perform spirometry meeting the ATS standards¹³. Studies have shown that some children presenting with severe acute asthma exacerbations may have difficulty performing the test during the acute phase^{20,21,26,27}. Nevertheless, near the time of discharge, when the most severe phase of the acute episode has resolved, most children are able to perform the necessary

maneuvers. Children who were able to perform acceptable spirometry were significantly older. We also found that those presenting with more severe exacerbations requiring admissions to the intensive care units were significantly less likely to be able to perform well on spirometry. No differences were found between the sex distribution, race, BMI, length of hospital stay, underlying asthma control and time of spirometry. Our findings of decreased FEV_1/FVC and FEF_{25-75} with normal FEV_1 were consistent with other studies on children with asthma^{28,29}. Studies suggest that most children have normal FEV_1 even when they are symptomatic^{28,29}. FEV_1/FVC has been shown to be the more sensitive indicator of airflow obstruction²⁹. FEF_{25-75} has also been said to be more sensitive than FEV_1 in detecting airway obstruction, especially of the small airways. Nevertheless, it is much more variable²⁹.

In our study population of children aged five and older who were admitted with asthma, 35.3% returned to the emergency department or were readmitted within a year. This rate could likely be higher as some of the patients have not had up to twelve months follow up since their index hospitalization. This rate of re-exacerbation is higher than most readmission rates reported in previous studies⁷⁻¹². Our higher rate may be due to the inclusion of emergency department visits apart from just hospital readmissions. Nevertheless, our study showed that many children continued to have inadequate control of their asthma post-hospitalization. This is consistent with studies suggesting that children with history of prior asthma hospitalization are at risk of future hospital readmissions⁴⁻⁷. From our group of 50 children who were able to perform acceptable spirometry, 23 developed re-exacerbation within a year, with ten of them having an exacerbation within three months. These ten had significantly lower lung function near their discharge, especially their FEV_1/FVC ratio and FEF_{25-75} . FEV_1 has been shown to inversely correlate with the risk of future asthma exacerbations in children with stable asthmatics in prior studies³⁰⁻³². Although not meeting statistical significance, the mean FEV_1 was lower but more than 70% predicted, meeting the NAEPP target for discharge¹. Longitudinal analyses on children participating in the Childhood Asthma Management Program (CAMP) trial also found that lower FEV_1/FVC ratio was

associated with persistent symptoms and severe exacerbations during the four years of the trial³³. Age, sex, race, BMI and underlying level of asthma control were no different between children with and without re-exacerbation within three months. Multiple logistic regression analyses performed on our limited sample suggest that children who are older and those who had a longer hospital stay were more likely to have a re-exacerbation within three months post-hospitalization.

Although this may be the first study to our knowledge in exploring the use of spirometry in hospitalized children with asthma, there were multiple limitations. This study was only done in our institution which is a tertiary children's hospital with facilities to perform spirometry within the hospital building. This may not be generalizable to other community or children's hospitals. Due to the nature of our study design, there may be misclassification in identifying children who were admitted with an asthma exacerbation and data abstraction. We made an effort to minimize this by reviewing manually all medical charts and exclude those that did not meet our inclusion criteria. We might be underestimating the rate of future asthma exacerbations by missing children who could have developed an exacerbation but received care outside the hospital. Lastly, this study was also limited by the small number of children who were able to perform acceptable and reproducible spirometry as well as those having re-exacerbations. Potential confounders were difficult to control for.

In conclusion, this study showed that few children admitted with asthma had spirometry as recommended in the NAEPP guidelines. Over half of the children over the age of five years were able to perform acceptable spirometry near discharge. Majority had normal FEV₁ but decreased FEV₁/FVC ratio and FEF₂₅₋₇₅. Lower lung function especially FEV₁/FVC ratio and FEF₂₅₋₇₅ near discharge was associated with developing an asthma exacerbation within 3 months following the index admission. Prospective study is warranted to confirm these findings and determine the values of lung function that can predict successful discharge for children hospitalized with asthma.

Table 1: Patient characteristics of children who had spirometry compared to those who did not.

Variables		Children who had spirometry (N=82)	Children who did not have spirometry (N=826)	p-value
Age, years (mean ± SD)		11.4±3.7	9.6±4.1	0.0007
Sex, %	Male	62.20	60.53	0.77
	Female	37.80	39.47	
Race, %	Black	65.85	50.73	0.07
	White	26.83	38.98	
	Hispanic	1.22	1.82	
	Other	6.10	8.47	
Insurance, %	Public	64.04	63.40	0.82
	Private	31.46	33.23	
	None	4.49	3.38	

Table 2: Characteristics of children who were able to perform acceptable spirometry compared to those who could not.

Variables		Acceptable Spirometry (N=50)	Not Acceptable Spirometry (N=39)	p-value
Age, years (mean±SD)		12.7±4.0	10.8±3.0	0.0169
Sex	Male	30 (60%)	25 (64%)	0.6924
	Female	20 (40%)	14 (36%)	
Race	Black	33 (66%)	28 (72%)	0.7024
	White	12 (24%)	10 (26%)	
	Hispanic	1 (2%)	0	
	Other	4 (8%)	1 (2%)	
BMIz (mean±SD)		0.76±1.29	0.44±1.63	0.6206
Exposure to tobacco smoke, %		56.5	43.2	0.2284
Length of stay, days (mean±SD)		2.8±1.4	2.6±1.8	0.4335
Time of spirometry (days to discharge) (mean±SD)		0.3±0.5	0.3±0.6	0.5389
Admission to ICU, %		22.00	43.59	0.0296

Asthma control	Well controlled	6 (12.24%)	6 (17.14%)	0.3493
	Not well controlled	26 (53.06%)	13 (37.14%)	
	Very poorly controlled	17 (34.69%)	16 (45.71%)	

Table 3: Characteristics and lung function parameters of children who developed a re-exacerbation within 3 months post-hospitalization compared to those who did not.

Variables		Children with exacerbation within 3 months post- discharge (N=10)	Children without exacerbation within 3 months post- discharge (N=40)	p-value
Age, years (mean±SD)		14.4±5.0	12.3±3.7	0.2859
Sex	Male	6 (60%)	24 (60%)	1.000
	Female	4 (40%)	16 (40%)	
Race	Black	9 (90%)	24 (60%)	0.4506
	White	1 (10%)	11 (27.5%)	
	Hispanic	0	1 (2.5%)	
	Other	0	4	
BMIz (mean±SD)		1.28±1.18	0.64±1.29	0.2096
Length of stay, days (mean±SD)		2.3±1.2	2.9±1.5	0.2125
Admission to ICU,%		0	27.5%	0.0918
Asthma control	Well controlled	0	6 (15.38%)	0.3137
	Not well controlled	5 (50%)	21 (53.85%)	
	Very	5 (50%)	12 (30.77%)	

	poorly controlled			
Exposure to tobacco smoke, %		44.44	59.46	0.4725
FEV1, % pred (mean±SD)		76.7±18.3	85.9±19.1	0.1522
FVC, % pred (mean±SD)		97.0±15.8	98.4±15.4	0.6187
FEV1/FVC, % (mean±SD)		68.5±9.1	76.0±9.5	0.0379
FEF₂₅₋₇₅, % pred (mean±SD)		45.6±28.1	65.2±30.2	0.0392
PEF, % pred (mean±SD)		70.7±16.4	73.9±18.7	0.6448

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