# Evaluation of Interpretation Strategies and Substantial Bronchodilator Response in Pediatric Patients With Normal Baseline Spirometry

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**BACKGROUND: Controversy exists regarding the best method to interpret pediatric spirometry. There is also controversy regarding the benefit of performing post-bronchodilator spirometry after normal baseline spirometry. This study compares the use of lower limit of normal (LLN) against percent of predicted (PP) in the interpretation of spirometry. We also investigate the occurrence of a substantial bronchodilator response for patients who received post-bronchodilator spirometry. METHODS: Spirometric tests performed in the pediatric clinic at San Antonio Military Medical Center were retrospectively reviewed. Results of spirometry were compared using LLN and PP for interpretation. Abnormal spirometry was defined as a low $FEV_1$ or low $FEV_1$/FVC, indicating evidence of airway obstruction. The presence of a substantial bronchodilator response was recorded and the results were analyzed. RESULTS: Of 242 tests, 212 normal and 30 abnormal tests were reported using the LLN interpretation strategy. Using the PP interpretation strategy, there was a significant difference in the number of normal (183) and abnormal (59) tests, when compared to the LLN ($P < .001$). No significant difference between LLN versus PP interpretation strategies was noted in the number of baseline tests, normal or abnormal, that demonstrated a substantial response to bronchodilator. Of the subjects with normal baseline spirometry, 10% (PP) and 12% (LLN) had a substantial bronchodilator response. An abnormal baseline spirometry was more likely to have a substantial response to bronchodilator, compared to normal baseline spirometry ($P < .001$). CONCLUSIONS: The use of LLN for interpretation is more likely to report a test as normal, when compared to the PP interpretation strategy. Although a substantial bronchodilator response is more likely to occur following abnormal baseline spirometry, 10–12% of subjects with normal baseline spirometry showed a substantial bronchodilator response. This suggests that normal baseline spirometry may miss reversible airway obstruction, which is a hallmark of asthma.** *Key words: spirometry; pulmonary function test; bronchodilator response; pediatric; $FEV_1$; FVC.* [Respir Care 2013;58(5):785–789]

## Introduction

Asthma is a chronic disease with a prevalence of 13% in children and is one of the most common reasons for outpatient pediatric clinic visits.[1] The substantial impact of this disease is illustrated by 12.8 million missed school days, 3% of all pediatric hospital admissions, and 2.8% of all emergency department visits in the United States.[1] Among the contributing factors to asthma morbidity, it has been noted that physicians frequently underestimate the

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The opinions and assertions presented herein are those of the authors and are not to be construed as reflecting the views of the Department of Defense.

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degree of asthma control.[2] Diagnosis of asthma can often be challenging, and the National Asthma Education and Prevention Program recommends the use of spirometry to assist in the evaluation of asthma. The recommendation suggests that an $FEV_1 < 80\%$ is an objective measurement that is consistent with persistent asthma, or asthma that is not well controlled.[2] However, evidence shows that a majority of patients with known asthma demonstrate normal baseline spirometry, based on an $FEV_1 \geq 80\%$ of predicted.[3] Controversy exists regarding the ideal method to interpret spirometry.[4-11] The American Thoracic Society and European Respiratory Society task force recommends using the lower limit of normal (LLN) for interpretation of spirometry.[4] However, the use of a percent of predicted (PP) threshold is still common practice.

There is no consensus for the interpretation of pediatric spirometry. A survey of pediatric training programs shows there was variability in the interpretative strategies, although the majority of programs used the $\geq 80\%$ predicted threshold to define normal spirometry.[6] The National Health and Nutrition Examination Survey III (NHANES III) survey provides a robust database for spirometry reference values.[12] It has been suggested that there should be more confidence in utilizing the LLN for pediatric interpretation, using the NHANES III reference set.[13] However, it is unknown how many pediatric pulmonary function labs have adopted LLN for interpretation.

Bronchodilator response (BDR) presents additional controversy to spirometry testing and interpretation. There is disagreement in adult patients on whether post-bronchodilator testing is necessary if the baseline spirometry is normal.[14-16] The value of performing post-bronchodilator testing in children with normal baseline spirometry is unknown.

In this retrospective analysis we compare pediatric spirometry results using 2 different interpretation strategies to determine if there is a difference in the diagnosis of normal spirometry. We also investigate the occurrence of substantial BDR despite normal baseline spirometry.

**QUICK LOOK**

**Current knowledge**

The National Asthma Education and Prevention Program recommends spirometry to evaluate asthma, and suggests that an $FEV_1 < 80\%$ of predicted is consistent with persistent or uncontrolled asthma. Many patients with asthma have normal $FEV_1$ ($\geq 80\%$). Controversy exists regarding the ideal method to interpret spirometry.

**What this paper contributes to our knowledge**

The use of the lower limit of normal for spirometry interpretation was more likely (than percent of predicted) to report a test as normal. A substantial bronchodilator response was more likely following abnormal baseline spirometry, but 10–12% of patients with normal baseline spirometry had a substantial bronchodilator response. Normal baseline spirometry may miss reversible airway obstruction. Baseline percent of predicted $FEV_1$ should not impact the decision to perform post-bronchodilator spirometry.

## Methods

Spirometry test results obtained in the general pediatric clinic at the San Antonio Military Medical Center from January 1, 2009, to January 30, 2010, were reviewed. Patients who presented for spirometry testing had a diagnosis of asthma, or were undergoing evaluation for asthma. Post-bronchodilator spirometry test results were performed if requested by the primary healthcare provider.

Spirometry was performed using a spirometer (Koko, nSpire Health, Longmont, Colorado) by a registered respiratory therapist with training in pulmonary function testing. FVC, $FEV_1$, $FEV_1$/FVC, and forced expiratory flow between 25% and 75% of vital capacity were recorded. All test results that met American Thoracic Society standards for lung function testing were included.[17] A minimum of 3 repeatable efforts ($< 10\%$ difference in the sum of $FEV_1$ and FVC values) with a minimum expiratory time of 6 seconds (3 seconds if the subject was $< 10$ years old) was used as criteria for an appropriately performed test.

Predicted values were defined by comparison using the NHANES III population data set for subjects 8–18 years of age.[12] For subjects below 8 years of age, the data set reported by Wang et al was used.[18] Subjects $> 18$ years of age were excluded. Abnormal spirometry (evidence of airway obstruction) was defined as $FEV_1 < 80\%$ predicted or $FEV_1/FVC < 0.8$ for PP interpretation. Abnormal spirometry results were also recorded using the LLN for $FEV_1$ or $FEV_1$/FVC.

Post-bronchodilator spirometry was obtained 15 min after 180 $\mu$g of albuterol was administered via 2 puffs from a metered-dose inhaler, using a disposable spacer. A substantial BDR was defined as an increase in $FEV_1$ of $\geq 12\%$ and 200 mL, compared to the baseline results obtained from the pre-bronchodilator spirometry.[5] The Student *t* test was used to evaluate statistical significance of the average age in each group. The Pearson chi-square test was used to evaluate sex difference in both groups, the association between baseline spirometry results, and the occurrence of a clinically important BDR. This project was reviewed and approved by the institutional review board at San Antonio Military Medical Center.

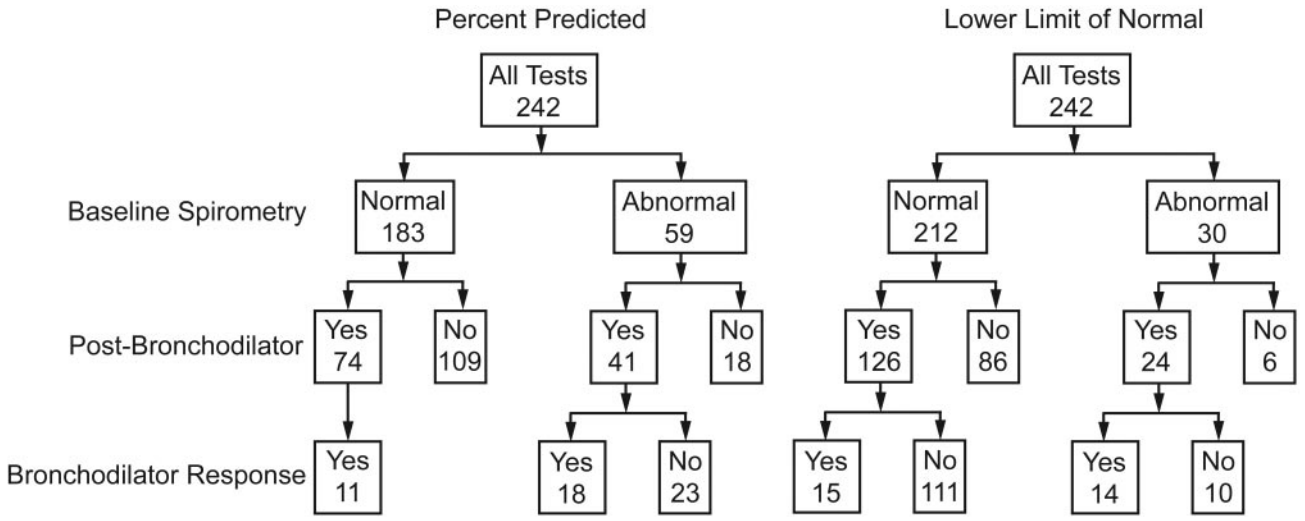


Fig. 1. Comparison of lower limit of normal versus percent predicted spirometry interpretation results and bronchodilator response.

## Results

Baseline demographic data show that subject age ranged from 6 to 18 years, with 140 male and 102 female. There was no significant difference between the average subject ages (12.7 y vs 13.0 y) or sex in the normal and abnormal baseline spirometry groups.

A total of 242 baseline pediatric spirometric tests were reviewed, with 212 normal results and 30 abnormal results using the LLN. One hundred twenty-six subjects with normal tests and 24 subjects with abnormal tests received post-bronchodilator tests. Fifteen subjects with normal baseline spirometry and 14 subjects with an abnormal baseline spirometry had a substantial BDR. Using the PP criteria, baseline spirometry showed 183 normal results with 59 abnormal results. One hundred nine subjects with normal tests and 41 subjects with abnormal tests received post-bronchodilator tests. Eleven subjects with normal baseline spirometry and 18 subjects with abnormal baseline spirometry had a substantial BDR (Fig. 1).

When comparing LLN to PP interpretation, there was a significantly higher number of baseline spirometry tests reported as abnormal in the PP group ($P < .001$) (Fig. 2). There was no difference in the percentage of normal baseline spirometry with a BDR in the LLN (12%), compared to the PP (10%) groups. Regardless of interpretation strategy, an abnormal baseline spirometry was more likely to have a substantial BDR, compared to a normal baseline spirometry ($P < .001$) (Table 1).

When the results are analyzed by baseline $FEV_1$, 7/20 subjects had a BDR when $FEV_1$ was 80–89%, 6/44 subjects had a BDR when $FEV_1$ was 90–99%, and 6/70 subjects had a BDR when $FEV_1 > 100\%$. When comparing BDR by the designated $FEV_1$ groups, there was a significant difference ($P < .04$) only when comparing the $FEV_1$ 80–89% group to the $FEV_1 > 100\%$ group (Table 2).

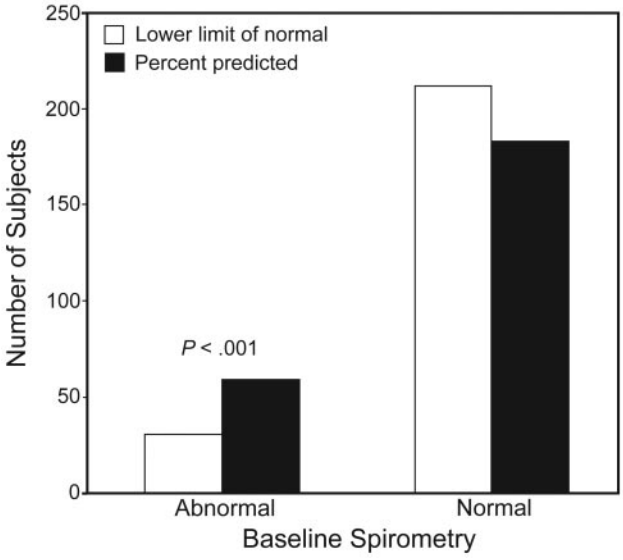


Fig. 2. Comparison of lower limit of normal versus percent predicted baseline normal and abnormal tests.

## Discussion

In this study we show that the diagnosis of an abnormal spirometry is significantly affected by the interpretation strategy. More tests were identified as abnormal utilizing the PP strategy. A potential concern would be the false reassurance of a normal test, which is more likely using the LLN strategy. Although the diagnosis of asthma should not rely on spirometry alone, a provider inexperienced at spirometry interpretation may rely heavily on the results.

Table 1. Comparison of Bronchodilator Response by Interpretation Strategy and Baseline Spirometry Results

| Interpretation Strategy | Baseline Spirometry | Bronchodilator Response | No Bronchodilator Response | Percent of Tests With Bronchodilator Response* |
|---|---|---|---|---|
| LLN | Normal | 15 | 111 | 12 |
| LLN | Abnormal | 14 | 10 | 58 |
| % Predicted | Normal | 11 | 98 | 10 |
| % Predicted | Abnormal | 18 | 23 | 44 |

* $P < .001$ for LLN (lower limit of normal) with normal baseline spirometry versus LLN with abnormal baseline spirometry. $P < .001$ for percent of predicted with normal baseline spirometry versus percent of predicted with abnormal baseline spirometry. Other differences not significant.

Table 2. Bronchodilator Response Tests Results Categorized by Baseline Percent of Predicted $FEV_1$

| Baseline $\%FEV_1$ | Total | Bronchodilator Response | Percent of Tests With Bronchodilator Response |
|---|---|---|---|
| < 80 | 16 | 10 | 63 |
| 80–89 | 20 | 7 | 35* |
| 90–99 | 44 | 6 | 14 |
| > 100 | 70 | 6 | 9* |

* $P = .04$.

Baseline spirometry has been shown to impact clinical decision making in asthma.[19] Many patients with asthma may have normal spirometry, and conversely an abnormal spirometry does not diagnose asthma. Caution must be taken when interpreting spirometry results. Although the American Thoracic Society/European Respiratory Society recommend use of the LLN, the PP method continues to be utilized in many pediatric pulmonary function labs.[12] Additional research is required to determine if a specific interpretative strategy is more useful in the diagnosis and management of pediatric asthma.

Our study also shows that normal baseline spirometry does not rule out reversible airway obstruction. As expected, having an abnormal baseline spirometry was more likely to be associated with a BDR, compared to a normal baseline spirometry. However, 10–12% of normal baseline spirometry had a BDR in this study. Normal spirometry is based upon comparisons with normative values derived from specific population sets. It is important to keep this in mind when analyzing spirometry and reporting the test as normal. An individual patient may not fall within the normative parameters set by the population sets used for a reference. Therefore, pre-bronchodilator and post-bronchodilator spirometry should be considered in pediatric patients with asthma, regardless of the baseline pre-bronchodilator spirometry results. This point is important; note that nearly one half of the patients in our study with a normal baseline spirometry did not perform post-bronchodilator spirometry.

Our study also shows that the baseline $FEV_1\%$ predicted should not determine whether or not post-bronchodilator spirometry should be performed. A recent adult study suggests that post-bronchodilator spirometry is not required if the $FEV_1$ is > 90% of predicted.[14] Our results show that > 10% of baseline tests with an $FEV_1 > 90\%$ had a BDR. These results also support performing post-bronchodilator spirometry in children, regardless of baseline spirometry results.

## Conclusions

The use of different interpretation strategies for pediatric spirometry may substantially alter the reported results. It is unknown whether or not a specific interpretation strategy is more useful in the diagnosis and management of asthma. A normal baseline spirometry should be analyzed with caution, and post-bronchodilator testing should be considered to evaluate for reversible airway obstruction, regardless of baseline spirometry results. $FEV_1\%$ predicted at baseline should not impact the decision to perform post-bronchodilator spirometry.

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