Evidence of Airway Obstruction in Children With Idiopathic Scoliosis*

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Restrictive pulmonary function abnormalities are reported in children and adolescents with idiopathic scoliosis. We hypothesized that spirometry alone, without more extensive testing, including the measurement of lung volumes, is inadequate in characterizing lung function in these children and may miss obstructive abnormalities including significant gas trapping. To examine this hypothesis, we reviewed the pulmonary function tests of 44 children (36 female, 8 male) between the ages of 10 and 18 years with idiopathic scoliosis prior to surgical correction. Spirometry, measurements of lung volumes with both plethysmographic and helium dilution techniques, and bronchodilator response were analyzed for evidence of reversible airway obstruction and gas trapping. Eighteen of 44 (41%) subjects had significant restriction. Only 3 (7%) subjects met standard criteria for airflow obstruction. However, 20 (46%) subjects had an elevated total gas volume by plethysmography-functional residual capacity by helium dilution ratio indicative of moderate or severe gas trapping, 10 (23%) subjects showed mild gas trapping, 8 (18%) subjects had a ratio suggestive of gas trapping, and only 6 (14%) subjects were normal. Additionally, significant improvement in airway mechanics was noted after bronchodilator administration. Specific conductance improved in all subjects, with a mean increase of 62%±8.0 (p<0.001). The residual volume-total lung capacity ratio and total gas volume by plethysmography also decreased significantly (mean decrease, 22.5%±3.0 and 15%±1.0, respectively, p<0.001) in response to inhaled bronchodilators. In conclusion, although restrictive defects are commonly present in children with idiopathic scoliosis, significant gas trapping and responses to bronchodilators also commonly occur. These abnormalities may be missed without extensive pulmonary function testing. (CHEST 1996; 109:1532-35)

Key words: gas trapping; helium dilution; idiopathic scoliosis; obstructive airway disease; restrictive airway disease; spirometry; total body plethysmography

Abbreviations: ATS=American Thoracic Society; BD=bronchodilator; BTPS=body temperature, ambient pressure, saturated with water vapor; FEFPSS=forced expiratory flow between 25% and 75% of the FVC; FRC=functional residual capacity by helium dilution; FRCsp=spirographic gas volume by plethysmography; ITS=Intermountain Thoracic Society/Pulmonary Function Standardization Task Force; RV=residual volume; sGaw=specific airway conductance; TLC=total lung capacity

Idiopathic scoliosis, which accounts for 80 to 85% of all lateral spine curvature, distorts the chest wall anatomy and results in functional pulmonary disability. Many investigators have reported that pulmonary function tests of patients with idiopathic scoliosis reveal a restrictive defect. The severity of the pulmonary function impairment has been correlated to the degree of spinal curvature. Decreases in FVC, FEV1, total lung capacity (TLC), as well as normal FEV1/FVC ratios have all been reported.1-5

Obstructive lung disease, on the other hand, is not normally associated with idiopathic scoliosis. Weber et al found no evidence of airway obstruction based on FEV1/VC, closing volume and expiratory flow rate at 50% of vital capacity). The decrease in absolute flow rates is due to small lung volumes rather than to airway obstruction. Reduction in effort-dependent peak flow, in particular, can be attributed to the suboptimal conditions of the respiratory muscles and slightly increased airway resistance.

We hypothesize that routine spirometry alone, without measurement of lung volumes, may miss airway obstruction and or trapped gas in children with idiopathic scoliosis. The purpose of this study was to examine the pulmonary function of children with idiopathic scoliosis for evidence of airflow obstruction and trapped gas, to test whether this obstruction could be reversed with an inhaled bronchodilator, and to test whether spirometry alone is adequate to fully characterize functional abnormalities.

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MATERIALS AND METHODS

Clinical Data

We performed pulmonary function tests on 59 children scheduled to have surgical correction of idiopathic scoliosis between January 1988 and December 1994. Forty-four subjects (36 females, 8 males) who had a thoracic curve greater than 35 degrees as measured by the method of Cobb and who did not have secondary scoliosis due to neuromuscular disease, metabolic disease, or trauma were included in the study.

All pulmonary function tests were done in a pediatric pulmonary function lab by the same technician. Any braces being worn were removed prior to all the tests. The armspan length was used as the corrected height for each subject. Each subject performed spirometry in a standing position with the use of a nose clip; standard guidelines were followed. Each subject performed at least three forced expiratory maneuvers on a PK Morgan 100-L dry rolling seal spirometer. Spirometry values were corrected for BTPS. Flow volume loops were displayed on a computer (IBM PCXT-286) after each maneuver, along with FVC, FEV, and the forced expiratory flow between 25 and 75% of the FVC (FEF(25-75)). The highest values were recorded and expressed as a percentage of the predicted normal value for age, sex, and height.

Lung volumes were measured in each subject by both the multibreath closed circuit helium dilution (PK Morgan Model C; PK Morgan; Haverhill, Mass) method and whole-body pressure plethysmography (PK Morgan) using standard techniques. Each subject was tested by spirometry, helium dilution, and plethysmography prior to the administration of 2.5 mg of albuterol mixed in 3 mL of normal saline solution by a nebulizer (Pulmoaid; DeVilbiss) and spirometry and plethysmography were repeated. The pre- and post-bronchodilator (BD) values of FVC, FEV, FEV/FVC ratio, FEF(25-75), thoracic gas volume by plethysmography (FRCpleth), functional residual capacity by helium dilution (FRCHe), specific airway conductance (sGaw), and the residual volume (RV)/TLC ratio were compared, to examine the bronchodilator response based on the recommendations by the International Thoracic Society (ITS)/Pulmonary Function Standardization Task Force and the American Thoracic Society (ATS).

Statistical Analysis

The volume of trapped gas was estimated by calculating the ratio of FRCpleth/FRCHe prior to giving a bronchodilator using criteria recommended by the ITS. Lung volume criteria for restrictive and obstructive disease were based on recommendations by the ATS. The BD response was measured as a percent predicted change from baseline values according to the formula: [(Pre-BD value minus Post-BD value)/Pre-BD value]×100. The results are expressed as the mean±SEM. Paired Student’s t tests were used to determine the significance of the BD response. Confidence intervals of 95% were also calculated for the BD response. All data were analyzed using the Microsoft Excel Version 4.0 Analysis Toolpak (Gray Matter International; Cambridge, Mass). Additionally, mid-expiratory flow response to BDs was examined by adjusting for expiratory time (post- and pre-expiratory time) and lung volumes (post- and pre-FVC) in all subjects using ITS guidelines.

RESULTS

The mean age of the subjects was 13.6±0.33 years (range, 10 to 18 years) and the mean thoracic angle was 47±1.62 degrees (range, 35 to 90 degrees).

Based on ATS criteria, 26 (59%) subjects had no restrictive defects, 4 (9%) subjects had mild defects, 7 (16%) subjects had moderate defects, and 7 (16%) subjects had moderately severe defects (Fig 1).

The mean percent predicted FEV was 67%±2.5, with an FVC of 68%±2.6. The difference between the predicted and measured FEV/FVC did not meet ITS criteria for airway obstruction in 41 (93%) subjects, while 3 (7%) subjects showed mild airway obstruction.

The mean percent predicted FRCHe and FRCpleth before use of BDs were 69%±2.8 and 91%±3.0, respectively.

The trapped gas volume was measured in all 44 subjects. Using ITS criteria, 6 subjects (14%) had an FRCpleth/FRCHe ratio that showed no gas trapping (ratio, <1.09). Eight (18%) subjects had a ratio that was “suggestive” of gas trapping and 10 (23%) subjects had a ratio between 1.21 and 1.34, which was consistent with mild gas trapping. Twenty (46%) subjects had a ratio that showed moderate or severe gas trapping (ratio, >1.35 [Fig 2]).

The effects of an inhaled BD are summarized in Table 1, including the 95% confidence interval for the absolute changes. The mean percent change in FVC after BDs was 0.4%±2.0 (p=not significant). There was a statistically significant increase in FEF(25-75) and FEV after BD, with a mean percentage of change of 24%±3.2 (p<0.001) and 4.5%±1.3 (p<0.001), respectively. Based on ITS criteria, 6 (14%) subjects showed a significant improvement in FEF(25-75) after BDs of greater than 45% from baseline. Applying ATS criteria, 33 (75%) subjects showed a significant improvement in mid-expiratory flow (FEF(25-75)>13%). When the expiratory time and volume adjustments are incorporated, however, only 1 (2%) subject showed clear improvement in FEF(25-75).

The sGaw before and after BD use was recorded in 42 of 44 subjects, and there was a significant increase (mean increase of 62%±8.0, p<0.001) post-BD use.
Twenty-six (62%) subjects had an increase in sGaw of more than 40%, while none showed a decrease. The mean percent FRCpleth after BD use was 78% ± 3.0. When compared with the pre-BD values, the post-BD FRCpleth decreased significantly, with a mean decrease of 15% ± 1.0 (p<0.001). In none of the subjects was the FRCpleth increased after use of BDs. Additionally, there was also a significant decrease in the RV/TLC ratio after BD use, with a mean decrease of 22.5 ± 3.0 (p<0.001).

**DISCUSSION**

It is generally accepted that alveolar hypoventilation and respiratory dysfunction leading to pulmonary hypertension and cor pulmonale is encountered with scoliosis patients whose curvature is greater than 90 degrees. However, pulmonary function defects may be seen with lesser degrees of scoliosis.\(^\text{15}\) The mean angle of our subjects was 47 degrees, a moderate class 2 deformity based on the classification by Gozioglu et al.\(^\text{1}\) Even though 45% of our subjects had restrictive defects, none had a history of respiratory complaints.

Previous studies have shown that patients with idiopathic scoliosis have restrictive lung disease.\(^\text{1-5,16}\) Chest wall deformity leading to decreased lung compliance, and defective mechanical coupling of inspiratory muscles to the chest wall leading to a decrease in respiratory muscle mechanics, has been shown to contribute to the restrictive properties.\(^\text{17}\) Standard criteria for hyperinflation or airflow obstruction may not be applicable in patients with idiopathic scoliosis. Expiratory flow rates will be reduced in proportion to the degree of restrictive disease, leading to an increased closing volume and subsequent gas trapping. In our study there was no evidence of airflow obstruction or hyperinflation when standard spirometric criteria were used.\(^\text{13,14}\) However, the majority of the subjects had evidence of trapped gas as seen in the FRCpleth/FRCHe ratios. Bjure et al.\(^\text{15}\) showed that with an increasing angle of scoliosis and age, the closing volume tends to occur at volumes greater than functional residual capacity, thus leading to gas trapping. Weber et al.\(^\text{2}\) however, found no evidence of gas trapping, but they used only the helium dilution method to measure lung volumes. Gas trapping may be missed if lung volumes are measured by a gas dilution method alone.

Although the FRCpleth was within normal limits in our subjects, there was a noticeable difference compared with the FRCHe. Furthermore, the decrease in FRCpleth after use of inhaled BDs suggests that these patients may have increased bronchomotor tone perhaps to compensate for the restricted chest wall. The small difference between the FRCHe and the post-BD FRCpleth may be due to compliance of the upper airways.\(^\text{19}\) Additional evidence for bronchospasm is seen with a 62% increase in sGaw and a 22% reduction in the RV/TLC ratio after inhalation of a BD. These

**Table 1—Mean Pre- and Post-Bronchodilator Values ± SEM With Percentage of Change From Baseline and 95% Confidence Interval for the Bronchodilator Response**

<table>
<thead>
<tr>
<th></th>
<th>Pre, % Predicted</th>
<th>Post, % Predicted</th>
<th>95% Confidence Interval</th>
<th>Probability Value</th>
<th>Post Minus Pre×100</th>
</tr>
</thead>
<tbody>
<tr>
<td>FVC, L</td>
<td>2.82±0.11</td>
<td>2.81±0.12</td>
<td>-0.08 to 0.07</td>
<td>Not significant</td>
<td>-0.4</td>
</tr>
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<td></td>
<td>(67.4%)</td>
<td>(67.7%)</td>
<td></td>
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<tr>
<td>FEV(_1), L</td>
<td>2.44±0.1</td>
<td>2.56±0.1</td>
<td>0.04 to 0.16</td>
<td>&lt;0.001</td>
<td>4.5</td>
</tr>
<tr>
<td></td>
<td>(67.1%)</td>
<td>(76.0%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FEF(25-75%), (L/s)</td>
<td>2.78±0.16</td>
<td>3.33±0.16</td>
<td>0.42 to 0.66</td>
<td>&lt;0.001</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>(67.4%)</td>
<td>(80.4%)</td>
<td></td>
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<td></td>
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<tr>
<td>sGaw</td>
<td>0.18±0.01</td>
<td>0.28±0.02</td>
<td>0.08 to 0.12</td>
<td>&lt;0.001</td>
<td>62</td>
</tr>
<tr>
<td></td>
<td>(56.2%)</td>
<td>(85.1%)</td>
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<tr>
<td>FRCpleth, L</td>
<td>2.14±0.1</td>
<td>1.83±0.08</td>
<td>-0.27 to -0.41</td>
<td>&lt;0.001</td>
<td>-15.5</td>
</tr>
<tr>
<td></td>
<td>(91.2%)</td>
<td>(77.8%)</td>
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<tr>
<td>RV/TLC, %</td>
<td>28.8±1.20</td>
<td>22.6±1.48</td>
<td>-4.28 to -8.04</td>
<td>&lt;0.001</td>
<td>-22.4</td>
</tr>
</tbody>
</table>

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Clinical Investigations
findings, however subtle, would be unnoticed if only spirometry was performed or if lung volumes had been measured only by one technique. In none of the previous studies reviewed has the response to bronchodilators been evaluated in patients with idiopathic scoliosis by examining spirometry, plethysmography, and helium dilution together.\textsuperscript{1-5,16} Stanbrook et al\textsuperscript{20} reported that many adults referred for pulmonary function testing with normal spirometry, had gas trapping as measured by FRC\textsubscript{pleth} minus FRC\textsubscript{He}, RV/TLC ratio, or RV\%. These patients usually had nonspecific bronchial hyperreactivity with positive methacholine challenge tests. We did not perform any bronchoprovocation studies, but our data showing significant responses to bronchodilators are consistent with this suggestion.

The overall clinical significance of these findings is unknown. In the era of cost containment, it is important that physicians critically evaluate the use of expensive tests. This study shows that extensive pulmonary function tests reveal abnormalities in children with idiopathic scoliosis that were not suggested by either history or simple spirometry. Areas of trapped gas may increase the perioperative risk of atelectasis and pneumonia with subsequent ventilation/perfusion mismatching and impaired alveolar gas exchange. In view of the improvement in airway mechanics in response to bronchodilators, perhaps studies should be done to evaluate the role of bronchodilators in the perioperative management of idiopathic scoliosis to minimize postoperative respiratory complications and perhaps to shorten ICU stays and possibly the length of hospitalization.

In conclusion, restrictive defects remain the predominant pulmonary function abnormality in children with idiopathic scoliosis. Since lung volumes in scoliosis patients may be small, commonly used criteria for gas trapping and bronchospasm may not be fulfilled. Gas trapping may not be detected by spirometry alone or even measurement of lung volumes by only one technique. Lung volume measurement by both plethysmography and a gas dilution technique allow these abnormalities to be detected in children with idiopathic scoliosis.

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REFERENCES