Obstructive Lung Disease in Children with Idiopathic Scoliosis

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Objective To measure the prevalence of obstructive lung disease (OLD) among patients undergoing preoperative pulmonary assessment for idiopathic scoliosis.

Study design This was a retrospective, descriptive review from clinical data in a tertiary care pediatric hospital in the US. Patients (n = 176) with idiopathic scoliosis with Cobb angles of ≥40 degrees who performed acceptable and repeatable preoperative pulmonary function testing were included. The primary outcome measure was the forced expiratory volume in the first second (FEV_1)/forced vital capacity (FVC) ratio.

Results The prevalence of OLD (low FEV_1/FVC ratio) was 39% (68/176 patients). In multivariate modeling, radiographic measures were poor predictors of pulmonary function outcomes of FVC (r^2 0.06), FEV_1 (r^2 0.05), FEV_1/FVC ratio (r^2 0.08), and total lung capacity (r^2 0.06).

Conclusions OLD is common in patients with idiopathic scoliosis. We recommend preoperative pulmonary function testing for patients with idiopathic scoliosis under consideration for spinal fusion surgery. *(J Pediatr 2015;166:1018-21)*.

The prevalence of idiopathic scoliosis is estimated at 2%-3% in children.[1] Complications of idiopathic scoliosis include back pain, poor body image, and impaired pulmonary function. Adolescents with idiopathic scoliosis and Cobb angles of 25-45 degrees are routinely managed with close observation, sometimes in conjunction with bracing to prevent spine curve progression.[1] Adolescents with Cobb angles above 45-50 degrees are routinely managed with spinal fusion surgery.[1] Progressive idiopathic scoliosis of this severity, requiring spinal fusion surgery, is associated with pulmonary function impairment.[1]

Among children with progressive idiopathic scoliosis, restrictive lung disease (RLD, defined as low lung volume) is common. In this population, decreases in lung capacity are associated with increases in the scoliosis Cobb angle.[2] A 1995 study of 70 children with idiopathic scoliosis reported that 71% of patients had a forced vital capacity (FVC, defined as total air exhaled on spirometry) ≤80% predicted.[3] Zhang et al studied 298 patients with scoliosis and reported that 61% of patients had an FVC <80% predicted.[4] The low FVC values found in these studies were suggestive of, but not diagnostic for, RLD. The gold standard measure of RLD, a low total lung capacity (TLC) on body plethysmography, was found in 41% of patients with idiopathic scoliosis.[5]

Obstructive lung disease (OLD), or abnormal airway function, can be found in patients with asthma, cystic fibrosis, or anatomic lower airway compression. OLD is defined by American Thoracic Society (ATS)/European Respiratory Society (ERS) as a low forced expiratory volume in the first second (FEV_1)/FVC ratio for age, sex, race, and height.[6] The FEV_1/FVC ratio is the volume of air exhaled in the first second divided by the total volume exhaled during a maximal expiratory flow maneuver. A reduced FEV_1/FVC ratio reflects narrowing, constriction, or compression of intrathoracic airways. Few studies have published pulmonary function measures of OLD in idiopathic scoliosis.

At our institution, all children with idiopathic scoliosis routinely perform pulmonary function testing (PFT) before surgery with spirometry and lung volume testing. Children with abnormal testing are referred for preoperative assessment in the pulmonary clinic. Based on our clinical experience, we hypothesized that OLD was common in children with idiopathic scoliosis who were undergoing preoperative evaluation.

Methods

This study was approved by the local Institutional Review Board. We included preoperative patients with thoracic Cobb angles of ≥40 degrees as measured

ATS	American Thoracic Society
ERS	European Respiratory Society
FEV_1	Forced expiratory volume in the first second
FRC	Functional residual capacity
FVC	Forced vital capacity
OLD	Obstructive lung disease
PFT	Pulmonary function testing
RLD	Restrictive lung disease
TLC	Total lung capacity

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by the clinical radiologist in the years 2005-2009. We included only patients with idiopathic scoliosis. During the years 2005-2009, all patients with idiopathic scoliosis had routine preoperative PFT with spirometry and lung volume measurement. We included patients who performed acceptable and reproducible preoperative spirometry within 3 months of their preoperative scoliosis radiographs.[7,8] Exclusion criteria for this study included prior known causes of OLD.

The definition of acceptable and repeatable PFT for study inclusion were defined by ATS/ERS consensus criteria.[7] The reference equations of Wang et al were used to calculate the mean predicted values and 95% CIs (±2 SD from the mean) for spirometry testing.[9] The reference equations of Zapletal et al were used to calculate the mean predicted values and 95% CIs for static lung volume testing.[10] Static lung volumes were obtained by body plethysmography. Pulmonary function results were converted from absolute volumes to percentages of the mean predicted values as determined by reference equations based on age, sex, height, and race.[9,10] Height was determined by arm span.[11] OLD was defined as a FEV_1/FVC ratio below the 95% CI. RLD was defined as a TLC below the 95% CI.

One orthopedic surgeon measured all Cobb angles, kyphosis angles, and the number of thoracic vertebrae within the spinal curves for patients on full-length, standing, posteroanterior, and lateral radiographs of the spine.

Statistical Analyses

To explore differences within the idiopathic scoliosis group, comparisons were made by OLD (yes vs no), and by RLD (yes vs no). For continuous variables, 2-sample *t* tests were used. For categorical variables, a likelihood χ^2 or Fisher exact test was used. Pearson correlations were conducted between radiographic measures and anthropometric variables, and PFT variables.

Multiple linear regressions were conducted, regressing PFT variables (separately) on Cobb angle, kyphosis angle, and number of thoracic vertebrae in the spine curve (T-level count). Covariates were chosen based on the results from the study published by Newton et al.[2] Backwards elimination was performed, removing predictor variables (one at a time) where the *P* values for association were $P > .10$. The parameter (β) estimates (with SEs and *P* values) for the predictors in the final models are reported, along with the proportion (r^2) of variation explained by each model. Significance for all tests was set a priori at $\alpha < 0.05$. All analyses were conducted using SAS 9.2 software (SAS Institute, Cary, North Carolina).

Results

One hundred seventy-six patients with idiopathic scoliosis were included. Patient characteristics are shown in Table I. The study population was 86% female, reflecting the natural history of idiopathic scoliosis.

The study group had normal mean values for FVC, FEV_1, FEV_1/FVC ratio, and TLC (Table I). However, there was marked heterogeneity within the group. One hundred seventy-six patients completed spirometry testing; 34% (68/176) had OLD on spirometry, defined as FEV_1/FVC ratio below the 95% CI. Of the 68 patients with OLD, 52 had repeat spirometry testing after bronchodilator administration; 73% (38/52) continued to have an

Table I. Idiopathic scoliosis patient characteristics, overall, and by lung disease category

		OLD†		RLD‡	
Continuous variables, mean ± SD (n)	**All patients (176)**	**Yes (68)**	**No (108)**	**Yes (31)**	**No (144)**
Height (cm)	161.7 ± 8.8	162.2 ± 9.1	161.3 ± 8.7	161.0 ± 10.0	161.7 ± 8.5
BMI-for-age z-score	0.3 ± 1.1	0.1 ± 1.0	0.4 ± 1.2	−0.3 ± 1.0*	0.5 ± 1.1
Age at scoliosis onset	13.2 ± 2.1	13.1 ± 2.2	13.3 ± 2.1	12.7 ± 2.2	13.3 ± 2.1
Cobb angle (degrees)	55.2 ± 11.7	55.9 ± 12.9	54.7 ± 10.9	57.7 ± 10.9	54.5 ± 11.8
Kyphosis angle (deg.)	27.6 ± 14.4	28.2 ± 14.4	27.3 ± 14.4	21.9 ± 16.6*	28.8 ± 13.5
T-level count	8.0 ± 1.9	8.2 ± 2.0	7.9 ± 1.8	7.8 ± 1.5	8.0 ± 1.9
FVC% predicted	100.9 ± 15.8	100.6 ± 17.8	101.1 ± 14.5	83.0 ± 11.8*	104.9 ± 13.6
FEV_1% predicted	92.2 ± 16.1	84.0 ± 14.9*	97.4 ± 14.6	75.8 ± 12.5*	96.0 ± 14.2
FEV_1/FVC	81.1 ± 7.4	74.2 ± 4.1*	85.5 ± 5.5	81.1 ± 7.9	81.2 ± 7.3
FEF 25%-75%	77.4 ± 23.7 (176)	56.4 ± 14 (68)*	90.7 ± 18.4 (108)	64.4 ± 21.4 (31)*	80.6 ± 23.0 (144)
TLC% predicted	94.9 ± 13.5	94.8 ± 15.3	95.0 ± 12.3	76.6 ± 6.4*	98.9 ± 11.1
FRC% predicted	86.7 ± 17.2	89.7 ± 17.9	84.9 ± 16.6	72.3 ± 9.0*	89.8 ± 17.0
RV% predicted	77.0 ± 27.9	76.8 ± 27.1	77.1 ± 28.4	60.9 ± 27.6*	80.4 ± 26.8
Categorical variable, % (n)					
Males	14%	12%	15%	10%	14%
Caucasian	84%	84%	84%	94%	82%
African American	13%	13%	12%	6%	14%
Other	3%	3%	4%	0%	4%

BMI, body mass index; *RV*, residual volume.
T-level count is the number of thoracic vertebrae in the spine curve.
% predicted is the percent of the mean predicted value based on standard reference equations.[9,10]
*$P < .05$ using 2-sample *t* test or χ^2 test – "yes" vs "no" for each lung disease category.
†OLD was defined as a FEV_1/FVC below the 95% CI.
‡RLD was defined as a TLC below the 95% CI.