2015

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Background: The literature regarding pulmonary function in adult patients with spinal deformity is limited, and the effect of spinal deformity surgery on pulmonary function has not been clearly understood. We hypothesized that adult patients with spinal deformity who had preoperative pulmonary impairment (a percent-predicted value of <65% forced expiratory volume in one second [FEV1] as measured by pulmonary function test) or who were undergoing revision surgery may be at risk for exacerbated decline in pulmonary function.

Methods: Pulmonary function test results were prospectively collected for 164 adult patients with spinal deformity (mean age, 45.9 years) who underwent surgical treatment at a single institution and were followed for a minimum of two years (mean, 2.8 years). One hundred (61%) of the patients underwent primary surgery, and sixty-four (39%) of the patients had revision surgery. For the majority of patients (77%), a posterior-only surgical approach was used. Radiographs for 154 patients were analyzed for major thoracic and sagittal T5-T12 curve magnitude/correction.

Results: For all patients, we noted a significant change in major thoracic Cobb angle, from a mean of 47.4° to 24.9°(p < 0.001), and in sagittal Cobb angle, from a mean of 35.5° to 30.0°(p < 0.001), as well as a significant decline in absolute and percent-predicted pulmonary function values, with percent-predicted FEV1 and percent-predicted forced vital capacity (FVC) decreasing 5.3% (p < 0.001) and 5.7% (p < 0.001), respectively. A clinically significant decline (a decline of ≥10% in percent-predicted FEV1) was observed in 27% of the patients. The number of patients with pulmonary impairment increased nonsignificantly from seventeen (10%) preoperatively to twenty-three (14%) after surgery (p = 0.31). Patients with preoperative pulmonary impairment demonstrated a significant improvement in absolute and percent-predicted FEV1 after surgery compared with those without preoperative impairment (2.7% compared with −6.2%; p < 0.001). Patients who underwent revision surgery did not differ from primary surgery patients in terms of postoperative percent-predicted results. However, revision surgery more frequently resulted in a significant decline in pulmonary function (twenty-three patients [36%] compared with twenty-two [22%]; p = 0.05). There was no difference in pulmonary function when comparing surgical approaches (anterior/combined anterior-posterior or posterior-only) or when comparing results by upper-instrumented vertebra (UIV).

Conclusions: We found a significant decline in absolute and percent-predicted results of pulmonary function tests following surgical correction for spinal deformity in adults.

Level of Evidence: Therapeutic Level IV. See Instructions for Authors for a complete description of levels of evidence.

Peer Review: This article was reviewed by the Editor-in-Chief and one Deputy Editor, and it underwent blinded review by two or more outside experts. The Deputy Editor reviewed each revision of the article, and it underwent a final review by the Editor-in-Chief prior to publication. Final corrections and clarifications occurred during one or more exchanges between the author(s) and copyeditors.

Disclosure: None of the authors received payments or services, either directly or indirectly (i.e., via his or her institution), from a third party in support of any aspect of this work. One or more of the authors, or his or her institution, has had a financial relationship, in the thirty-six months prior to submission of this work, with an entity in the biomedical arena that could be perceived to influence or have the potential to influence what is written in this work. In addition, one or more of the authors has a patent or patents, planned, pending, or issued, that is broadly relevant to the work. No author has had any other relationships, or has engaged in any other activities, that could be perceived to influence or have the potential to influence what is written in this work. The complete **Disclosures of Potential Conflicts of Interest** submitted by authors are always provided with the online version of the article.

Despite the large body of literature regarding pulmonary function following surgery in young patients with adolescent idiopathic scoliosis, limited information is available regarding the effect on pulmonary function of spinal deformity surgery in adult patients. There is an inevitable natural decline in pulmonary function with aging, which may be more pronounced in patients with untreated spinal deformity[1-3]. Some adults with spinal deformity present with substantially reduced pulmonary function, and an important unanswered question is whether corrective/fusion surgery in patients with preoperative pulmonary impairment can improve pulmonary function[4], or, more importantly, if surgical treatment results in a substantial worsening in pulmonary status[5]. Preoperative counseling regarding the risks of surgical treatment is paramount, particularly given the substantial risk of perioperative medical and pulmonary complications that has been found after adult spinal deformity surgery[6]. Some surgeons postulate that surgery to optimize deformity correction may also prevent or reverse pulmonary function deterioration[4]. Others suggest the opposite, recommending against surgical correction as a means of improving pulmonary function[5].

The purpose of this study was to analyze the effect of spinal deformity surgery on pulmonary function in adults and to determine if preoperative pulmonary impairment or revision surgery may impact pulmonary function at midterm follow-up. We hypothesized that patients with preoperative pulmonary impairment (a percent-predicted value of <65% forced expiratory volume in one second [FEV1] as measured by pulmonary function test) and patients undergoing revision surgery may be at risk for exacerbated decline in pulmonary function.

Materials and Methods

Following institutional review board approval, we performed a prospective observational study, evaluating pulmonary function in adult patients with spinal deformity who were treated surgically by two surgeons at a single institution from 1996 to 2009. We obtained data on pulmonary function and radiographic changes at the preoperative and postoperative examination. Included in the study were patients eighteen years of age or older who were undergoing primary or revision surgery for spinal deformity; all patients were included, regardless of the total number of levels fused or the extent of fusion. Excluded were patients with a history of any respiratory comorbidities, such as asthma or acute or chronic upper-respiratory infection, or previous diagnosis of chronic pulmonary disease.

Radiographic Measurements

Standing anteroposterior and lateral radiographs of the spine on 91-cm long cassettes were made. Measurements of the major thoracic spinal curvature in the coronal plane as well as measurement of the thoracic spine in the sagittal plane, from the superior end plate of T5 to the inferior end plate of T12, were performed with use of the Cobb method[7]. Fusion levels were noted. All radiographic data were measured by two of us (R.A.L. and D.G.K.), independent of the surgical team.

Pulmonary Function Measurements

All patients had pulmonary function tests to evaluate pulmonary volume and flow preoperatively and at one year and two years. All pulmonary function tests were performed on the same computerized spirometer (6200 Autobox; SensorMedics, Yorba Linda, California) that had an accuracy of ± 3%, which met the criteria of the American Thoracic Society[8]. The tests were performed with the patient standing, each measurement was repeated three times, and the highest reading was selected. Pulmonary function test results were expressed both as absolute values and percent-predicted values with use of the arm span as representative of height, as a proxy for height loss caused by the scoliosis and the subsequent gain of trunk height from corrective surgery[9]. For analysis and comparison of pulmonary function, we chose forced vital capacity (FVC) and FEV1. These two parameters provide an adequate assessment of function in terms of volume and flow as measured by the pulmonary function tests[8]. FEV1 is a measurement both of volume and mean flow over the first second. Reduction in FEV1 reflects the total effects of reduction in total lung capacity, airway obstruction, loss of lung recoil, and weakness of respiratory muscles. Impairment in FEV1 was categorized as mild, moderate, or severe. Mild impairment was defined as 65% to 80% of the normal value, moderate impairment was 50% to 64% of the normal value, and severe impairment was <50% of normal. For the purposes of evaluation, patients were divided into two groups, those with preoperative pulmonary impairment (a percent-predicted FEV1 value of <65%), and those with no pulmonary impairment (a percent-predicted FEV1 value of ≥65%).

Statistical Analysis

Primary outcomes were the change in pulmonary function test values from before surgery to final follow-up between patient groups (pulmonary impairment compared with no impairment as well as primary compared with revision surgery). Secondary outcomes included a comparison of the change in pulmonary function test values and amount of curve correction, as well as the change in the number of patients with pulmonary impairment. Descriptive statistics were used to provide distributions of the variables as means, standard deviations, and ranges. Pearson correlations were used to assess the association among radiographic measurements and pulmonary function test results at the preoperative and final time points. Comparisons across the groups for measurements made at one time point were performed with use of analysis of variance (ANOVA). For continuous variables measured at two time points, two-sample t tests were used for assessment of the change over time within a group. We used the Fisher exact test or the chi square test for categorical variables (such as with or without pulmonary impairment). A p value of <0.05 was considered to be significant.

Source of Funding

There was no external funding source for this study.

Results

Demographic Data

Complete pulmonary function test data were available for analysis for 164 patients (150 female [91.5%] and fourteen male [8.5%]), with a mean age of 45.9 years (range, eighteen to seventy-three years) (Table I). All patients had a minimum duration of follow-up of two years (mean, 2.8 years; range, 1.9 to 11.9 years). There were 138 nonsmokers, twenty with a history of smoking (having smoked more three months prior to surgery), and six current or recent smokers (having smoked less than three months prior to surgery).

One hundred (61%) of the patients were undergoing primary surgery and sixty-four (39%), revision surgery. The indication for surgery was idiopathic scoliosis for 130 (79%) of the patients, de novo scoliosis for nineteen (12%) of the patients, and other indication (Scheuermann kyphosis, kyphoscoliosis, neuromuscular, traumatic, congenital, or genetic) for fifteen (9%) of the patients. For the majority (127 [77%]) of the patients, the surgical approach was posterior-only; however, in thirty-two (20%) of the patients, a combined anterior-posterior approach was used, and in five (3%), anterior-only. Osteotomies were performed in eighty-four patients (in thirty-seven patients, Smith-Petersen osteotomy alone; in seventeen patients,

TABLE I Patient Demographic Data

Parameter	Findings
Age *(yr)*	
Mean	45.9
Range	18-73
Follow-up *(yr)*	
Mean	2.8
Range	1.9-11.9
Sex*	
Male	14 (8.5%)
Female	150 (91.5%)
Type of surgery*	
Primary	100 (61%)
Revision	64 (39%)
Surgical approach*	
Posterior-only	127 (77%)
Combined anterior-posterior	32 (20%)
Anterior-only	5 (3%)
Smoking status*	
Nonsmoker	138 (84%)
Previous smoker	20 (12%)
Current smoker	6 (4%)
Diagnosis*	
Idiopathic scoliosis	130 (79%)
De novo scoliosis	19 (12%)
Genetic syndrome	4 (2.4%)
Kyphoscoliosis	3 (1.8%)
Trauma	3 (1.8%)
Scheuermann kyphosis	2 (1.2%)
Congenital	2 (1.2%)
Neuromuscular	1 (0.6%)
Osteotomies†	
Total	84
SPO alone	37
PSO alone	17
VCR alone	7
SPO + PSO	12
SPO + VCR	10
SPO + PSO + VCR	1

*Values are presented as the number of patients with the percentage in parentheses. †Values are presented as the number of patients. SPO = Smith-Petersen osteotomy, PSO = pedicle subtraction osteotomy, and VCR = vertebral column resection.

pedicle subtraction osteotomy alone; in seven patients, vertebral column resection alone; in twelve, Smith-Petersen osteotomy as well as pedicle subtraction osteotomy; in ten, Smith-Petersen osteotomy as well as vertical column resection; and in one, Smith-Petersen osteotomy as well as pedicle subtraction osteotomy and vertical column resection). The most common upper-instrumented vertebra (UIV) was T4 (forty-one [25%] of the patients), followed by T3 (38 [23%] of the patients), and T2 (37 [23%] of the patients). The most common lowest-instrumented vertebra (LIV) was the sacrum/pelvis (99 [60%] of the patients), followed by L3 (20 [12%] of the patients) (see Appendix).

Radiographic Results

Preoperative and postoperative radiographs were available for 154 patients. For all, there was a significant change in major thoracic Cobb angle from a mean of 47.4° to 24.9° (mean change, −22.5°; 47% correction; $p < 0.001$), and in sagittal Cobb angle from a mean of 35.5° to 30.0° (mean change, −5.5°; 15% correction; $p < 0.001$).

Pulmonary Function Test Results

For all patients, there was a significant decline in all measures of pulmonary function. Absolute FEV1 and FVC values decreased an average of 0.15 L and 0.17 L, respectively ($p < 0.001$). Percent-predicted values declined significantly as well: FEV1 by 5.3% ($p < 0.001$) and FVC by 5.7% ($p < 0.001$). A clinically significant decline (a decline of ≥10% in percent-predicted FEV1) was observed in 27%. We noted an increase in the number of patients with pulmonary impairment, from seventeen (10%) preoperatively to twenty-three (14%) after surgery, but this was not significant ($p = 0.31$). A subgroup analysis of patients with idiopathic scoliosis demonstrated similar results, with an overall significant decline in absolute and percent-predicted values of pulmonary function (−0.15 L and −5.1% for FEV1 and −0.18 L and −5.6% for FVC; $p < 0.001$), a clinically significant decline in pulmonary function in thirty-four (26%) of the patients, and an increase in the number of patients with pulmonary impairment, from thirteen (10%) to seventeen (13%).

There was a significant, strongly positive correlation between preoperative and two-year percent-predicted values: $r = 0.749$, $p < 0.001$ for FEV1, and $r = 0.752$, $p < 0.001$ for FVC. We also found a significant, moderately negative correlation between the amount of change in percent-predicted values and the preoperative percent-predicted values: $r = -0.482$, $p < 0.001$ for FEV1, and $r = -0.494$, $p < 0.001$ for FVC. There was a significant, positive correlation between the amount of change in percent-predicted values and the two-year percent-predicted values: $r = 0.220$, $p = 0.005$ for FEV1, and $r = 0.202$, $p = 0.010$ for FVC. We found no significant correlation between the amount of change in percent-predicted values and patient age at surgery, number of lumbar levels fused, number of thoracic levels fused, number of anterior levels fused, or total number of levels fused.

We found a significant positive correlation between the amount of major curve correction and both the percent-predicted FEV1 ($r = 0.230$, $p = 0.004$) and the percent-predicted FVC ($r = 0.216$, $p = 0.007$). There was a negative correlation detected between the preoperative Cobb angle of the major curve and both the preoperative percent-predicted FEV1 ($r = -0.277$, $p = 0.001$) and the preoperative percent-predicted FVC ($r = -0.257$, $p = 0.001$). We also found a significant negative correlation between the postoperative Cobb angle of the major curve and both the two-year percent-predicted FEV1 ($r = -0.237$, $p = 0.003$) and

TABLE II Comparison of Radiographic and Pulmonary Function Measurements in Patients with or without Preoperative Impairment

	Preoperative Impairment	No Preoperative Impairment	P Value
No. of patients	17	147	
Radiographic measure*			
Preop. major thoracic curve *(deg)*	56.4	46.5	0.31
Postop. major thoracic curve *(deg)*	34.1	23.9	0.17
Change in major thoracic curve *(deg)*	−22.3	−22.6	0.97
Preop. sagittal curve *(deg)*	37.1	35.3	0.82
Postop. sagittal curve *(deg)*	23.6	30.7	0.10
Change in sagittal curve *(deg)*	−13.5	−4.6	0.07
Pulmonary function measure			
Preop. percent-predicted FEV1*	54.2%	94.1%	<0.001†
Postop. percent-predicted FEV1*	56.9%	87.9%	<0.001†
Change in percent-predicted FEV1*	2.7%	−6.2%	<0.001†
Clinically significant decline in pulmonary function *(no. of patients [%])*	0	45 (31%)	<0.001†
Change in no. of patients with impairment postop. *(no. of patients [%])*	−5 (−29%)	+11 (7.5%)	<0.001†

*Values are presented as the mean. FEV1 = forced expiratory volume in one second. †A significant difference.

the two-year percent-predicted FVC (r = −0.235, p = 0.003). A significant negative correlation was found between the number of instrumented thoracic vertebrae and the two-year percent-predicted FEV1 (r = −0.210, p = 0.007) and the two-year percent-predicted FVC (r = −0.256, p = 0.001).

Preoperative Pulmonary Impairment Versus No Impairment

Patients with preoperative pulmonary impairment had a significant improvement in absolute and percent-predicted FEV1 after surgery compared with those without preoperative impairment (2.7% compared with −6.2%; p < 0.001), with no significant differences in major thoracic or sagittal curve correction between the two groups (major thoracic, −22.3° compared with −22.6°; p = 0.97; sagittal, −13.5° compared with −4.6°; p = 0.07) (Table II). A subgroup analysis of patients with idiopathic scoliosis demonstrated similar results; patients with preoperative pulmonary impairment compared with no impairment had a significant improvement in absolute and percent-predicted FEV1 after

TABLE III Comparison of Patient Radiographic and Pulmonary Function Measurements by Revision or Primary Surgery

	Revision Surgery	Primary Surgery	P Value
No. of patients (%)	64 (39%)	100 (61%)	
Radiographic measure*			
Preop. major thoracic curve *(deg)*	44.2	49.5	0.13
Postop. major thoracic curve *(deg)*	32.9	19.7	<0.001†
Change in major thoracic curve *(deg)*	−11.3	−29.8	<0.001†
Preop. sagittal curve *(deg)*	36.0	35.1	0.81
Postop. sagittal curve *(deg)*	29.5	30.4	0.69
Change in sagittal curve *(deg)*	−6.5	−4.7	0.53
Pulmonary function measure			
Preop. percent-predicted FEV1*	91.6%	88.9%	0.46
Postop. percent-predicted FEV1*	82.3%	86.3%	0.17
Change in percent-predicted FEV1*	−9.3%	−2.6%	0.01†
Clinically significant decline in pulmonary function *(no. of patients [%])*	23 (36%)	22 (22%)	0.05†
Change in no. of patients with impairment postop. *(no. of patients [%])*	+3 (4.7%)	+3 (3%)	0.37

*Values are presented as the mean. FEV1 = forced expiratory volume in one second. †A significant difference.

TABLE IV Comparison of Radiographic and Pulmonary Function Measurements by Anterior/Combined or Posterior-Only Surgical Approach

	Anterior/Combined	Posterior-Only	P Value
No. of patients	37	127	
Mean age at surgery *(yr)*	46.1	45.8	0.92
Mean duration of follow-up *(yr)*	3.3	2.7	0.08
Radiographic measure*			
No. of thoracic levels fused	5.1	7.9	0.02†
No. of lumbar levels fused	5.3	4.5	<0.001†
No. of anterior levels fused	3.8	0	<0.001†
Total no. of levels fused	10.4	12.4	0.01†
Preop. major thoracic curve *(deg)*	42.2	49.1	0.07
Postop. major thoracic curve *(deg)*	27.1	24.2	0.39
Change in major thoracic curve *(deg)*	−15.1	−24.9	<0.001†
Preop. sagittal curve *(deg)*	25.7	38.6	<0.001†
Postop. sagittal curve *(deg)*	31.9	29.4	0.38
Change in sagittal curve *(deg)*	6.2	−9.2	<0.001†
Pulmonary function measure			
Preop. percent-predicted FEV1*	90.1%	89.9%	0.95
Postop. percent-predicted FEV1*	84.9%	84.7%	0.96
Change in percent-predicted FEV1*	−5.2%	−5.2%	0.98
Clinically significant decline in pulmonary function *(no. of patients [%])*	11 (29.7%)	34 (26.8%)	0.83
Preop. pulmonary impairment *(no. of patients [%])*	3 (8.1%)	14 (11.0%)	0.77
Postop. pulmonary impairment *(no. of patients [%])*	6 (16.2%)	17 (13.4%)	0.79

*Values are presented as the mean. FEV1 = forced expiratory volume in one second. †A significant difference.

surgery (4.6% compared with −6.3%; $p < 0.001$), with no significant differences found in terms of radiographic parameters (see Appendix).

Analysis of Primary Compared with Revision Surgery

Patients who underwent revision surgery compared with those who underwent primary surgery had no difference in postoperative percent-predicted pulmonary function. However, there were significantly more revision patients with a clinically significant decline in pulmonary function (twenty-three [36%] compared with twenty-two [22%]; $p = 0.05$) (Table III).

Analysis of Surgical Approach

There were thirty-seven patients whose surgery involved an anterior or combined anterior-posterior approach. For six (16%) of these patients, a thoracotomy for anterior thoracic exposure was used, and for the remainder, anterior lumbar exposure was achieved through either a transabdominal or retroperitoneal approach. For 127 patients, a posterior-only approach was used. None of the thoracotomy patients had preoperative or postoperative pulmonary impairment, although three had a clinically significant decline in pulmonary function. Two posterior-only procedures included thoracoplasty; however, neither of the two patients had preoperative or postoperative pulmonary impairment, although both had a clinically significant decline in pulmonary function. While there were some significant differences between the anterior/combined and posterior-only groups in terms of radiographic parameters, preoperative and postoperative pulmonary function results did not differ significantly between the two groups, and no significant differences were noted in terms of the number of patients with preoperative or postoperative pulmonary impairment or a clinically significant decline in pulmonary function (29.7% compared with 26.8%; $p = 0.83$) (Table IV).

Discussion

To our knowledge, ours is the largest study to date to evaluate the results of pulmonary function tests following surgery among adult patients with spinal deformity (164 patients) with a minimum duration of follow-up of two years. Our results demonstrated significant decline in all measures of pulmonary function (5% to 6% decline compared with predicted age-related decline) following deformity surgery with a clinically significant decline (a decline of ≥10% in percent-predicted FEV1) in pulmonary function in 27% of the patients. However, patients with preoperative pulmonary impairment (percent-predicted FEV1 of <65%) had an overall 2.7% improvement in pulmonary function, which was significantly different from the decline in pulmonary function for all other patients (−6.2%). While the clinical significance of a small improvement in pulmonary function is unknown, our results suggest that patients with preoperative pulmonary impairment may benefit clinically from deformity correction surgery by preventing further decline. We also found that revision surgery more frequently resulted in a clinically significant decline in pulmonary function (36% of patients compared with 22% of patients who underwent primary surgery); however, surgical approach and UIV did not significantly affect pulmonary function test results.

Numerous studies have investigated the topic of long-term pulmonary function in young patients (less than eighteen years of age) who undergo surgery for adolescent idiopathic scoliosis[9-19]. Scoliosis is a three-dimensional distortion of the spine and chest cage, which typically produces a reduction in pulmonary function. This reduction may be a result of chest-cage stiffness, reduced hemidiaphragmatic movement, and uneven distribution of inhaled air in the lung (decreased on the convex side of the curve)[12,20]. Therefore, some surgeons have postulated that surgical correction for adolescent idiopathic scoliosis can improve not only the structural deformity, but may affect long-term pulmonary function[21]. However, even for this extensively studied group of patients with adolescent idiopathic scoliosis, there continues to be controversy regarding the effect of surgical correction on long-term pulmonary function; some investigators have reported substantial improvements in measured pulmonary function[9,22-25], while others have demonstrated no difference[19,26,27] or even loss of pulmonary function at long-term follow-up[17,26-29].

There is a substantial gap in knowledge regarding the impact of surgery for deformity correction on long-term pulmonary function in adult patients. Study of this population is more difficult than it is for the adolescent idiopathic scoliosis population because pulmonary reserves peak, in terms of age, in the mid-twenties and decline with increasing age[4,10,30-36]. Adult patients with deformity compared with patients with adolescent idiopathic scoliosis may also be affected by medical comorbidities and smoking histories, which may exacerbate the general age-related decrease in pulmonary function[37]. In a study of twenty-one patients with a mean age of forty-seven years, Menon and Aggarwal found decreased lung volume, hypoxemia, arterial oxygen desaturation, and decreased exercise capacity in patients with kyphoscoliosis[38]. The authors found no correlation between pulmonary function test results and the degree of kyphoscoliosis, although the small study was likely underpowered[38].

Medical complications, particularly pulmonary-related problems, are a major consideration following spinal deformity surgery in adults, although few studies have identified the true incidence[6]. Additionally, many patients undergoing surgery for spinal deformity have coexisting medical conditions that may predispose them to postoperative complications. An overall complication rate for adult patients undergoing spinal deformity surgery ranges from 40% to 86%[6,39,40]. Given that one of the leading causes of death among persons over sixty-five years of age in the U.S. is pneumonia[41], the clinical importance of small diminutions of pulmonary reserves following deformity surgery in adults remains unknown. Pulmonary complications are a serious source of morbidity; in one study, 64% of patients had radiographic abnormalities on postoperative chest radiographs, and those with abnormalities had a longer mean length of hospital stay[42].

Zhang et al. also noted that the incidence of postoperative pulmonary complications was eighteen times greater for adult patients with spinal deformity who underwent transthoracic procedures compared with posterior-only approaches[43]. Despite this high rate of early postoperative pulmonary complications, there have been limited reports to date evaluating long-term pulmonary function in this patient population[1,4,5]. Pehrsson et al. evaluated twenty-four patients with surgically untreated severe idiopathic scoliosis, who ranged in age between fifteen and sixty-seven years, and found over a twenty-year period that pulmonary function decreased by the same magnitude as predicted decline due to age[1]. The authors also found that long-term respiratory failure was more likely in patients with vital capacity below 45% predicted and with coronal deformity of >110°[1]. Pehrsson et al., in 1992, evaluated 107 adult patients with deformity who had home ventilator or long-term oxygen therapy requirements and, again, found similar risk factors for respiratory failure, namely a Cobb angle of >100° and vital capacity <50% of predicted[44]. These authors found no operatively treated patients with respiratory failure and suggested that corrective surgery may prevent development of respiratory failure[44]. Wong et al. evaluated fourteen adult patients with deformity whose treatment included a thoracotomy and anterior arthrodesis, with five patients also having a posterior arthrodesis[5]. The authors found a reduction in FVC at midterm follow-up (mean follow-up of thirty-two months) and recommended against surgical intervention with anterior spinal fusion surgery to improve pulmonary function[5].

The method used in our study of categorizing the severity of lung function impairment based on percent-predicted FEV1 is similar to that of several previous studies, including GOLD (Global Initiative for Chronic Obstructive Lung Disease)[45] and the American Thoracic Society guidelines[8]. The number of categories and the exact cutoff points are arbitrary. In general, the ability to work and function in daily life is related to pulmonary function, and pulmonary function is a measure used to rate impairment in several published systems[8]. Pulmonary function level is also associated with morbidity, and patients with lower function have more respiratory complaints. Lung function level is also associated with prognosis, including a fatal outcome from heart as well as lung disease, even in patients who have never smoked[5,46,47]. In the Framingham study, vital capacity level was a major independent predictor of cardiovascular morbidity and mortality[46]. In several occupational cohorts, FEV1 and FEV1/FVC values were independent predictors of all-cause or respiratory disease mortality[48,49]. In addition, a meta-analysis of mortality in six surveys in various U.K. working populations showed that the risk of dying from COPD (chronic obstructive pulmonary disease) was related to FEV1 level. Compared with those whose FEV1 level at an initial examination was within 1 standard deviation (SD) of average, those whose FEV1 level was >2 SD below average were twelve times more likely to die of COPD, more than ten times as likely to die of non-neoplastic respiratory disease, and more than twice as likely to die of vascular disease over a twenty-year follow-up period[49]. Although there is good evidence that FEV1 level correlates with the severity of symptoms and prognosis in many circumstances[49,50], the correlations do not allow one to accurately predict symptoms or prognosis for individual patients.

A limitation of our study was the use of a heterogeneous population who underwent different types of procedures. Also, the collection of prospective observational data and subgroup analysis of post-hoc cohorts may have increased the chance of bias. Also, we performed statistical analysis of various cohort subgroups, and some may have had an inadequate sample size to make definitive conclusions; a greater number of patients in each subgroup would have strengthened our findings. The strengths of our study include an overall large number of patients evaluated and treated by the same two surgeons at a single institution. Most importantly, our study is, to our knowledge, the first to evaluate the effect of modern surgical procedures on pulmonary function among adults with spinal deformity.

In conclusion, our study evaluating the results of pulmonary function tests among adult patients with spinal deformity found a significant decline in absolute and percent-predicted results at two years following surgical correction. Patients with preoperative pulmonary impairment had improvement in absolute and percent-predicted pulmonary function postoperatively. Revision surgery more frequently resulted in a clinically significant decline in pulmonary function, although surgical approach and UIV did not significantly affect pulmonary function.

Appendix

eA A table presenting a subgroup comparison of radiographic and pulmonary function measurements in patients with idiopathic scoliosis with or without preoperative pulmonary impairment and a table presenting data regarding osteotomies performed in relation to upper-instrumented vertebra (UIV) are available with the online version of this article as a data supplement at jbjs.org. ■

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