Pulmonary function in adolescent idiopathic scoliosis: a 25 year follow up after surgery or start of brace treatment

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Abstract

***Background*—Pulmonary function in patients with adolescent idiopathic scoliosis many years after posterior spinal surgery or brace treatment has not been documented.**

***Methods*—A consecutive group of patients treated by posterior fusion or a brace at least 20 years previously was investigated. 90% attended a clinical follow up. Lung volumes were determined before treatment in 251 patients, 1.4 years after surgery in 141 patients, and 25 years after surgery or start of brace treatment in 110 patients. Vital capacity (VC) was calculated as percentage predicted according to height and age and the results were corrected for loss of height due to scoliosis. Scoliosis angles were measured and smoking habits were recorded. An age and sex matched control group was also examined with the same questionnaire and pulmonary function tests.**

***Results*—VC increased from 67% predicted immediately before surgery to 73% (p<0.001) after surgery and to 84% (p<0.001) at the present follow up, mean change 10.8% (95% CI 9.5 to 12.1). In the brace treated patients VC increased from 77% predicted before treatment to 89% (p<0.001) 25 years after start of treatment, mean change 12.3% (95% CI 10.5 to 14.1). The mean Cobb angle at the present follow up study was 40° in both surgically and brace treated patients. The present results of lung volumes did not correlate with pretreatment or post-treatment Cobb angles or smoking habits.**

***Conclusions*—Patients treated by posterior fusion or a brace gradually increase their pulmonary function up to 25 years after treatment. Smoking and curve size are not risk factors for reduced pulmonary function.**

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Keywords: adolescent idiopathic scoliosis; pulmonary function; long term outcome

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It has been shown that patients with untreated scoliosis have an increased risk of developing respiratory failure and dying prematurely,[1 2] but in more recent studies in patients with adolescent onset of idiopathic scoliosis we were unable to show increased mortality.[3] However, respiratory failure was seen in untreated patients with idiopathic scoliosis who had a large scoliotic angle and low vital capacity, especially if the onset of their scoliosis was at a younger age.[4] Posterior spinal surgery with Harrington instrumentation and fusion has been used in Sweden since 1965. Earlier studies showed an increase in lung volume 3 years after posterior spinal surgery.[5] A meta-analysis[6] confirmed these results and suggested that the lung function improves some years after posterior spinal surgery with Harrington instrumentation. On the other hand, anterior spinal surgery necessitating thoracotomy or thoracoscopy resulted in a fall in lung volumes after 32 months.[7] Recently, Vedantam *et al*[8] reported lower pulmonary function after scoliosis surgery by the anterior transthoracic approach than by the posterior approach.

However, the impact of surgery or brace treatment on long term pulmonary function has not been reported. An evaluation many years after intervention is needed as the procedures could possibly result in increased stiffness of the thoracic cage. After brace treatment, in particular, the scoliotic angle might increase with time and cause a reduction in pulmonary function.

The Göteborg scoliosis data bank contains information about all patients treated for scoliosis since the 1960s. This gives a unique opportunity for long term studies. We have studied the long term development of lung volumes and respiratory symptoms during at least 20 years in patients with adolescent idiopathic scoliosis treated by posterior fusion with Harrington instrumentation or a brace. To evaluate the outcome of respiratory symptoms an age and sex matched control group was also examined. In addition, we have determined whether smoking habits and scoliosis angle are risk factors for decreased pulmonary function.

Methods

PATIENTS

All patients from the Göteborg scoliosis data bank were included who fulfilled all the following criteria: (1) adolescent idiopathic scoliosis (onset of scoliosis 10–16 years according to Scoliosis Research Society[9]); (2) treatment either with surgery or brace; (3) treatment started between 1968 and 1976; (4) treatment completed before the age of 21 years; (5) present follow up performed at least 20 years after completion of treatment.

These inclusion criteria were fulfilled by 283 consecutive patients, 156 of whom had been treated with surgery and 127 with a brace; 91% of those treated with surgery and 87% of those treated with a brace were re-investigated (table 1).

TREATMENT

Patients with scoliotic curves with thoracic involvement—that is, thoracic, thoracolumbar, and double major curves—with Cobb angles of less than 50° were treated with a brace during this time period using a Milwaukee brace (until 1974) or a Boston brace (after 1974) until skeletal maturity.[10 11] Patients with Cobb angles of more than 45° were treated surgically with posterior fusion and Harrington instrumentation[12] followed by a postoperative brace for 6—12 months. Patients with lumbar curves were treated with a brace if the curve was less than 60° and with surgery if more than 60°.[13 14]

STUDY PROTOCOL

The 141 patients who were treated surgically were investigated immediately before the operation, at completion of the treatment 1–2 years after surgery, and at the present follow up at least 20 years after surgery. The 110 patients treated with a brace were investigated before and at least 20 years after start of treatment. Pulmonary function and scoliosis curves were analysed. In addition, information on respiratory symptoms and smoking habits was obtained by questionnaire.

CONTROL GROUP

Three hundred subjects without scoliosis randomly selected from the Swedish postal registry were invited by letter to participate in the study as controls. Of these, the first 100 to reply were included in the study; 90 were women and the mean (SD) age was 39.9 (2.9) years (range 35–45). They were all living in and around Göteborg in both urban and rural settings, similar to the patients included in the study. They were examined using the same protocol as the patients in the present follow up and did not differ from the treatment groups in age or sex.

SPINAL CURVE

The spinal curve angle was measured by the same orthopaedic surgeon (AD) according to Cobb[15] on anterior-posterior radiographs. Data were analysed with special regard to curve types according to the SRS spinal classification nomenclature.[16] In patients with double primary curves the angle of the upper curve was used in the analyses. A detailed analysis of the spinal curve data is presented elsewhere.[17]

PULMONARY FUNCTION

Total lung capacity (TLC) was determined with a body plethysmograph in the present follow up study but by the helium dilution technique in the measurements before start of surgery or brace treatment and 1.4 years after surgery. Forced expiratory volume in one second (FEV_1) and quasi-static vital capacity (VC) were measured with a rolling seal spirometer (Sensormedics) in the present investigation and by a water sealed spirometer (Bernstein) in previous investigations. The equipment was regularly calibrated.

Patients were investigated in the sitting position. Normal values for measurements at all time points were predicted for age, height, and sex according to Berglund *et al*[18 19] and were corrected for loss of height due to scoliosis according to Lindh and Bjure.[5] The results are given in BTPS.

RESPIRATORY SYMPTOMS AND SMOKING HABITS

A translation of a British MRC questionnaire[20] containing questions about dyspnoea, wheezing, and smoking habits was used which has been used in previous studies of patients with scoliosis.[4] Dyspnoea severity was graded from 1 to 5 where grade 3 = breathlessness when walking with someone else of similar age on level ground. Smokers and ex-smokers were analysed as one group of smokers in comparison with never smokers.

STATISTICAL METHODS

Distribution of variables are given as means, standard deviations (SD), and ranges. For changes in pulmonary function over time 95% confidence intervals are given. Fisher's non-parametric permutation test[21] was used for comparison between groups and Fisher's exact test was used for comparison between proportions. Changes over time within groups were analysed using Fisher's non-parametric permutation test for matched pairs.[21] Pitman's non-parametric permutation test was used for all correlation analyses.[21] In addition, Pearson's correlation coefficient (r) was calculated for descriptive purposes. All significance tests were two tailed and conducted at the 1% significance level because of multiple analyses.

The study was approved by the human research ethical committee of Göteborg University.

Results

Investigations were performed a mean of 1.4 years after completion of surgical treatment and the present follow up study was a mean of 25 years after surgery or start of brace treatment (table 1). As expected, the brace

Table 1 Age, sex, and scoliosis curves of 251 patients with adolescent idiopathic scoliosis

	Surgically treated (n=141)	*Brace treated (n=110)*
Age at start of treatment (years)	15.0 (1.8), (11.4–19.3)	14.3 (1.4), (10.9–18.4)
Age at completed surgical treatment or completed brace treatment	16.4 (1.8), (12.9–20.9)	17.1 (1.2), (14.0–20.9)
Age at present follow up	39.6 (2.4), (33.9–45.8)	39.3 (2.3), (34.4–45.4)
Sex, female, n (%)	131 (93%)	106 (96%)
Cobb angle at start of treatment (°)	62 (13), (38–122)	33 (10), (12–60)
Cobb angle at completed surgical treatment (°)	33 (9), (12–65)	
Cobb angle at present follow up (°)	37 (10), (14–66)	38 (15), (5–71)
Thoracic scoliosis, n (%)	96 (68%)	48 (43%)
Double primary scoliosis, n (%)	33 (23%)	40 (37%)

Values are mean (SD), range.

Table 2 VC (l) and VC (% predicted) in patients with adolescent idiopathic scoliosis before treatment, after surgery, and at present follow up in patients treated with surgery or brace treatment

	Surgically treated (n=141)		Brace treated (n=110)	
	VC (l)	VC (% predicted)[1]	VC (l)	VC (% predicted)[1]
Before treatment	3.1 (0.7) (0.8–6.1)	67 (13) (23–104)	3.4 (0.6) (2.1–4.7)	77 (10) (52–106)
1.4 years after surgery	3.5 (0.7) (1.5–7.0)	73 (11) (44–108)		
Present follow up	3.6 (0.7) (1.5–7.1)	84 (13) (47–123)	3.8 (0.7) (2.4–5.8)	89 (13) (56–127)
Change from before to after surgery	0.4*** (0.4) (−0.8–1.6)	6*** (8) (−28–34)		
Change from after surgery to present follow up	0.1*** (0.3) (−1.5–0.7)	11*** (8) (−26–31)		
Change from before treatment to present follow up	0.5*** (0.5) (−1.6–1.8)	17*** (11) (−29–48)	0.4*** (0.4) (−0.7–1.5)	12*** (10) (−14–36)

VC = vital capacity.
Values are means (SD), (range).
[1]VC % predicted means value corrected for age and for loss of height due to scoliosis.
***p<0.001.

Table 3 FEV_1 (l) and FEV_1 (% predicted) in patients with adolescent idiopathic scoliosis before treatment, after surgery, and at present follow up in patients treated with surgery or brace treatment

	Surgically treated (n=141)		Brace treated (n=110)	
	FEV_1 (l)	FEV_1 (% predicted)[1]	FEV_1 (l)	FEV_1 (% predicted)[1]
Before treatment	2.6 (0.6) (0.7–5.1)	71 (14) (24–124)	2.9 (0.5) (1.7–4.1)	84 (12) (55–109)
1.4 years after surgery	3.0 (0.6) (1.4–5.6)	78 (12) (47–112)		
Present follow up	2.9 (0.5) (1.3–4.7)	84 (14) (52–122)	3.1 (0.5) (1.0–4.4)	91 (16) (32–135)
Change from before to after surgery	0.4*** (0.4) (−1.3–1.5)	7*** (10) (−50–36)		
Change from after surgery to present follow up	−0.1** (0.3) (−1.1–0.7)	6*** (9) (−24–30)		
Change from before treatment to present follow up	0.3*** (0.5) (−1.5–1.5)	13*** (13) (−53–51)	0.1** (0.4) (−1.5–1.3)	7*** (12) (−46–42)

FEV_1 = forced expiratory volume in one second.
Values are mean (SD), (range).
[1]FEV_1 % predicted mean values corrected for age and for loss of height due to scoliosis.
***p<0.001.
**p<0.01.

treated patients had less severe scoliosis than the surgically treated patients from the start of treatment.

CURVE SIZE

In the surgically treated patients the mean Cobb angle before surgery was 62° and 1.4 years after surgery it was reduced to 33° (table 1). At the present follow up it was 37°. In the brace treated patients the mean Cobb angle before treatment was started was 33° and at the present follow up it was 38°.

At the present follow up 11 patients with curves with thoracic involvement (three surgically treated and eight brace treated) had a Cobb angle above 60° and the mean VC was 83% predicted (range 56–101%). The most pronounced curve was seen in a brace treated patient with a scoliotic angle of 71°. VC in this patient was 87% predicted.

PULMONARY FUNCTION

In surgically treated patients percentage predicted VC and FEV_1 increased significantly from the follow up 1.4 years after surgery to the present follow up study (tables 2 and 3). The mean change in VC during that period was 10.8% predicted (95% CI 9.5 to 12.1) and at the present follow up the mean VC was 84% predicted. The mean change in FEV_1 from the follow up 1.4 years after surgery to the present follow up was 6.5% predicted (95% CI 5.0 to 7.9). For the 15 surgically treated patients who dropped out the mean (SD) VC was 3.3 (0.6) l before treatment compared with 3.1 (0.7) l in the follow up group. TLC increased significantly from 1.4 years after surgery to the present follow up (table 4). Mean (SD) TLC at the present follow up was 89 (11)% predicted in the surgically treated patients and 106 (11)% in the control group. Patients with thoracic involvement had similar VC to that of the total group of surgically treated patients (table 5). Two patients with lumbar curves were treated with surgery; their VC at the present follow up was 95% and 99% predicted, respectively.

In brace treated patients the percentage predicted VC and FEV_1 increased during the 25 year follow up period (tables 2 and 3). The change in VC was 12.3% predicted (95% CI 10.5 to 14.1) and in FEV_1 was 7.1% predicted (95% CI 4.8 to 9.4). Mean VC was 89% predicted at the present follow up. For the 17 brace treated patients who dropped out the mean (SD) VC was 3.3 (0.6) l before treatment

Table 4 TLC in patients with adolescent idiopathic scoliosis, treated with surgery or brace treatment. Values before treatment, after surgery, and at present follow up

	Surgically treated (n=138) TLC (l)	Brace treated (n=108) TLC (l)
Before treatment	3.9 (0.8) (2.3–7.5)	4.4 (0.8) (2.6–6.5)
1.4 years after surgery	4.4 (0.8) (2.9–8.7)	
Present follow up	5.0 (0.9) (3.2–9.4)	5.1 (0.9) (3.3–7.4)
Change from before to after surgery	0.5*** (0.5) (−0.8–1.8)	
Change from after surgery to present follow up	0.6*** (0.4) (−0.3–1.7)	
Change from before treatment to present follow up	1.1*** (0.6) (−0.4–3.4)	0.8*** (0.5) (−0.7–2.1)

Values are means (SD), (range).
***p<0.001.

Table 5 VC (% predicted) in 139 surgically treated patients with curves with thoracic involvment before surgery, 1.4 years after surgery, and at the present follow up 25 years after surgery

	Double primary (n=33)	*Thoracic (n=96)*	*Thoracolumbar (n=10)*	*All patients (n=139)*
Before surgery	65 (15) (41–104)	66 (12) (23–102)	76 (14) (51–94)	67 (13)
1.4 years after surgery	71 (13) (55–108)	73 (10) (44–105)	80 (10) (64–93)	73 (11)
Present follow up	83 (11) (64–108)	82 (12) (47–114)	100 (15) (74–123)	84 (13)
Change from before surgery to after surgery	5.7*** (5.3) (−5.8–19.6)	6.4*** (8.4) (−28.3–34.2)	3.8 (7.8) (−7.9–19.8)	6.0*** (7.7) (−28.3–34.2)
Change from after surgery to present follow up	11.9*** (6.9) (−4.5–26.4)	9.2*** (7.5) (−25.8–28.9)	19.5 (6.4) (8.2–31.0)	10.8*** (7.8) (−25.8–31.0)
Change from before surgery to present follow up	17.6*** (8.3) (−4.5–39.8)	15.7*** (11.6) (−29.4–48.1)	21.7 (5.6) (14.2–29.0)	16.7*** (10.6) (−29.4–48.1)

Values are mean (SD), (range).
***p<0.001.

compared with 3.4 (0.6) l in the follow up group. TLC increased (table 4) and, at the present follow up, the mean TLC was 93 (12)% predicted. Percentage predicted VC and FEV_1 were significantly lower at the present follow up in the surgically treated group than in the brace treated group (p<0.001) and the control group (p<0.001). The change in percentage predicted VC from before treatment to the present follow up was significantly higher in surgically treated patients than in brace treated patients (p<0.001). The mean VC in the control group was 103 (11)% predicted and mean FEV_1 was 104 (13)% predicted.

RESPIRATORY SYMPTOMS AND SMOKING HABITS

The dyspnoea score was above grade 3 in three surgically treated patients, one brace treated patient, and three from the control group. There was no significant difference in the dyspnoea score at the present follow up between patients with scoliosis and controls, nor in wheezing which occurred in 33% of surgically treated patients, 30% of brace treated patients, and 23% of the control group.

There was no statistical difference between scoliosis patients and controls in smoking habit at the present follow up study (55% of surgically treated patients, 56% of brace treated patients, and 46% of the control group were never smokers). The mean (SD) number of pack-years among the current smokers and ex-smokers was 11.6 (7.3) for surgically treated patients, 8.3 (5.6) for brace treated patients, and 11.0 (7.3) for the control group.

CORRELATIONS BETWEEN PULMONARY FUNCTION, CURVE DEGREES, AND SYMPTOMS

Before surgery there was a correlation (p<0.001) between scoliosis angle and both percentage predicted VC (r = –0.31) and FEV_1 (r = –0.30). In the present study there were no significant correlations between VC and FEV_1 and scoliosis angles before any treatment, after surgery, nor with the difference between the scoliosis angles before and after surgery.

The present percentage predicted FEV_1 and VC in surgically treated and brace treated smokers were not significantly different from never smokers. There was no significant difference between smokers and never smokers in the reporting of wheeze in either surgically treated or brace treated patients at the present follow up.

COBB ANGLES AND SMOKING HABITS IN PATIENTS WITH SEVERELY IMPAIRED VC

At the present follow up 59 surgically treated patients (42%) had VC <80 % predicted and 11 of these (8%) had VC <70% predicted (95% CI for the proportions 34 to 50 and 4 to 14, respectively). The 11 patients with VC <70% predicted had a mean Cobb angle before surgery of 59° (range 43–78°), a mean Cobb angle after completed surgery of 31° (range 19–47°), and a mean Cobb angle at the present follow up of 35° (range 18–52°). Their mean VC was 57% predicted (range 23–76%) before surgery and 61% predicted (range 44–73%) 1.4 years after surgery. Four of the 11 (36%) with VC <70% were smokers compared with 46% in the patients with VC >70% predicted (NS). The minimum VC was 47% predicted. This patient suffered an accident in 1991 with severe paraparesis. In other patients there were other co-existing explanations for the reduction in VC—for example, radiation treatment for breast cancer or encephalitis in childhood.

At the present follow up 23 brace treated patients (21%) had VC <80% predicted and seven (6%) had VC <70% predicted (95% CI for the proportions 14 to 30 and 3 to 13, respectively). The seven patients with VC <70% had a mean Cobb angle of 33° (range 23–48°) before brace treatment and 30° (range 5–53°) at the present follow up. Four of the seven were smokers. The minimum VC was 56% predicted which occurred in a patient with a common cold during the present measurements and with a feeling of strong discomfort regarding the brace treatment.

Discussion

This study shows that pulmonary function has increased in patients with adolescent idiopathic scoliosis 25 years after posterior spinal surgery or after start of brace treatment when compared with measurements before intervention. For surgically treated patients the pulmonary function also improved from completion of surgical treatment 1.4 years after the operation to the present follow up after 25 years. As surgery and brace treatment were initiated during the growth period at 15 years of age, the calculation of normal values for the pulmonary function is an important issue to take into consideration. We used formulae for predicting normal values for VC and FEV_1 from the age of 7–70 years.[18] We also generally presented VC or FEV_1 as percentage predicted.

Before surgery the patients showed a severity of disease that was equal to earlier published series with a mean Cobb angle of 62° and a VC of 67% predicted.[5 6 22] Compared with earlier published studies, this study includes more patients followed for a considerably longer time and, in fact, the number of patients is similar to the number in a meta-analysis of five studies described by Kinnear.[6] This study also confirms previous findings of an improvement in ventilatory function at completion of surgical treatment after 1–3 years.[6]

We have followed patients for more than 20 years and, surprisingly, there was a further increase in VC compared with both the values before surgery and those after completion of treatment. We do not think that survival bias in the study influenced the results as the drop out rate was only 10% and the initial VC values in those who dropped out did not differ from the those in the patients followed for 25 years. Theoretically, the improvement in VC could be due to improved methodology of spirometric measurements. However, all the measurements were performed in the same clinical physiological laboratory with well standardised methods and specialised staff using established calibration procedures. Other explanations for the increase in VC might be related to growth of the lungs or the function of the thoracic cage. As the growth in the number of alveoli is complete by the age of 8 years,[23] it is unlikely that the reduced VC before intervention was due to reduced lung tissue. It is more likely that the development of adolescent scoliosis after the age of 10 decreases the VC because of the restricted movement or stiffness of the thoracic cage. It is possible that the operation, as well as the rod, might influence the chest cage and ventilation during and at least 1.4 years after the start of treatment in these growing adolescent patients. Our data also show that there was a further improvement in lung function after completion of surgery which might be due to a continuing improvement in the function of the thoracic cage. In other studies in which patients were followed for about 3 years after surgery the improvement in VC tended to be larger than after 1.4 years in our study.[5 22 24] Our data suggest that after treatment, even more than 20 years after surgical or brace treatment, the thoracic cage gradually takes up a better position to promote an increase in lung volume compared with studies only a few years after surgery.

The surgical method used appears to influence pulmonary function. Wong[7] reported decreased ventilatory capacity 32 months after anterior spinal surgery in a group of 14 patients. Recently, Vedantam[8] reported differences in the pulmonary function after spinal fusion surgery related to different surgical approaches. Patients who had no disruption of the rib cage experienced a significantly greater improvement in pulmonary function 2 years after surgery than patients in whom the rib cage was disrupted. Our patients who had posterior fusion and no rib cage disruption had increased pulmonary function after spinal surgery even up to 25 years later.

To our knowledge there has been no previous study of pulmonary function many years after bracing. With long term brace treatment there is a reduction in lung volumes, probably due to external compression of the chest wall.[25] However, brace treatment for 2 years did not reduce lung volumes.[26] In our patients we did not perform any short term follow up. In brace treated patients VC increased from before onset of bracing until 25 years after treatment in spite of a somewhat increasing scoliosis angle compared with values at the start of treatment. The scoliosis curve 25 years after the start of brace treatment was about the same size as in the surgically treated group who initially had a considerably larger scoliosis curve.

We have analysed pulmonary function in the total group of patients with adolescent idiopathic scoliosis and have also analysed separately those with thoracic involvement (thoracic, double primary, and thoracolumbar curves) to see if these patients have an increased risk of reduced pulmonary function. Our results showed that patients with thoracolumbar curves had normal VC at the present follow up (table 5). Patients with lumbar curves were very few and did not influence the results of the total group.

Risk factors for reduced pulmonary function in our surgically or brace treated patients were evaluated. Smoking habits did not influence FEV_1; this may be because our follow up study was performed in patients of about 40 years of age which is probably too early to show a negative smoking effect on FEV_1. The present Cobb angles did not correlate with pulmonary function (neither VC nor FEV_1), probably because of the small sizes of the curves.

Should regular lung function measurements be recommended in patients with adolescent idiopathic scoliosis after surgery or brace treatment? Our patients at the age of 40 had a mean VC of 85% predicted which is fairly good. In an earlier follow up study of non-treated adult patients with idiopathic scoliosis we found a reduction in VC related to ageing and therefore recommended lung function follow up measurements only in at risk patients.[4] However, in this study we have not been able to identify any such risk factors and the current data do not give any basis for recommendations concerning regular follow up measurement of pulmonary function. Advice to stop smoking is very important in all young women, and especially in patients with reduced pulmonary function caused by conditions such as scoliosis.

We conclude from this long term follow up study in patients with adolescent idiopathic scoliosis, treated by posterior spinal surgery or a brace, that pulmonary function improved with both orthopaedic methods in most patients up to 25 years after treatment.

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