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ORIGINAL ARTICLE

Risk factors for postoperative pulmonary complications in the treatment of non-degenerative scoliosis by posterior instrumentation and fusion

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Abstract

Purpose The aim of this study was to evaluate the prevalence and risk factors for postoperative pulmonary complications (PPC) after posterior instrumentation and fusion (PIF) in patients with non-degenerative scoliosis.

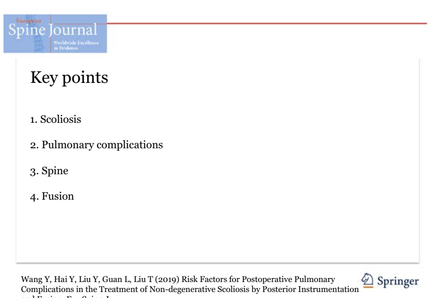
Methods We retrospectively evaluated 703 patients (224 males, 479 females) diagnosed with non-degenerative scoliosis who underwent PIF in our center from January 2010 to January 2018. Preoperative, perioperative, demographic data, surgical methods and radiographic parameters were extracted and analyzed to identify risk factors for PPC.

Results The mean age of the patients was 20.8 ± 9.0 years with the following diagnoses: congenital scoliosis (287/703, 40.8%), idiopathic scoliosis (281/703, 40.0%), neuromuscular scoliosis (103/703, 14.7%) and syndromic scoliosis (32/703, 4.5%). PPC manifested in 82 patients (11.7%) including pleural effusion (39/82, 47.6%), pneumonia (33/82, 40.2%), pneumothorax (3/82, 3.7%), respiratory failure (3/82, 3.7%), hemothorax (2/82, 2.4%), pulmonary edema (1/82, 1.2%) and pulmonary embolism (1/82, 1.2%). Multifactorial regression analysis confirmed that revision surgery [odds ratio (OR) = 2.320, $P = 0.030$], preoperative respiratory disease (OR = 14.286, $P < 0.001$), preoperative Cobb angle of main curve > 75° (OR = 1.701, $P = 0.046$) and thoracoplasty (OR = 4.098 $P < 0.001$) were risk factors for PPC after PIF in patients with non-degenerative scoliosis.

Conclusions A prevalence of 11.7% PPC was observed after PIF. Risk factors were preoperative Cobb angle of main curve > 75°, preoperative respiratory disease, revision surgery and thoracoplasty. Surgeons should recognize and pay attention to these risk factors and take appropriate preventive measures to prevent severe pulmonary complications.

Graphical abstract

These slides can be retrieved under Electronic Supplementary Material.



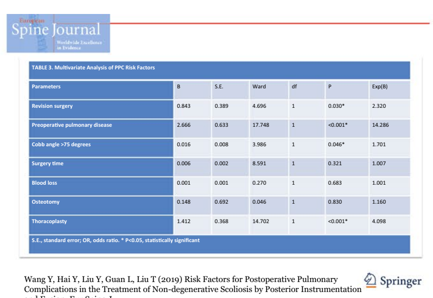
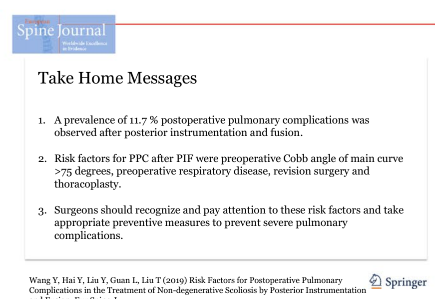


TABLE 3. Multivariate Analysis of PPC Risk Factors

Parameters	B	S.E.	Ward	df	P	Exp(B)
Revision surgery	0.843	0.389	4.696	1	0.030*	2.320
Preoperative pulmonary disease	2.666	0.633	17.748	1	<0.001*	14.286
Cobb angle >75 degrees	0.016	0.008	3.986	1	0.046*	1.701
Surgery time	0.006	0.002	8.591	1	0.321	1.007
Blood loss	0.001	0.001	0.270	1	0.683	1.001
Osteotomy	0.148	0.692	0.046	1	0.830	1.160
Thoracoplasty	1.412	0.368	14.702	1	<0.001*	4.098

S.E., standard error; OR, odds ratio. * P<0.05, statistically significant



Keywords Scoliosis · Pulmonary complications · Spine · Fusion

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Extended author information available on the last page of the article

Introduction

Postoperative pulmonary complications (PPC), including pneumonia, respiratory failure, pulmonary embolism, pleural effusion and other pulmonary diseases, are the most common non-neurological complications following posterior instrumentation and fusion (PIF) for scoliosis. The incidence of PPC after PIF for scoliosis is 0.7–18.2% [1–9]. In addition, in particular types of scoliosis, the incidence of PPC could be as high as 26.3–50.0% [10–12]. Moreover, some studies have reported that in 41.9–46.2% of patients undergoing PIF, PPC can lead to death [3, 4]. Consequently, PPC is an important factor that affects the outcome and prognosis of patients with scoliosis.

Non-degenerative scoliosis is the most common type of spinal deformity including congenital scoliosis, idiopathic scoliosis, neuromuscular scoliosis and syndromic scoliosis. For patients with scoliosis, especially for those with idiopathic scoliosis, nonoperative treatment is usually recommended. Yet, if this treatment approach fails and the major coronal curve reaches 50° or more, operation should be considered. The treatment of choice for these patients is PIF. Several studies have shown that age, Cobb angle, preoperative pulmonary function, anesthesia time, blood loss, thoracoplasty and revision surgery were associated with PPC after PIF [1, 2, 6, 13, 14]. Nevertheless, the risk factors for PPC still remain unknown. In this study, we have identified the risk factors for PPC in patients with non-degenerative scoliosis after PIF. We believe that our data could help spine surgeons to guide perioperative management and surgical planning, thus reducing the probability of PPC after PIF.

Materials and methods

Patient cohort

A retrospective consecutive case review was performed to identify patients diagnosed with non-degenerative scoliosis who had undergone PIF between January 2010 and January 2018 in our center. The major inclusion criteria were patients diagnosed with non-degenerative scoliosis including congenital scoliosis, idiopathic scoliosis, neuromuscular scoliosis and syndromic scoliosis. The type of surgery was PIF. All preoperative radiographs, pulmonary functional tests and intraoperative data were available. Patients diagnosed with kyphosis or degenerative scoliosis were excluded from the study. In addition, patients who had undergone anterior instrumentation or non-fusion surgery or with incomplete or insufficient data were excluded. The institutional review board of our center approved this study.

Clinical data

Clinical demographic data including age, gender, body mass index (BMI), smoking, preoperative respiratory disease, revision surgery and diagnosis (congenital, idiopathic, neuromuscular or syndromic) were assessed. Total lung capacity (TLC), forced vital capacity (FVC), forced expiratory volume in one second (FEV1) and FEV1/FVC % were selected as parameters for preoperative pulmonary function. Surgical, anesthesia and intubation times, blood loss, number of fusion vertebrae, location of screw, osteotomy and thoracoplasty were selected as surgical parameters.

Radiographic parameters

Anterior–posterior (A–P) and lateral total spine radiographs before surgery were assessed, and radiographic parameters were measured using the Picture Archiving Communication System (PACS). We defined maximum kyphosis in the sagittal plane based on the location of the apical vertebra in T5–T11, T12–L1 and L2–L5 as thoracic kyphosis, thoracolumbar kyphosis and lumbar kyphosis. We have collected Cobb angle and location of the main curve, and angle and location of maximum kyphosis.

Statistical analysis

SPSS Statistics Version 25.0 (IBM, Armonk, New York) was used for all statistical analyses. Descriptive statistics are represented as mean and standard deviation. Paired or independent Student t test was used to analyze continuous data. The Chi-square test was used to analyze enumeration data. The power calculation, which was used to calculate the minimum sample size, was 0.9. Factors with P value <0.05 were considered statistically significant and included as potential risk factors in binary logistic regression analysis to determine significant independent risk factors for PPC.

Results

General information and clinical data

We retrospectively evaluated 703 patients (224 males, 479 females) in this study. They were selected based on our inclusion and exclusion criteria. The mean age at surgery was 20.8 ± 8.95 years (ranging from 10 to 43 years). There were 287 patients with congenital scoliosis (40.8%), 281 with idiopathic scoliosis (40.0%), 103 with neuromuscular scoliosis (14.7%) and 32 with syndromic scoliosis (4.5%). Eighty-two patients (11.7%) experienced PPC and included 39 with pleural effusion (47.6%), 33 with pneumonia

(40.2%), three with pneumothorax (3.7%), three with respiratory failure (3.7%), two with hemothorax (2.4%), one with pulmonary edema (1.2%) and one with pulmonary embolism (1.2%).

The preoperative Cobb angle of the main curve was 79.3° ± 26.39°, and the maximum kyphosis angle was 60.0° ± 33.80°. The pulmonary function was evaluated using total lung capacity (TLC), forced vital capacity (FVC), forced expiratory volume in one second (FEV1) and FEV1/FVC. The surgical parameters included operation time, anesthesia time, intubation time, blood loss, number of fusion vertebrae, location of screw, osteotomy and thoracoplasty. Results of all the parameters are shown in Table 1.

Univariate analysis

Patients were divided into two groups based on whether PPC was encountered: PPC group (82) and non-PPC group (621). Likewise, parameters were divided into four categories: patient-related, radiographic, pulmonary and surgery-related parameters. Significant differences (P value < 0.05) between the two groups were found for the following parameters: revision surgery ($P = 0.011$), preoperative pulmonary disease ($P < 0.001$), preoperative Cobb angle of the main curve ($P < 0.001$), surgery time ($P = 0.042$), blood loss ($P = 0.031$), osteotomy ($P = 0.046$) and thoracoplasty ($P < 0.001$). Results of the univariate analysis are shown in Table 2.

Multivariate analysis

The parameters with P value < 0.05 in the univariate analysis were selected for multivariate analysis. The results of binary logistic regression showed that revision surgery (OR = 2.320, $P = 0.030$), preoperative pulmonary disease (OR = 14.286, $P < 0.001$), preoperative Cobb angle of main curve > 75° (OR = 1.701, $P = 0.046$) and thoracoplasty (OR = 4.098, $P < 0.001$) were risk factors for PPC. The results of multivariate analysis are shown in Table 3. The cutoff value (preoperative Cobb angle of main curve = 75°) was determined using the receiver operating characteristic (ROC) curve.

Table 1 General information and clinical data

Parameter	Data
Age (years)	20.8 ± 8.95
Gender (male/female)	224/479
Diagnosis (congenital/idiopathic/neuromuscular/syndromic)	287/281/103/32
Body mass index (BMI)	19.3 ± 2.84
Smoking (smoking/none)	78/625
Revision surgery (revision/none)	82/621
Preoperative respiratory disease (respiratory disease/none)	24/679
Postoperative pulmonary complications (complications/none)	82/621
Preoperative Cobb angle of main curve (°)	79.3 ± 26.39
Location of main curve (thoracic/thoracolumbar/lumbar)	507/119/77
Preoperative maximum kyphosis angle (°)	60.0 ± 33.80
Location of maximum kyphosis (thoracic/thoracolumbar/lumbar)	568/107/28
TLC (L)	3.41 ± 1.09
FVC (L)	2.50 ± 0.86
FEV1 (L)	2.12 ± 0.73
FEV1/FVC (%)	84.73 ± 6.53
Operation time (min)	246.9 ± 72.07
Anesthesia time (min)	292.6 ± 76.96
Intubation time (min)	319.4 ± 94.28
Blood loss (ml)	895.9 ± 715.60
No. of fusion vertebrae	11.7 ± 2.81
Upper thoracic (T1–T4) screw placement (placement/none)	468/235
Middle thoracic (T5–T8) screw placement (placement/none)	565/138
Lower thoracic (T9–T12) screw placement (placement/none)	619/84
Lumbar (L1–L5) screw placement (placement/none)	650/53
Osteotomy (osteotomy/none)	257/446
Thoracoplasty (thoracoplasty/none)	293/410

TLC total lung capacity; *FVC* forced vital capacity; *FEV1* forced expiratory volume in one second

Table 2 Univariate analysis of PPC risk factors

Parameters	PPC group	Non-PPC group	P
Patient-related parameters			
Age (years)	23.2 ± 8.72	20.5 ± 8.94	0.066
Gender (male/female)	25/57	199/422	0.095
Diagnosis (congenital/idiopathic/neuromuscular/syndromic)	40/24/13/5	247/257/90/27	0.055
Body mass index (BMI)	18.9 ± 2.50	19.3 ± 2.88	0.180
Smoking (smoking/none)	12/70	66/555	0.278
Revision surgery (revision/none)	17/65	65/556	0.011*
Preoperative respiratory disease (respiratory disease/none)	16/66	8/613	< 0.001*
Radiographic parameters			
Preoperative Cobb angle of main curve (°)	100.7 ± 23.20	76.5 ± 25.49	< 0.001*
Location of main curve (thoracic/thoracolumbar/lumbar)	64/14/4	443/105/73	0.052
Preoperative maximum kyphosis angle (°)	62.9 ± 39.06	59.6 ± 31.92	0.275
Location of maximum kyphosis (thoracic/thoracolumbar/lumbar)	66/15/1	502/92/27	0.174
Pulmonary parameters			
TLC (L)	3.29 ± 0.97	3.43 ± 1.10	0.063
FVC (L)	2.35 ± 0.78	2.52 ± 0.86	0.053
FEV1 (L)	2.09 ± 0.68	2.12 ± 0.73	0.147
FEV1/FVC (%)	83.07 ± 7.16	84.95 ± 6.42	0.080
Surgery-related parameters			
Surgery time (min)	272.6 ± 81.78	243.5 ± 67.43	0.042*
Anesthesia time (min)	315.3 ± 85.31	289.6 ± 71.75	0.051
Intubation time (min)	329.3 ± 92.56	318.1 ± 97.83	0.073
Blood loss (ml)	998.2 ± 808.54	882.4 ± 675.12	0.031*
No. of fusion vertebrae	11.8 ± 2.25	11.7 ± 2.86	0.210
Upper thoracic (T1–T4) screw placement (placement/none)	59/23	409/212	0.095
Middle thoracic (T5–T8) screw placement (placement/none)	64/18	501/120	0.155
Lower thoracic (T9–T12) screw placement (placement/none)	73/9	546/75	0.773
Lumbar (L1–L5) screw placement (placement/none)	74/8	576/45	0.419
Osteotomy (osteotomy/none)	38/44	213/408	0.046*
Thoracoplasty (thoracoplasty/none)	62/20	231/390	< 0.001*

BMI body mass index; *TLC* total lung capacity; *FVC* forced vital capacity; *FEV1* forced expiratory volume in one second

*$P < 0.05$, statistically significant difference between the two groups

Table 3 Multivariate analysis of PPC risk factors

Parameters	B	SE	Ward	*df*	*P*	Exp(*B*)
Revision surgery	0.843	0.389	4.696	1	0.030*	2.320
Preoperative pulmonary disease	2.666	0.633	17.748	1	< 0.001*	14.286
Cobb angle > 75°	0.016	0.008	3.986	1	0.046*	1.701
Surgery time	0.006	0.002	8.591	1	0.321	1.007
Blood loss	0.001	0.001	0.270	1	0.683	1.001
Osteotomy	0.148	0.692	0.046	1	0.830	1.160
Thoracoplasty	1.412	0.368	14.702	1	< 0.001*	4.098

SE standard error; *OR* odds ratio

*$P < 0.05$, statistically significant

Discussion

Postoperative pulmonary complications are severe perioperative complications that may appear in patients with non-degenerative scoliosis following PIF and may lead to death [3, 4]. Several studies have demonstrated that age, Cobb angle, preoperative pulmonary function, surgery time, anesthesia time, blood transfusion, thoracoplasty and revision surgery are all associated with PPC. However, risk factors that play a major role in PPC are still unknown [1, 2, 6, 13, 14]. In this study, the prevalence of PPC was 11.7%. The main risk factors were preoperative Cobb angle of main curve > 75°, preoperative respiratory disease, revision surgery and thoracoplasty.

Previous studies have suggested that increased Cobb angle was associated with impaired pulmonary function due to increased airway blockage [15, 16]. Seo et al. [6] demonstrated that larger Cobb angle leads to a higher risk of postoperative non-neurological complications, particularly pulmonary complications for adults and juvenile scoliosis patients. Our retrospective study confirmed that preoperative Cobb angle greater than 75° was a risk factor for PPC. The increased Cobb angle causes abnormal chest and lung development and results in poor pulmonary function reserve. According to Jun et al. [17], even though the height of the chest and lungs increased, and the symmetry of the lungs improved after PIF, no significant changes to lung volume were observed in the short term. Hence, pulmonary function was still compromised after surgery and was a potential risk factor for PPC.

Our data indicated that thoracoplasty was another risk factor for PPC. Greggi et al. [2] showed that thoracoplasty was a risk factor for PPC in patients with adolescent idiopathic scoliosis, while Liang et al. [1] and Lao et al. [7] suggested that thoracoplasty could increase the risk of PPC in patients with impaired pulmonary function. Vedantam et al. [13] and Shi et al. [18] found that thoracoplasty significantly damages the structure of the thorax and reduces lung function in patients after surgery. However, pulmonary function could be restored to preoperative levels 2 years after surgery. In addition, Gitelman et al. [19] demonstrated that the long-term effects of chest wall injury after thoracoplasty on pulmonary function might persist for 10 years. Based on our study, we suggest that thoracoplasty should not be performed with PIF in patients with multiple risk factors for PPC. If improvement to razorback deformity is required, surgery should be performed after full pulmonary function recovery.

Our retrospective analysis also confirmed that preoperative respiratory disease is one of the risk factors for PPC. Lao et al. [7] and Toll et al. [20] found a significant impairment of pulmonary function in patients with severe restrictive ventilation dysfunction. Furthermore, Liang and his team [1] discovered that preoperative symptomatic respiratory system dysfunction was a risk factor for PPC. In this study, 24 patients with preoperative respiratory disease were selected. Twenty patients had moderate or severe restrictive ventilation dysfunction, three patients had respiratory failure and one had pulmonary hypertension. Patients with obvious reduction of pulmonary function and poor pulmonary function reserve had poor tolerance to general anesthesia. Han et al. [21] have reported a successful surgery for a neuromuscular scoliosis patient by pulmonary rehabilitation with forced vital capacity below 30; a home ventilator was used for pulmonary rehabilitation during follow-up. Their data suggested that pulmonary function could be improved before operation, using a variety of ways in order to increase the safety of the operation, lower the risk of PPC and improve pulmonary function.

In addition, our study also demonstrated that revision surgery was a risk factor for PPC. Ramos et al. [8] suggested that revision surgery was a risk factor for PPC for patients with adolescent idiopathic scoliosis. In this study, the prevalence of PPC in patients who underwent revision surgery was 20.7%. Previous studies have reported that it takes 1–2 years for recovery of pulmonary function to preoperative levels after PIF [14, 18]. We think that patients undergoing revision surgery may have impaired pulmonary function before surgery, which explains the potential risk for PPC.

Previous studies had shown that surgery time, anesthesia time, blood loss and screw placement were associated with PPC [6, 22]. However, in our study, these factors did not play a significant role in PPC. For PPC, the incidence of pleural effusion is higher and has been associated with age, congenital scoliosis, osteotomy and thoracoplasty [23]. Our study demonstrated that thoracoplasty had an effect on pleural effusion. Of the 82 patients with PPC, only one patient died of pulmonary embolism while the other patients had satisfactory prognosis without sequela after specific treatment.

Although we found various risk factors for PPC, this study has some limitations. First, our study was a retrospective single-center study. Second, the causal nature of these risk factors is not clear. However, we do believe that our study has contributed to identifying various risk factors associated with PPC. Future multicenter studies with larger cohorts should be performed to identify different risk factors to guide surgeons in selecting treatment strategies. Jain et al. [24] have indicated that PPC could increase the cost of scoliosis surgery, which is a challenge to risk stratification and resources allocation of modern medicine and surgery for spine surgeons. Our data may provide additional guidance for the perioperative planning of scoliosis surgery and may reduce the risk of PPC.

In summary, risk factors for PPC after PIF in patients with non-degenerative scoliosis were preoperative Cobb angle greater than 75°, preoperative respiratory disease, revision surgery and thoracoplasty. Spinal surgeons should be aware of these risk factors and provide perioperative management for patients with such risk factors in order to reduce the incidence of PPC.

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Compliance with ethical standards

Conflict of interest All the authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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