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A predictive scoring system for pulmonary complications after posterior instrumentation and fusion for non-degenerative scoliosis

Yunsheng Wang, Yong Hai*, Yuzeng Liu, Li Guan, Tie Liu

Department of Orthopedic Surgery, Beijing Chao-Yang Hospital, Capital Medical University, GongTiNanLu 8#, Chaoyang District, Beijing, China

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ABSTRACT

Objectives: The aim of this study was to identify perioperative risk factors of pulmonary complications (PC) after posterior instrumentation and fusion (PIF) for non-degenerative scoliosis and devise a predictive scoring system that could be used by spine surgeons to predict the level of risk requiring advanced measures.

Patients and methods: A retrospective review was performed of 703 patients who underwent PIF at our center between January 2010 and January 2018. Preoperative, peri-operative, demographic data, surgical methods, and radiographic parameters were extracted to identify the predictors of PC, and a predictive scoring system was created using multiple logistic regression and receiver operator characteristic (ROC).

Results: There were statistically significant differences in revision surgery, preoperative pulmonary disease, Cobb angle and thoracoplasty between the patients who suffered from PC as compared to those who did not. The predictive scoring system included four dimensions. The area under the ROC curve for the system was 0.82 for PC after PIF at the optimal cut-off point, and the sensitivity was 79.2%, which demonstrated good diagnostic accuracy.

Conclusion: We identified a significant relationship between perioperative parameters (revision surgery, preoperative pulmonary disease, Cobb angle and thoracoplasty) and PC after PIF for non-degenerative scoliosis and created a predictive scoring system that can be used to prepare measures to manage PC after PIF. The system was proven to be reliable in this study.

1. Introduction

Posterior instrumentation and fusion (PIF) is a major undertaking for both patients and surgeons. Postoperative complication rates can be high, and pulmonary complications (PC) are the most common non-neurological complications after PIF, which were reported to be the main cause of death after PIF. The incidence of PC after PIF is 0.7–18.2% [1–4]. The proportion of postoperative deaths due to PC was reported to be 41.9–46.2% [3,4]. Therefore, PC is an important factor affecting the outcome of patients with scoliosis.

Age, Cobb angle, preoperative pulmonary function, operative time, anesthesia time, blood loss, thoracoplasty and revision surgery are known to be associated with PC after PIF [1,2,5–7]. However, there is no predictive system to help clinicians to predict the prevalence of PC, thereby helping them to prepare and prevent it in advance. Some studies reported a scoring system for pediatric scoliosis to predict the need of pediatric intensive care unit or high-dependency unit after surgery [8]. However, it is necessary to conduct a study to identify risk factors of PC after PIF and establish a predictive scoring system to guide peri-operative management and surgical planning. The aim of this study was to determine the possibility of using preoperative variables to predict the PC and establish a predictive scoring system to manage patients with non-degenerative scoliosis post-operation.

2. Patients and method

A retrospective consecutive case review was conducted of 703 patients with non-degenerative scoliosis who had undergone PIF between January 2010 and January 2018 at our center. The main inclusion criteria were patients diagnosed with non-degenerative scoliosis, including congenital scoliosis, idiopathic scoliosis, neuromuscular scoliosis and syndromic scoliosis. The surgery was PIF and all the preoperative radiographs, pulmonary function tests and intra-operative data were available. Patients diagnosed with kyphosis or degenerative scoliosis were excluded. Patients who had undergone anterior instrumentation or non-fusion surgery or with incomplete peri-operative data were also excluded. Pulmonary complications with symptoms and confirmed by imaging and laboratory tests were included in our study.

* Corresponding author.
E-mail address: spinesurgeoncy@163.com (Y. Hai).

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All the complications were abstracted and assessed by respiratory physicians. The study was approved by the institutional review board of our center.

Clinical demographic data including age, gender, body mass index (BMI), smoking, preoperative pulmonary disease, revision surgery and diagnosis (congenital, idiopathic, neuromuscular, or syndromic) were evaluated. In this study, total lung capacity (TLC), forced vital capacity (FVC), forced expiratory volume in one second (FEV1) and FEV1/FVC% were chosen as pulmonary function parameters. Operation time, anesthesia time, intubation time, blood loss, number of fusion vertebrae, location of screw, osteotomy and thoracoplasty were selected as operation parameters to be evaluated. The Cobb angle of main curve, location of main curve, angle of maximum kyphosis and location of maximum kyphosis were used as radiographic parameters.

The software package SPSS Statistics Version 25.0 (IBM, Armonk, New York) was used for statistical analyses and the predictive scoring system was established by R software (version 3.3.5). Descriptive statistics were listed as mean and standard deviation. Paired or independent Student's *t*-test was used to analyze continuous data, while the $\chi 2$ test was used to analyze enumeration data. P-values < 0.05 were considered to be statistically significant and included as potential risk factors in binary logistic regression analysis to determine significant independent risk factors for PC. A scoring system was derived from nomogram of final model using "rms" R package. And "validate function" in "rms" R package was used to test the predictive scoring system. Using the predictive scoring system, ROC curve was drawn to calculate the optimum cut-off scores for PC after PIF.

3. Results

A total of 703 patients were identified for inclusion in the study. Of these, 479 were female and 224 were male. The median age for female patients was 20.8 ± 8.95 years (range 10–43 years). There were 287 congenital scoliosis, 281 idiopathic scoliosis, 103 neuromuscular scoliosis and 32 syndromic scoliosis patients. A total of 82 patients (11.7%) suffered from PC 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%).

Patients were divided into two groups according to the presence or absence of PC. There was a statistically significant difference in revision surgery ($p = 0.011$), preoperative pulmonary disease ($p < 0.001$), preoperative Cobb angle of main curve ($p < 0.001$), operation time ($p = 0.042$), blood loss ($p = 0.031$), osteotomy ($p = 0.046$) and thoracoplasty ($p < 0.001$) between the two groups (Table 1). These parameters were included into the multivariate analysis. The results of binary logistic regression showed that revision surgery (odds ratio [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 of PC after PIF. The cut-off value (preoperative Cobb angle of main curve = 75°) was determined using the ROC curve. Hence, these four parameters were selected as predictors for PC (Table 2).

We established the predictive scoring system using R software (Table 3). The area under the ROC (AUC) for the system was 0.82 (95% confidence interval: 0.77–0.87) for prediction of PC after PIF (Fig. 1). The sensitivity of the system was 79.3% and the specificity was 73.4% (Fig. 1). We also calculated the risk grade based on the system using R software (Table 4). If the total score according to the system is ≤10, the risk rate of PC after PIF will be < 10%, which is low grade of PC. Similarly, if total score is 11–15, the corresponding risk rate of PC will be 18–49%, which we considered to be medium grade. And if the score is > 15, the risk grade is high, with the risk rate > 49%. The result of nomogram is shown in Figs. 2 and 3.

4. Discussion

Pulmonary complications (PC) are severe peri-operative complications after the posterior instrumentation and fusion (PIF) for patients with non-degenerative scoliosis, which were reported to result in high mortality. [3,4] Several studies have reported that age, Cobb angle, preoperative pulmonary function, operative time, anesthesia time, blood transfusion, thoracoplasty and revision surgery were associated with PC [1,2,5–7]. This study found that the risk factors of PC after PIF were preoperative Cobb angle of main curve > 75°, preoperative pulmonary disease, revision surgery and thoracoplasty. These four risk factors were chosen as predictors for PC.

In this study, preoperative pulmonary disease was found to be a risk factor of PC with high odds ratio (OR = 14.286). In the predictive scoring system, the weight of preoperative pulmonary disease was the largest of all risk factors. That means preoperative pulmonary disease plays an important role in occurrence of PC. According to the nomogram of the system and the weight of preoperative pulmonary disease, we defined its score as 10 and that was the baseline of all the predictors. Some studies had proven that scoliosis could affect pulmonary function [9–11]. Lao et al. [12] and Toll et al. [13] had reported that patients with severe restrictive ventilation dysfunction suffered from significant impairment of pulmonary function, which constituted a high risk of PC. Similarly, Liang et al. [1] had shown that preoperative symptomatic respiratory system dysfunction influenced the occurrence of PC. In this study, we defined preoperative pulmonary disease as all types of pulmonary diseases that could affect respiratory function including respiratory failure, respiratory infections, moderate and severe respiratory dysfunction. There were 24 patients with preoperative pulmonary disease in this study. These patients had obvious reduction of pulmonary function and poor pulmonary function reserve, which constitute poor tolerance to general anesthesia.

This study also showed that Cobb angle, revision surgery and thoracoplasty are risk factors of PC. All three predictors were selected in the scoring system. Increased Cobb angle was shown to be associated with impaired pulmonary function, mainly because of the increase of airways closure [14]. The increased Cobb angle facilitated abnormal chest and lung development that resulted in poor pulmonary function reserve. Greggi et al. [2] had shown that thoracoplasty was the risk factor of PC for patients with adolescent idiopathic scoliosis, while Liang et al. [1] and Lao et al. [12] had suggested that thoracoplasty could increase the risk of PC in patients with impaired pulmonary function. For patients with razor back, thoracoplasty was a common method to correct the deformity of back. Thoracoplasty resected 3–5 ribs at the highest part of the razor back and the length of the resected part was 4–6 cm. Vedantam et al. [6] and Shi et al. [15] showed that thoracoplasty damaged the structure of the thorax and significantly reduced the lung function of patients after surgery. We also found that both Cobb angle and thoracoplasty are important risk factors. According to the nomogram of predictive scoring system, the risk of Cobb angle and thoracoplasty was higher than that of revision surgery. Hence, the score of Cobb angle and thoracoplasty was higher than that of revision surgery. The score of Cobb angle in the system was 6 and that of thoracoplasty was 5. The score of revision surgery was lower in the system as compared to the three predictors.

In this study, statistically significant differences were observed between peri-operative parameters and PC after PIF. Since the study was a retrospective review, it eliminated potential observer bias and the predictive scoring system was established. The aim of the system is to guide the prevention and prepare for PC after PIF. In this predictive scoring system, we selected objective parameters to limit variability and increase the reproducibility of results. This predictive scoring system has convenient application and calculated the risk grades, so that surgeons could assess the risk of PC after PIF. During peri-operative period, the surgeon needs to calculate the score and evaluate risk grades based on the predictive scoring system after making a surgery plan.

Table 1
Univariate Analysis of PPC Risk Factors.

Parameters	PPC Group	Non-PPC Group	*p*
Age (y)	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 pulmonary disease (pulmonary disease/none)	16/66	8/613	< 0.001*
Preoperative Cobb angle of main curve (deg.)	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 (deg.)	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
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 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 2
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 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

SE: standard error; OR: odds ratio. *p < 0.05, statistically significant.

Table 3
The predictive scoring system for PC after PIF.

Clinical predictor	Score
Revision surgery or initial surgery	
Initial surgery	0
Revision surgery	3
Cobb angle	
≤75 degrees	0
>75 degrees	6
Preoperative pulmonary disease	
No pulmonary disease	0
Pulmonary disease	10
Thoracoplasty	
No thoracoplasty	0
Thoracoplasty	5

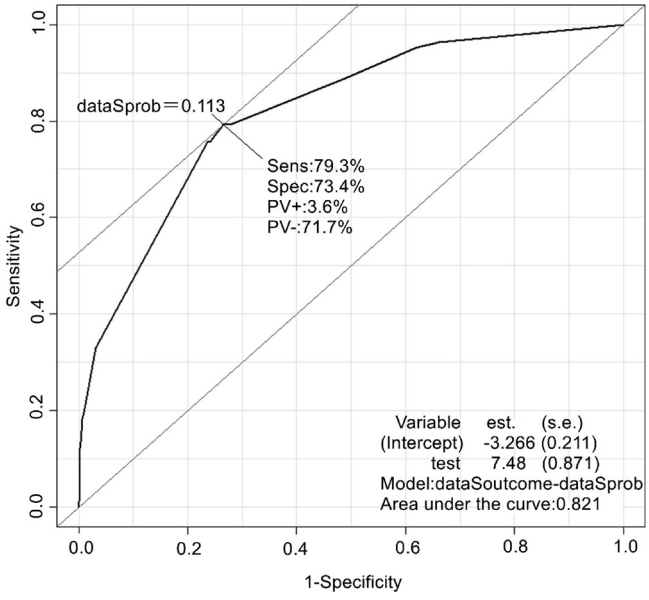

Fig. 1. ROC of the predictive scoring system.

Table 4
Risk grade of PC after PIF.

Risk score	Risk rate	Risk grade
≤10	<18%	Low
11-15	18–49%	Medium
>15	>49%	High

After the evaluation of risk grades, peri-operative preventive measures should be designed, or the surgical plan needs to be changed. For example, if patients suffered from moderate or severe respiratory dysfunction before operation and the risk of PC was high, we recommended that preoperative traction and pulmonary function exercise should be used to improve the pulmonary function, or did not undergo thoracoplasty during PIF. It could be safer that thoracoplasty performed to improve the razor back after the improvement of pulmonary function after PIF.

Although we established the predictive scoring system for PC, there were several limitations in this study. First, this was a retrospective and single-center study. Second, the system needs to be further applied to

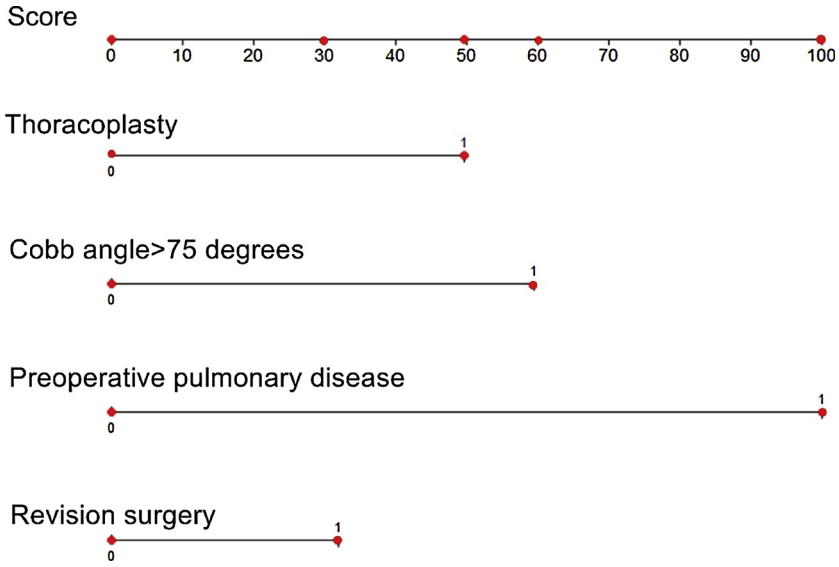

Fig. 2. scores corresponding to parameters in the system.

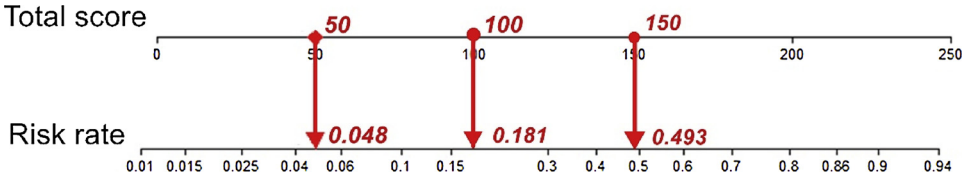

Fig. 3. risk rate corresponding to total score in the system.

determine its operability and clinical significance. This study has laid the foundation for future study of PC after PIF.

In summary, revision surgery, preoperative pulmonary disease, Cobb angle and thoracoplasty were identified as risk factors of PC after PIF for non-degenerative scoliosis, and a predictive scoring system was established that can be used to prepare for and manage PC after PIF. The system was proven to be reliable in this study and needs further application to determine its operability and clinical significance.

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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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