

ORIGINAL PAPER

RELATIONSHIP BETWEEN RADIOLOGICAL PARAMETERS AND PREOPERATIVE PULMONARY FUNCTION IN ADOLESCENTS WITH IDIOPATHIC SCOLIOSIS – PRELIMINARY STUDY

ZALEŻNOŚĆ PARAMETRÓW RADIOLOGICZNYCH I PRZEDOPERACYJNYCH WARTOŚCI PARAMETRÓW ODDECHOWYCH U NASTOLETNIICH CHORYCH ZE SKOLIOZĄ IDIOPATYCZNĄ – BADANIE WSTĘPNE

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ABSTRACT

Introduction

Thoracic spine deformity in adolescents with idiopathic scoliosis (IS) has been suggested to impair pulmonary function. The number of the curve vertebrae, curve magnitude and decreased kyphosis angle in thoracic spine may contribute to decreased pulmonary parameters. The results of previous research on the relationship between the pulmonary function and radiographic parameters have not been consistent.

Aim

The aim of the study was to analyze the relationship of the thoracic curve magnitude, number of involved vertebrae and angle of thoracic kyphosis with the pulmonary parameters in adolescents with IS.

Material and methods

Preoperative pulmonary testing and radiographic examination were performed in 31 adolescents diagnosed with IS, aged 12–18 years old (mean age 14.7 ± 1.85). Correlation and multiple regression analysis were performed to assess the relationship between radiological measurements and pulmonary parameters (Forced Vital Capacity (FVC) and Forced Expiratory Volume in One second (FEV1)).

Results

In 51% of the patients the pulmonary parameters were normal while 16% presented pulmonary impairment. Significant negative correlation between pulmonary parameters versus thoracic curve magnitude and pulmonary parameters versus number of the vertebrae involved was found. However, these parameters may explain 25.16% and 26.47% of the observed variability of the FVC and FEV1 respectively. No significant correlation of pulmonary parameters versus thoracic kyphosis angle was found.

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Conclusions

Normal pulmonary parameters occurred in half of adolescents with idiopathic scoliosis qualified for surgical treatment. The magnitude of the thoracic curve and the number of involved vertebrae correlate negatively with the preoperative pulmonary parameters in adolescents with idiopathic scoliosis.

Keywords: pulmonary function testing, idiopathic scoliosis, radiological parameters

STRESZCZENIE

Wstęp

Skolioza idiopatyczna (SI) zlokalizowana w odcinku piersiowym kręgosłupa może mieć negatywny wpływ na parametry oddechowe. Liczba kręgów tworzących skrzywienie w odcinku piersiowym kręgosłupa oraz jego wielkość, a także utrata kifozy piersiowej mogą się przyczyniać do obniżenia wartości parametrów oddechowych. Wyniki wcześniej prowadzonych badań dotyczących wpływu parametrów radiologicznych na parametry oddechowe są niejednoznaczne.

Cel

Celem badania była analiza zależności pomiędzy wielkością kąta Cobba w odcinku piersiowym kręgosłupa, liczby kręgów tworzących łuk skrzywienia oraz kąta kifozy piersiowej a parametrami oddechowymi u nastoletnich chorych ze SI, kierowanych do leczenia operacyjnego.

Materiał i metody

Badanie spirometryczne i badanie radiograficzne wykonano u 31 pacjentów z rozpoznaną SI, w wieku 12–18 lat (średnia 14.7 ± 1.85) przygotowywanych do leczenia operacyjnego. Przeprowadzono analizę korelacji i regresji liniowej, aby ocenić zależność między pomiarami radiologicznymi a parametrami oddechowymi- Natężoną Pojemnością Życiową (FVC) oraz Natężoną Objętością Wydechową Pierwszosekundową (FEV1).

Wyniki

U 51% pacjentów wartości parametrów oddechowych były prawidłowe, natomiast u 16% pacjentów były znacznie obniżone. Stwierdzono istotną statystycznie ujemną korelację między parametrami oddechowymi a wielkością kąta Cobba w odcinku piersiowym kręgosłupa oraz parametrami oddechowymi a liczbą kręgów tworzących łuk skrzywienia. Mogą one wyjaśniać 25.16% i 26.47% obserwowanej zmienności FVC i FEV1. Nie stwierdzono istotnej korelacji między parametrami spirometrycznymi a kątem kifozy piersiowej.

Wnioski

Prawidłowe wartości parametrów oddechowych występowały u połowy chorych z SI zakwalifikowanych do leczenia operacyjnego. Wielkość kąta Cobba oraz liczba kręgów tworzących łuk skrzywienia ujemnie korelują z parametrami oddechowymi u dzieci ze skoliozą idiopatyczną.

Słowa kluczowe: badania spirometryczne, skolioza idiopatyczna, parametry radiologiczne

Introduction

Idiopathic scoliosis is a three-dimensional spine and trunk deformity that may negatively influence pulmonary function by reducing the lung volumes especially when the curve is localized in the thoracic region (Weinstein, 1999). Several studies investigated the possible factors that may contribute to severity of pulmonary impairment in adolescents with idiopathic scoliosis. Kotani *et al.* (2004) suggested that one of the features of the respiratory impairment in patients with idiopathic scoliosis is a limitation of the chest wall mobility. Rib cage deformity may increase stiffness of the chest wall and reduce the force of respiratory muscles and the mechanical dysfunction of the diaphragm.

Wen's *et al.* (2016) study showed that lung volumes determined on the CT scans are lower in patients with adolescent idiopathic scoliosis than in aged-matched controls. Also, the study revealed that there is a positive correlation between volume of the right lung determined on the CT scans and the values of the pulmonary parameters.

Several researchers confirmed the correlation of pulmonary parameters (considered as percent of predicted value of Forced Vital Capacity and percent of predicted value of Force Expiratory Volume in one second) and radiological measurements- the thoracic curve magnitude in the frontal plane (Jackson, 1989; Kearon, 1993; Upadhyay, 1995; Johnston, 2011; Newton, 2005) and number of the vertebrae involved in the curve (Kearon, 1993; Newton, 2005). However, conclusions about association between thoracic kyphosis angle and pulmonary function were not consistent. Upadhyay *et al.* (1995) revealed no correlation between FVC, FEV1 and angle of thoracic kyphosis. However, Kearon *et al.* (1993) concluded that the loss of normal thoracic kyphosis was a significant factor influencing pulmonary function.

Weinstein *et al.* (1981) suggested that there was a significant correlation between Forced Vital Capacity (FVC), Forced Expiratory Volume in one second (FEV1) and increasing

severity of the thoracic curve, but the reduction of the pulmonary function occurred when the Cobb angle was greater than 100°-120°. However, Newton's *et al.* (2005) findings suggested that the pulmonary function deficit may occur in patients with smaller curves.

Pulmonary function is considered normal when FVC and FEV1 predicted value are above 80%. Results below that threshold suggest pulmonary impairment: mild ($70\% \leq \text{FVC}$, $\text{FEV1} < 80\%$), moderate ($60\% \leq \text{FVC}$, $\text{FEV1} < 70\%$), severe ($50\% > \text{FVC}$, $\text{FEV1} \geq 35\%$) [9]. However, Newton *et al.* (2005) and Johnston *et al.* (2011) refer to different stratification of the pulmonary impairment. While the threshold for the normal pulmonary function is unchanged, the value below that indicated: mild ($80\% \geq \text{FVC}$, $\text{FEV1} > 65\%$), moderate ($65 \geq \text{FVC}$, $\text{FEV1} > 50\%$) or severe (FVC , $\text{FEV1} < 50\%$) pulmonary impairment.

Floresa *et al.* (2016) suggested that adolescent patients with idiopathic scoliosis presented impairment in muscles strength and significantly decreased values of the FEV1, FVC and PEF comparing to aged-matched control group. They concluded that the preoperative muscle strengthening training may be beneficial for the patients with adolescent idiopathic scoliosis.

Furthermore, Laurentowska *et al.* (2009) suggested that the comprehensive rehabilitation program may have a positive effect on pulmonary function after surgical treatment in patients with idiopathic scoliosis. Also, they concluded that in patients after thoracoplasty endurance rehabilitation program may improve respiratory muscles capacity.

Aim

The aim of the study was to analyze the relations of thoracic curve angle, the number of involved vertebrae and thoracic kyphosis angle versus pulmonary parameters (Forced Vital Capacity, Forced Expiratory Volume in one second) in adolescents with idiopathic scoliosis addressed for surgical treatment.

Material and methods

The preoperative radiological and pulmonary assessment was performed in 31 adolescents diagnosed with IS. All patients met inclusion criteria as follows: diagnosed idiopathic scoliosis, Lenke 1 or 3 type, no pulmonary disorder, qualification to surgical treatment, spirometric evaluation.

Pulmonary testing prior to surgery was performed in a sitting position using MicroLoop MK8 spirometer (Micro Medical; Chatham, Kent, UK). Forced Vital Capacity (FVC) and Forced Expiratory Flow in One second (FEV1) were chosen as parameters providing an assessment of the volume and flow function characterizing pulmonary function. Each parameter was examined three times and the single maximal effort was analyzed. Percentages of predicted values of parameters (%FVC, %FEV1) were established based on age, gender, body height and weight according to the American Thoracic Society.

Radiographic measurements were performed on standard anteroposterior and lateral radiographs of whole spine. Thoracic curve magnitude was measured using Cobb method on anterior-posterior radiographs (Cobb, 1948). The number of involved vertebrae in the thoracic curve was determined- vertebrae between upper and lower end vertebrae were counted on AP radiographs. The angle of thoracic kyphosis was measured on lateral radiographs from the upper endplate of T2 to lower end plate of T12.

The mean value, standard deviation were established. Normal data distribution was analyzed with Shapiro-Wilk test. A correlations analysis was conducted between pulmonary parameters – FVC, percent of FVC predicted values and FEV1, percent of FEV1 predicted values- and radiological measurements- thoracic Cobb angle, number of involved vertebrae and thoracic kyphosis angle to determine Pearson correlation coefficient parameters. The coefficient of multiple regression determination (R²) was calculated for radiological measurements that had significant p values. The t-student test was used to determine if the thoracic curve

magnitude influences pulmonary function. The p level of 0.05 was considered significant. The analysis was performed with Statistica Software (TIBCO Software Inc.).

Results

The study comprised 31 adolescents – 23 girls, 8 boys, aged 12–18 years old (mean 14.7 ± 1.85). The mean body height was 1.67m ± 0.09, range 1.48–1.82 m (girls mean 1.64 m ± 0.07, range 1.48–1.80 m; boys mean 1.76m ± 0.08, range 1.58–1.82 m). Mean body weight was 57.39kg ± 13.24, range 14.79–31.71 kg (girls mean 54.74kg ± 12.84, range 36–96 kg; boys mean 65.0kg ± 12.0, range 54–91kg).

The mean Body Mass Index (BMI) was 20.5 kg/m² ± 3.7, range 14.8–31.7 kg/m² (girls mean 20.3 ± 3.7 kg/m², range 14.8–31.7 kg/m²; boys mean 21.1 ± 3.8 kg/m², range 16.3–28.1 kg/m²).

FVC-Forced Vital Capacity; %FVC-percentage of predicted value for FVC; FEV1 – Forced Expiratory Flow in One second; %FEV1 – percentage of predicted value for FEV1. All values are presented as mean, standard deviation, minimum and maximum in the brackets.

The boys were significantly taller than girls (1.76 m vs. 1.64 m, p=0.0005). Also, the boys had significantly larger FVC values (3.76 L vs. 2.91 L, p=0.01). Although, the FEV1, %FVC and %FEV1 showed no significant differences (Table 1).

Based on American Thoracic Society standard, in 51% of adolescents pulmonary parameters were normal (FVC, FEV1 > 80%), in 23% suggested mild restriction (80% > FVC, FEV1 ≥ 70%), in 16% moderate restriction (70% > FVC, FEV1 ≥ 60%), in 10% severe restriction (50% > FVC, FEV1 ≥ 35%). If considering stratification proposed by Newton *et al.* (2005) and Johnston (2011) also, in 51% of patients pulmonary parameters were normal (FVC, FEV1 > 80%), in 33% mild impairment (80% ≥ FVC, FEV1 > 65%) and in 16% moderate impairment (65% ≥ FVC, FEV1 > 50%).

Significant negative correlations between pulmonary parameters – FVC, FEV1 – versus radiological measurements- thoracic curve

Table 1. Radiological and pulmonary parameters of patients

Parameter	All N=31	Girls N=23	Boys N=8	P
FVC [Litr]	3.1 ± 0.8 (1.58–5.01)	2.91 ± 0.77 (1.58–4.35)	3.76 ± 0.7 (2.69–5.01)	0.0100*
%FVC	81.58 ± 16.27 (51–125)	82.13 ± 17.73 (51–125)	80.0 ± 11.95 (62–102)	0.7557
FEV1 [Litr]	2.61 ± 0.7 (1.28–3.89)	2.41 ± 0.64 (1.28–3.59)	2.94 ± 0.68 (1.84–3.89)	0.0593
% FEV1	78.90 ± 17.23 (41–123)	80.04 ± 17.48 (51–123)	75.62 ± 12.20 (41–95)	0.5413
Thoracic Cobb angle [°]	70.6° ± 12.4 (53°–104°)	70.96° ± 13.20 (53°–104°)	66.75° ± 12.51 (55°–89°)	0.4382
Number of vertebrae	7 ± 1 (4–9)	7.08 ± 1.13 (4–9)	6.87 ± 0.99 (5–8)	0.6404
Thoracic kyphosis angle [°]	30.9° ± 13.0 (11°–54°)	31.91° ± 11.65 (11°–50°)	27.87° ± 15.23 (13°–54°)	0.4415

Table 2. Correlations between pulmonary parameters and radiographic measurements tested with Pearson correlation coefficient

	FVC	%FVC	FEV1	%FEV1
Thoracic Cobb angle [°]	-0.45*	-0.40*	-0.45*	-0.36*
Number of involved vertebrae	-0.40*	-0.24*	-0.41*	-0.26*
Thoracic kyphosis angle [°]	0.27	0.35	0.32	0.36

%FVC – percent of FVC predicted values; %FEV1 – percent of FEV1 predicted values;
*p < 0.05

magnitude and the number of vertebrae involved in the thoracic curve were found as presented in Table 2.

No significant correlation was found between FVC versus thoracic kyphosis and FEV1 versus thoracic kyphosis. Also, no significant correlation was found between %FVC versus thoracic kyphosis and %FEV1 versus thoracic kyphosis angle (Table 2).

Regression analysis revealed that the thoracic Cobb angle and number of vertebrae involved in thoracic curve enable to possibly predict the FVC values. Their contribution is quantified by $R^2=0.2516$. The FVC value may be explained in a variation of 25.16% by thoracic Cobb angle and number of vertebrae.

Also, 26.47% of FEV1 value may be explained by thoracic Cobb angle and the number of

vertebrae involved in the thoracic curve ($R^2=0.2647$).

Thoracic curve magnitude impacts the pulmonary parameters- the greater Cobb angle the greater declination of FVC ($p=0.003$) and FEV1 ($p=0.004$).

Discussion

Several studies were conducted to address the influence of different factors namely, chest mobility (Kotani, 2004), braces treatment (Kennedy, 1989; Pehrsson, 2001; Ran, 2016) surgery technique (Vedantam, 2000; Lenke, 2004; Kim, 2007) radiological measurements that may influence pulmonary function in adolescents with idiopathic scoliosis (Jackson, 1989; Kearon, 1993; Upadhyay, 1995; Newton, 2005; Johnston, 2011).

The aim of the present study was to associate radiographic parameters – thoracic curve magnitude, length and thoracic kyphosis angle with pulmonary parameters in adolescents with idiopathic scoliosis. The study confirmed the relationship between thoracic curve magnitude and thoracic curve length versus FVC and FEV1 parameters. No correlation was found between the thoracic kyphosis angle versus pulmonary parameters.

Our study showed a negative correlation between pulmonary function measured by FVC, %FVC and FEV1, %FEV1 versus thoracic curve magnitude. Similar correlation between the degree of Cobb angle and pulmonary parameters was reported in previous studies. Newton *et al.* (2005) found that thoracic curve magnitude correlated negatively with percent of predicted value of %FVC and %FEV1 ($p < 0.002$) in the group of 631 patients. Johnston's *et al.* (2011) study on 41 untreated adults with idiopathic scoliosis revealed a negative correlation between thoracic curve magnitude greater than 40° and FVC ($p < 0.008$). Upadhyay *et al.* (1995) results concerning the negative correlation between the thoracic Cobb angle versus percent of FVC predicted values were consistent with results of other authors.

Thoracic hypokyphosis was identified as a factor associated with pulmonary function impairment. However, the results of the previous studies are not consistent. According to Kearon *et al.* (1993) the loss of normal thoracic kyphosis was a significant factor ($p = 0.002$) contributing to pulmonary impairment. Also, Newton *et al.* (2005) associated thoracic hypokyphosis ($p < 0.002$) with decreased pulmonary parameters. On the other hand, Jackson *et al.* (1989) did not make any conclusion about the effect of hypokyphosis. They concluded that thoracic hyperkyphosis ($> 50^\circ$) was related to decreased pulmonary function. In our study, no statistically significant correlation was found between FVC versus thoracic kyphosis angle and FEV1 versus thoracic kyphosis angle.

A factor previously identified as the one that may contribute to pulmonary function decrease was the number of vertebrae forming the curve in the thoracic region. The greater the number, the greater pulmonary impairment. That relation was confirmed in our study and the results are consistent with results presented by other authors (Kearon, 1993; Newton, 2005).

Modified pulmonary impairment stratification was used by Newton *et al.* (2005) and Johnston *et al.* (2011) who based on the suggestion that 65% of predicted value of pulmonary parameters is a minimal healthy level of pulmonary function which probably will not lead to respiratory impairment in adulthood. In Newton's *et al.* (2005) study, 20% of the patients with thoracic curve magnitude between 50° to 70° and 41% of the patients with thoracic Cobb angle between 71° – 80° had pulmonary impairment ($< 65\%$). In Johnston's *et al.* study (2011), in 19% of the patient results showed decrease in pulmonary function. Our results are similar – 16% of patients presented decreased pulmonary parameters.

The results of the Weinstein's *et al.* study (1981) conducted on 219 patients with untreated adolescent idiopathic scoliosis suggested that pulmonary function was affected in patients with thoracic curve approaching the threshold 100° – 120° . However, current studies suggest that pulmonary impairment may occur in patients with smaller curves. It is possible that major thoracic curves affect pulmonary function differently than the compensatory curves- distorting the orientation and functions of the diaphragm or mechanics of the thorax (2005).

Pulmonary parameters values were not corrected for the possible body height reduction due to spine deformation. That may lead to overestimation of the pulmonary function.

Conclusions

In 51% of the patients the pulmonary parameters were normal (%FVC,%FEV1 $> 80\%$) while 16% presented pulmonary impairment

(%FVC and %FEV1 < 65%). The magnitude of the thoracic curve and the number of involved vertebrae correlate negatively with the pulmonary parameters in adolescents with pre-surgical idiopathic scoliosis. Also, the results of the study suggested a usefulness of the spirometric examination in planning the perioperative physiotherapeutic rehabilitation.

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