Assessment in adolescent scoliosis

Connor J. S. McKee[1]

Abstract

Background: Adolescent idiopathic scoliosis is associated with lateral spinal curvature, vertebral rotation and rib cage distortion which disrupts normal, symmetrical thoracic movement leading to restriction of lung expansion and impaired pulmonary function. The effects of scoliosis on lung growth, airway function and exercise capacity are well documented but it is unclear how altered rib positioning affects lung function. This paper compares two different radiological measurements with pulmonary function.

Methods: The study compared two measures of deformity: Cobb angle and average rib-vertebral angle difference with pulmonary functioning. Existing literature describes Cobb angle as a useful indicator of pulmonary dysfunction. However, there are few reports on the use of rib-vertebral angle difference and these are limited to a single measurement taken at the apical vertebrae. This study of 53 patients used an average rib-vertebral angle difference over five vertebral levels. This measure gives a more representative measurement of the scoliotic deformity. This measure was then correlated with the patient's Cobb angle and pulmonary function.

Results: Using Spearman's rank correlation coefficient, average rib-vertebral angle difference correlated strongly with Cobb angle (0.83), forced vital capacity (-0.81), forced expiratory volume in 1 second (-0.76), and peak expiratory flow (-0.60).

Conclusions: The study found that measurement of Cobb angle is superior to average rib-vertebral angle difference across five vertebral levels.

Keywords: Idiopathic, scoliosis, RVAD, Cobb, measurement.

Study design: Retrospective correlation of pre-operative pulmonary function tests and radiological measurements

Introduction

Adolescent idiopathic scoliosis describes abnormal lateral curvature of the spine with no known cause affecting individuals between 10 and 18 years of age. It is a chronic debilitating disease that can result in impaired respiratory function. The prevalence of scoliosis is reported to range from 0.5% to 5.2% of the adolescent population [1]. Females are more frequently affected than males with a reported female to male ratio ranging from 1.5:1 to 3:1. This ratio increases with the severity of the curve, rising to 10:1 for Cobb angles greater than 30º [2]. The majority of scoliosis cases (85%) are idiopathic[3]. Many pathogenic mechanisms have been suggested as causes of idiopathic scoliosis. Hormonal, metabolic, biomechanical and neural changes have all been postulated to result in production of deformity. However, it remains unclear whether these factors cause the deformity or occur secondary to it [4]. Other causes of scoliosis include congenital, traumatic, infective, neuromuscular, postural and metabolic aetiologies [2].

Irrespective of cause, scoliosis results in a three dimensional deformity of the vertebral column with lateral spinal curvature, vertebral rotation and rib cage distortion. These deformities disrupt normal, symmetrical thoracic cage movement during respiration which lead to restriction of lung expansion. In severe scoliosis, the deformities may lead to compression of intra-thoracic organs, decreased lung volumes, disruption of respiratory muscle mechanics and limitation of rib movement. The lack of compliance and the restricted expansion of the thoracic cavity adversely affects the patient's vital capacity (VC), forced expiratory volume in 1 second (FEV1) and tidal volume (TV) [5]. Decreased thoracic volume reduces the space available for lung expansion, reducing total lung capacity (TLC). It also restricts lung growth and functional lung volume which affects gas transfer during respiration. Scoliotic patients may also have difficulty completely emptying their lungs [6]. Prolonged hypo-inflation and compression of the underlying lungs can lead to irreversible atrophic changes in lung tissue, causing a further reduction in lung volume in a pattern consistent with restrictive lung disease. Furthermore, scoliotic deformity can also be associated with displacement and rotation of the trachea and main stem bronchi, producing airway obstruction. Lower airway obstruction due to airway hyper responsiveness is also observed but this is usually reversible with the use of bronchodilators [2]. The relationship between increasing scoliotic deformity and decreased pulmonary function has yet to be fully defined.

Clinicians use radiological measurements to quantify the

[1]Royal Victoria Hospital, 274 Grosvenor Rd, Belfast BT12 6BA, Belfast, Northern Ireland.

Address of Correspondence
Dr. Connor J. S. McKee,
Royal Victoria Hospital, 274 Grosvenor Rd, Belfast BT12 6BA, Belfast, Northern Ireland.
E-mail: connor.mckee@ntlworld.com
cmckee43@qub.ac.uk

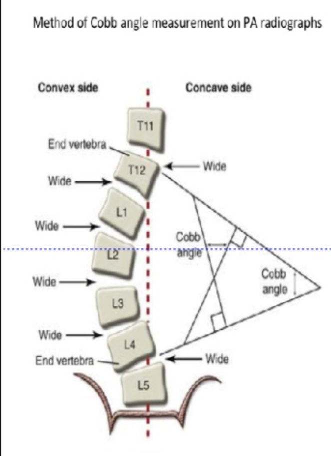

Fig. 1: Method of Cobb angle measurement on PA radiographs

Fig. 2: Method of RVAD measurement on PA radiographs

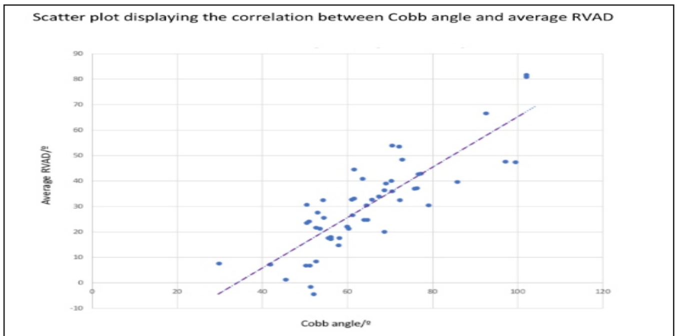

Fig. 3: Scatter plot displaying the correlation between Cobb angle and average RVAD

severity of scoliosis. The radiological techniques include measuring Cobb angle, rib-vertebral angle (RVA) and rib-vertebral angle difference (RVAD). The existing literature promotes Cobb angle as a useful indicator of pulmonary dysfunction [7]. Cobb angle is a widely used radiological method for quantifying the magnitude of the lateral curvature in scoliosis, however, it is subject to a high degree of inter-observer variability [8]. Most authors agree that lung dysfunction becomes clinically significant once the Cobb angle exceeds 50º [3]. Patients with a spinal Cobb angle of greater than 90º are at increased risk of pulmonary hypertension and cardiorespiratory failure [9].

Increased lateral angulation of the spine in scoliosis alters tension in the thoracic wall musculature. Intercostal muscles on the convex side of the scoliotic angulation experience an increase in stretch as the distance between the ribs increases while intercostal muscles are compressed by narrowing of the intercostal distance on the concave side [11]. This asymmetrical strain results in vertebral rotation and disruption to ribcage alignment.

There are few reports on the use of rib-vertebral angle difference (RVAD) as a means of predicting pulmonary dysfunction. RVAD was originally described as a method of predicting resolution or progression of curves in infantile scoliosis [10]. The rib-vertebra angle (RVA) is closely correlated with Cobb angle.

A previous study that investigated how apical RVAD related to pulmonary functioning in adolescent idiopathic scoliosis showed a negative correlation between RVAD in the erect posteroanterior (PA) radiographs and functional residual capacity (FRC) [12]. However, it was confined to use of RVAD at the apical vertebrae alone, at the level of maximal angulation.

The aim of the current study was to retrospectively review the radiological and clinical data of a cohort of patients with adolescent idiopathic scoliosis. Cobb angle was correlated with an average of five measures of RVAD from the five vertebrae around the point of maximal angulation. An average of five was chosen to give a more representative estimate of the scoliotic deformity. The average RVAD was then correlated with each patient's pulmonary function tests to evaluate its effectiveness in predicting decline in pulmonary function.

Materials and Methods

Application to access patients radiographs and notes was sought and granted by the Belfast Trust Clinical Audit/Governance Department.

A cohort of patients with moderate to severe adolescent idiopathic scoliosis without previous corrective surgery was selected. The majority subsequently underwent corrective spinal surgery at the Royal Victoria Hospital and the Royal Belfast Hospital for Sick Children between January 2015 and December 2017. Excluded from the cohort were patients outside the 10-18 year old age range, patients with previous spinal surgery, patients with neuromuscular scoliosis (caused by Duchenne muscular dystrophy, cerebral palsy or spina bifida), and those without erect PA films. After these exclusion criteria were applied, a cohort of 53 patients (12 male, 41 female) with a mean age of 14.6 years (standard deviation [SD] = 2.2 years) were available for analysis.

Radiological measurements were calculated by reviewing PA erect radiographs of the thoracic spine. Cobb angle was calculated by drawing lines parallel to the superior border of the upper vertebral body, and the inferior border of the lowest vertebrae of the curve. Perpendicular lines to these were generated, and Cobb angle was measured where these intersected (Fig 1).

Rib-vertebral angle (RVA) is a measurement used for defining the relationship between each rib and its corresponding thoracic vertebrae [10]. It was calculated by superimposing a line perpendicular to the inferior vertebral endplate [13]. Following this, a line created from the midpoint of the rib neck to the midpoint of the rib head was superimposed. It was continued until it intersected the original perpendicular line, the angle created was then measured (Fig 2).

Rib-vertebral angle difference (RVAD) was calculated by subtracting the convex RVA from the concave RVA. RVAD was measured over five ribs pairs, centred on the apex of the curve. An average value was obtained for each of the five levels. If the apex was located at an intervertebral disc, the vertebrae above the disc was taken as the apex, as described in previous literature [14]. The level of the apical vertebrae of each patient was recorded as was the laterality of convex side.

Several measures of pulmonary function were extracted from the patients spirometry tests. These were available for 31 of the 53 individuals, due to data loss or the tests not being performed. Pulmonary function tests were recorded with the patients standing. The following data were recorded using a computerised spirometer and peak flow meter:

- Forced vital capacity (FVC): the volume of air in litres that can be forcibly expelled after maximum inspiration.
- Forced expiratory volume in 1 second (FEV1): the volume of air in litres that can be forcibly expired in one second, after maximum inspiration.
- FEV1/FVC
- Peak expiratory flowrate (PEF): peak airflow achieved during
- at needed forced expiration. Measured in litres/second

Data analysis was performed using SPSS (version 25) statistical software.

Results

The normality of the data distribution for average RVAD and Cobb angle was tested using the Shapiro-Wilk test. Values exceeding P=0.05 suggested a normal data distribution. Average RVAD displayed a normal distribution (P=0.077). However, Cobb angle values were not normally distributed (P=0.009). Due to this non-parametric distribution, Spearman's rank was preferred for analysis. The results from the present study displayed a very strong positive correlation between Cobb angle and average RVAD of 0.83 (p=0.01), demonstrated in (Fig 3).

The cohort had a mean Cobb angle of 65º (range 30º - 102º), and mean average RVAD over five vertebral levels was 30º (range -4º - 82º). Within the sub-group of 31 patients with radiology and pulmonary function tests available, the mean values for Cobb angle and average RVAD were similar at 66º and 33º respectively. The greatest difference between concave and convex RVA was observed at the second vertebrae above the apex in 98% of the cohort. The median level of the apex of the scoliotic curve was observed at T8. Concavity was to the left side in 91%.

When compared to a refence population, the study cohort collectively displayed a reduction in the mean percent of predicted values for the components of the PFTs. The mean percent of predicted values for FVC, FEV1 and PEF were 78.27%, 77.60% and 82.33% respectively. Males displayed lower mean percentage predicted values for FVC, FEV1, PEF and observed FEV1/FVC ratio than females. The FEV1/FVC ratio was preserved in both sexes, 78.41% in males and 88.50% in females.

An inverse relationship was found between both Cobb angle and average RVAD, and pulmonary function test results. Table 1 shows that increasing Cobb angle demonstrated a very strong negative correlation with the percent of predicted values for FVC, FEV1 and a strong correlation with PEF of -0.87, -0.82, and -0.67 respectively. Similarly, average RVAD demonstrated strong negative correlations with each of these components with values of -0.81 (FVC), -0.76 (FEV1) and -0.60 (PEF). No correlation was identified between either independent variable and the FEV1/FVC ratio.

Data was analysed by linear regression. Adjusted R square values of 0.699, 0.647 and 0.29 were obtained between Cobb angle and percentage of predicted values of the dependant variables FVC, FEV1 and PEF respectively. Cobb angle was responsible for 69.9% of the variability found in FVC, 64.7% of the variability in FEV1 and 29% in PEF. Adjusted R square values from linear regression analysis of average RVAD and FVC, FEV1 and PEF were 0.583, 0.610 and 0.31 respectively. This suggests that average RVAD was responsible for 58.3% of the variability found in FVC, 61% in FEV1 and 31% in PEF.

No correlation was observed between gender and magnitude of cobb angle. There was no statistically significant correlation between the level of the apex of the scoliotic curve and pulmonary function test components.

Discussion

The current study demonstrated a strong positive correlation between Cobb angle and average RVAD, this is supported by existing literature [15,16,17,18,19]. Patients with moderate to severe scoliosis are known to have greatly reduced values of FEV1, FVC and vital capacity [5,20,21]. The current study showed that both increasing Cobb angle and average RVAD had strong negative correlations with measures of pulmonary function except for FEV1/FVC. In contrast, Upadhyay et al. 1995, did not demonstrate a correlation between apical RVAD and FVC [12]. They reported a preserved FEV1/FVC ratio, consistent with restrictive lung disease in scoliosis. Obstructive or mixed restrictive lung disease with air trapping have been documented in 46% of pre-operative scoliotic patients [22]. The current study identified a correlation between average RVAD and PEF, which is a measure of obstructive lung disease. PEF can be affected by a range of

Table 1 - Correlation coefficient found between Cobb angle and average RVAD with each component of pulmonary testing

	FVC % Predicted	FEV1 % Predicted	FEV1/FVC Observed	PEF % Predicted
Cobb angle/º Correlation Coefficient	-0.87	-0.82	0.44	-0.67
Sig (2-tailed)	0.01	0.01	0.81	0.01
N	31	31	31	31
Average RVAD/º Correlation Coefficient	-0.81	-0.76	-0.13	-0.6
Sig. (2-tailed)	0.01	0.01	0.48	0.01
N	31	31	31	31

Sig = significance. N = number of individuals.

factors including: changes to the structure of these airways, decreased respiratory muscle strength and thoracic cage deformity affecting chest wall expansion. Displacement and rotation of the tracheobronchial tree and asymmetric chest wall expansion may also contribute to this correlation [23].

The study cohort demonstrated a 3.5:1 female preponderance, which was consistent with the existing literature. The majority of individuals in the cohort had their scoliotic curve concave to the left. This study was unable to identify a correlation between the level of apical vertebrae and decline in pulmonary function.

Measuring average RVAD on PA films is a simple technique which is readily available. Taking an average across five vertebral levels provides a more representative estimate of scoliotic deformity than merely using RVAD of the apical vertebrae alone. It was found to be an accurate predictor of pulmonary dysfunction in patients with adolescent idiopathic scoliosis. The current study demonstrates a strong correlation between average RVAD and percentage predicted values for FVC, FEV1 and PEF. However, when compared with Cobb angle, a single global measurement, average RVAD was not found to be superior to existing Cobb angle techniques.

Conclusions: The study found that measurement of Cobb angle is superior to average rib-vertebral angle difference across five vertebral levels.

References

1. Konieczny M, Senyurt H, Krauspe R. Epidemiology of adolescent idiopathic scoliosis. J Child Orthop. 2012;7(1):3-9.

2. Koumbourlis AC. Scoliosis and the respiratory system. Paediatric respiratory reviews. 2006 Jun 1;7(2):152-60.

3. Tsiligiannis T, Grivas T. Pulmonary function in children with idiopathic scoliosis. Scoliosis. 2012 Dec;7(1):7.

4. Grauers A, Einarsdottir E, Gerdhem P. Genetics and pathogenesis of idiopathic scoliosis. Scoliosis and spinal disorders. 2016 Dec;11(1):45.

5. Lenke LG. Pulmonary and chest cage physiology. In: Spinal deformities. The comprehensive text. New York, NY: Thieme. 2003:126-34.

6. Bowen RM. Respiratory management in scoliosis. In: Moe JH, Bradford DS, Eds., Moe'stextbookofscoliosis and other spinal deformities. Philadelphia: Saunders. p 572.

7. Johnston CE, Richards BS, Sucato DJ, et al. Correlation of preoperative deformity magnitude and pulmonary function tests in adolescent idiopathic scoliosis. Spine. 2011; 36, 1096-1102.

8. Loder RT, Urquhart A, Steen H, et al. Variability in Cobb angle measurements in children with congenital scoliosis. The Journal of bone and joint surgery. British volume. 1995 Sep;77(5):768-70.

9. Praud JP, Canet E. Chest wall function and dysfunction. In: Kendig's Disorders of the Respiratory Tract in Children (Seventh Edition) 2006. p 733-746.

10. Mehta M. The rib-vertebra angle in the early diagnosis between resolving and progressive infantile scoliosis. The Journal of bone and joint surgery. 1972. 54, 230-243.

11. Rimmer KP, Ford GT, Whitelaw WA. Interaction between postural and respiratory control of human intercostal muscles. Journal of Applied Physiology. 1995 Nov 1;79(5):1556-61.

12. Upadhyay SS, Mullaji AB, Luk KD, Leong JC. Relation of spinal and thoracic cage deformities and their flexibilities with altered pulmonary functions in adolescent idiopathic scoliosis. Spine. 1995 Nov;20(22):2415-20.

13. Canavese F, Turcot K, Holveck J, Farhoumand AD, Kaelin A. Changes of concave and convex rib–vertebral angle, angle difference and angle ratio in patients with right thoracic adolescent idiopathic scoliosis. European Spine Journal. 2011 Jan 1;20(1):129-34.

14. Ferreira JH, de Janeiro R, James JI. Progressive and resolving infantile idiopathic scoliosis: the differential diagnosis. The Journal of bone and joint surgery. British volume. 1972 Nov;54(4):648-55.

15. Kristmundsdottir F, Burwell RG, James JI. The rib-vertebra angles on the convexity and concavity of the spinal curve in infantile idiopathic scoliosis. Clinical orthopaedics and related research. 1985 Dec(201):205-9.

16. Burwell RG, Cole AA, Cook TA, et al. Pathogenesis of idiopathic scoliosis. The Nottingham concept. Acta OrthopaedicaBelgica. 1992;58:33-58.

17. Xiong B, Sevastik JA, Hedlund R, Sevastik B. Radiographic changes at the coronal plane in early scoliosis. Spine. 1994 Jan;19(2):159-64.

18. Sevastik B, Xiong B, Sevastik J, Lindgren U, Willers U. Rib-vertebral angle asymmetry in idiopathic, neuromuscular and experimentally induced scoliosis. European Spine Journal. 1997 Mar 1;6(2):84-8.

19. Modi HN, Suh SW, Song HR, Yang JH, Ting C, Hazra S. Drooping of apical convex rib-vertebral angle in adolescent idiopathic scoliosis of more than 40 degrees: a prognostic factor for progression. Clinical Spine Surgery. 2009 Jul 1;22(5):367-71.

20. Widmann RF, Bitan FD, Laplaza FJ, Burke SW, DiMaio MF, Schneider R. Spinal deformity, pulmonary compromise, and quality of life in osteogenesis imperfecta. Spine. 1999 Aug 15;24(16):1673.

21. Newton PO, Faro FD, Gollogly S, Betz RR, Lenke LG, Lowe TG. Results of preoperative pulmonary function testing of adolescents with idiopathic scoliosis: a study of six hundred and thirty-one patients. JBJS. 2005 Sep 1;87(9):1937-46.

22. Boyer J, Amin N, Taddonio R, Dozor AJ. Evidence of airway obstruction in children with idiopathic scoliosis. Chest. 1996 Jun 1;109(6):1532-5.

23. Farrell J, Garrido E. Effect of idiopathic thoracic scoliosis on the tracheobronchial tree. BMJ open respiratory research. 2018 Mar 1;5(1):e000264.

24. Kearon C, Killian J. Factors Determining Pulmonary Function in Adolescent Idiopathic Thoracic Scoliosis. American Journal of Respiratory and Critical Care Medicine. 1993;148:288-94.

25. Pehrsson K, Danielsson A, Nachemson A. Pulmonary function in adolescent idiopathic scoliosis: a 25 year follow up after surgery or start of brace treatment. Thorax. 2001 May 1;56(5):388-93.

26. Lenke LG, Bridwell KH, Baldus C, Blanke K. Analysis of pulmonary function and axis rotation in adolescent and young adult idiopathic scoliosis patients treated with Cotrel-Dubousset instrumentation. Journal of spinal disorders. 1992 Mar;5(1):16-25.

27. Vedantam R, Lenke LG, Bridwell KH, Haas J, Linville DA. A prospective evaluation of pulmonary function in patients with adolescent idiopathic scoliosis relative to the surgical approach used for spinal arthrodesis. Spine. 2000 Jan 1;25(1):82.

28. Lenke LG, Bridwell KH, Blanke K, Baldus C. Analysis of pulmonary function and chest cage dimension changes after thoracoplasty in idiopathic scoliosis. Spine. 1995 Jun;20(12):1343-50.

Conflict of Interest: NIL
Source of Support: NIL

How to Cite this Article

McKee C J S | Assessment in adolescent scoliosis | International Journal of Paediatric Orthopaedics | Jan-April 2020; 6(1): 2-6.