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Pulmonary function study in Adolescent Idiopathic Scoliosis before and after surgical correction

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Abstract
From July 2018 to August 2021, 20 patients with adolescent idiopathic scoliosis requiring surgical correction were admitted in AL KARAMA teaching Hospital. They were 18 female and 2 male with age range from 13-20 years (15.1 years mean). The curve magnitude by Cobb's method ranged from 45-80 degrees (57 degree of mean). The vital capacity ranged from 1.1-3.5ml (2.33 ml of mean) and the height ranged from 138-158cm (148.9cm of mean). They had all undergo surgical correction, postoperatively the curve was corrected from mean of 57 degree to mean to mean of 28 degree (22-40 range), the vital capacity improved to mean of 2.89 ml, and 3.05 ml three months postoperatively and one year postoperatively respectively. The height was corrected to mean of 152.3 cm postoperatively. All these changes in the above mentioned parameters were significant, the P value < 0.05. Despite the variation in reports about the fate of pulmonary function test (PFT) after surgical correction, our humble study is in the favour of improvement not only in PFT, but also the height.

Keywords: Pulmonary, function, PFT

Introduction

Pulmonary function testing

Obstructive Pattern: total lung capacity TLC is normal or larger than normal, but during a maximal forced expiration from TLC, a smaller than normal volume is slowly expired.

Restrictive Pattern: TLC is smaller than normal, but a maximal forced expiration from TLC, the smaller volume is expired quickly and more completely than in a normal pattern.

Introduction to Adolescent Idiopathic Scoliosis

Lateral and posterior curvature of the spine have been recorded since earliest medical writing. Hippocrates one of the first to write on the subject applied the name scoliosis to any curvature of the spine. He also described an apparatus for forcibly reducing the deformity but it didn't appear to be very effective. Ambroise Pare in 1579 was the first to attempt trunk support by anterior and posterior metal plates, made by armories. Hare, in 1849 described the use of traction to the had and pelvis in horizontal position. The first carefully fitted supports were made about 1895 by Friedrich Hessing, he also emphasized the need of concomitant exercises to furnish active correction by the end of the nineteenth century, Plaster of Paris applied as a circular Jacker became an accepted method of holding correction of curvature. At the turn of the century earlier attempt at correction included the passive correction brace by Steindler and the ingenious lever system of Barr-Buschenfeldt.

Definition and Classification

Scoliosis can be defined as lateral curvature of the spine that exceeds ten degrees as measured by Cobb's method on standing radiographs.

Postural Scoliosis: the deformity is secondary or compensatory to some conditions outside the spine, such as a short leg or pelvic tilt due to contracture of the hip. When patient sits the curvature disappears.

Structural Scoliosis: it's a non-correctable deformity of the affected spinal segment, an essential component of which is vertebral rotation.
Scoliosis is actually a triplaner deformity with lateral anteroposterios and rotational component. Secondary curves nearly always develop to counterbalance the primary deformity and may later become fixed.

Age of presentation
1. Infantile idiopathic scoliosis: the curves occur during the first 3 years of life.
2. Juvenile idiopathic Scoliosis: occurs between 4 years of age and the onset of puberty, and it accounts for 12-16% of all cases of idiopathic scoliosis. Its uncommon and carry characteristics which are similar to those of adolescent group, the prognosis is worse and surgical fusion may be necessary before puberty.
3. Adolescent Idiopathic Scoliosis (AIS): this is the commonest form of scoliosis. It accounts for curves in patients presenting with scoliosis at or after the onset of puberty but before the completion of skeletal maturity. 90% of patients are girls and most common presentation are thoracic curves which are usually convex to the right, lumber curves to the left, thoracolumber and double primary curves also occur, most curves under 20 degrees either resolve spontaneously or remain unchanged. However, once a curve starts to progress it usually goes on doing so throughout the remaining growth period.

Curves Direction and Location
After location of apex, curve level defined as follows
- Cervical curve: apex between C1-C6.
- Cervicothoracic: apex at C7or T1.
- Thoracic curve: apex between T2-T11.
- Thoracolumber curve: apex at T12 or L1.
- Lumber curve: apex between L2-L4.
- Lumbosacral curve: apex at L5 or S1.

Etiology
Despite extensive research, the true etiology remain obscure with data supporting many different theories at the same time. Investigations centered on neurogenic causes of IS revealed a neurogenic dusfunction arise from disturbance of equilibrium and balance, recent studies centered on disturbed vibration sensitivity reflecting posterior column dysfunction of the spinal cord. Family survey have established a definit genetic component of scoliosis with high incidence among first degree relatives (6-8%).but the real nature of the genetic component still uncertain. Metabolic and biochemical disturbance of collagen and IVD components has been studies for long time.

Epidemiology
Since scoliosis have definite familial tendency, its not surprising that studies in different geographic regions gave different frequencies of scoliosis. In North America the following results were scoliosis with a Cobb angle of 10 degrees had a prevalence of approximately 25 per 100 in the population. Increasing the threshold reduces the prevalence, it drops to 3-5 per 1000 for curves more than 20 degrees, and to 1-3 per 1000 for angles more than 30 degrees. Curves more than 40 degrees have a prevalence of less than ne per 1000. The female to male ratio for curves more than 10 degrees reveals 1.4-2 to 1, the ratio increases to 5.4 to 1 for curves more than 30 degrees. a positive family history is found in 19 % of patients. AIS occurs in 15-20% of children with a parent who had AIS. Only 2 of 2000 AIS requires treatment.

Clinical evaluation
History should be detailed and complete with special inquiry about the deformity which is usually the presenting symptom. Special care is taken about patient's idea for the severity of his deformity and its progression since discovery. a family history of scoliosis should also be documented, the patients age and for female the age of menstruation should be accurate to the month. Physical examination starts with the general exam regarding patients height, weight and arm span which must be recorded every visit, sexual maturity, and if there is signs of non-idiopathic scoliosis such as café au lait spots and subcutaneous nodules of neurofibromatosis etc. The spine and the patient is examined from back, side and front. unique test for idiopathic scoliosis is the forward bending test, in structural scoliosis this will show clearly any rotational deformity and prominence of ribs which are made more obvious by the test, and that's not the case in the non-structural scoliosis where the deformity disappear with bending. From the front shoulder asymmetry, chest wall deformities and pectus excavatum should be recorded. From the side, patient is examined standing and bending forwards to look for any sagittal plane deformity, there may appear to found excessive lordosis of kyphosis. Torso balance is examined when a plumbline is dropped from spinous process of C7, if there is no cervical curvature, this line should pass through the line of the natal cleft if the spinal deformity is well compensated. Finally, a complete and careful neurological examination should be carried out and recorded, the patient's intelligence and mental status should be noted during the examination.

Imaging studies
An PA view shuld be taken in the standardized fashion, a standing lateral film is taken, and a Ferguson view provides an PA view to the lumbosacral joint, is taken perpendicular to the plane of L5-S1. Views should include iliac epiphysis in order to assign a Risser grade and skeletal maturity. A supine bending lateral view is of a great value in preparation for surgery which helps to distinguish structural from functional curves and to assess the flexibility of the spine and allowable surgical correction. A painful functional scoliosis my require a bone scan to rule out tumor, infection or spondylolisthesis as the cause for scoliosis. On the other hand MRI generates high quality medical image more accurate, more specific, sensitive, non-invasive and superior imaging of intraspinal and spinal region in comparison with CT scan and other conventional imaging techniques.

Curve measurement
Cobb method (1948) is recommended by SRS. For this, lines are drawn on PA film tangential to the superior endplate of the superior end vertebra and to the inferior endplate of the inferior end vertebra, the meeting of these lines or perpendicular lines on them forms the Cobb angle measured by goniometer. If the superios or the inferior endplates are difficult to be seen then the lines can be drawn along the the upper or the lower borders of the pedicles of those vertebrae which usually give the same measure for the angle of the lateral curvature of the spine. Ferguson method of measurement is done by dots placed in the center of the apical and the end vertebral bodies. Lines through these dots create the scoliosis angle and the dots should be placed in the center of three vertebrae, namely the two end vertebrae and the apical vertebra, two lines are then passed, one

between the upper and the central dot, the other between lower and central dot, and angle formed is the curve angle.

Measurement of vertebral rotation

One of the most popular current methods for measuring rotation is the methods of Nash and Moe (1969) or modification of it. In this technique, the displacement of the convex side pedicle towards the midline in the AP radiograph is visually estimated and expressed as a ratio with vertebral body width. CT scan has been used to measure rotation by the three dimensional representation of the scoliosis deformity.

Curve patterns of AIS

1. Right thoracic this curve typically from T5to T11 with apex at T8. A compensatory curve will be located in the lumber region.
2. Thoracolumber. This curve extends from T8 to L3 with apex at T12, L1 or the intervening disc space. The forward bending test will show a single hump in the region of the curve.
3. Lumber. This curve extends from about T11to L4 it may be in either direction, but more commonly to the left. On forward bending there is a lumber prominence.
4. Double major. This curve pattern has a right thoracic and left lumbar curves, the thoracic extends from T5to T11 or T12 and the left lumber extends to L4.
5. Double thoracic major. This curve pattern has two primary curves, but both are in the thoracic region. The upper one is to the left extending from T2to T7. The lower one is to the right and extend from T7to L1. On physical examination, the left shoulder is higher than the right and the neck may appear to be asymmetrical.

   Regarding their incidence the Rt thoracic is 32.5%, the thoracolumbar is 15%, the lumbar is 25.7% and the double curve is 26.8%.

Evaluation of pulmonary function in AIS

The deformity of thoracic scoliosis affects pulmonary function after a certain threshold of the deformity is passed. In scoliotic patients, it is well established that the total lung capacity and vital capacity are reduced. Until late in the pathologic process, the residual volumes are normal. Pulmonary symptoms are usually those of shortness of breath after variable degree of activity. Some patients with scoliosis may complain of S.O.B even with essentially normal pulmonary function. The dynamic aspect of pulmonary function (FEV1) forced expiratory volum at one second is proportionally decreased. Patient when having low VC he will exhale the reduced volume at a normal rate, because there is no element of obstruction, all giving the restrictive form of pulmonary function. The decreased lung capacity may be related to:

1. Abnormal muscle function due to under development of chest wall.
2. Magnitude of curvature; pulmonary symptoms, VC and PaO2 showed a linear correlation with the severity of the curvature. Only few patients with curvatures less than 65 degrees have reduced VC, whole patients with curvature more than 90 degree have a VC reduced by a much greater degree than the total lung capacity.
3. Using the CT scan to study the thoracic curves in three dimension s, both static (TLC, VC, FRV) and dynamic (FEV1) parameters of pulmonary function are found to be negatively correlated to lordosis. This suggests that treatment should be concerned with both scoliosis and the sagittal curvature.
4. Reduced chest and lung elasticity and distensibility.

Management of scoliosis

1. **Non operative:** if the curve is between 20 and 30 is progressing, some form of bracing may be needed like Milwaukee brace, Boston brace. Less than 30 degree and well balanced treatment is unnecessary unless there is definite progression, so exercise often prescribed.
2. **Operative:** for curves more than 30 degree and if the curve is progressing significantly then surgery is indicated.

Aim of study

Restrictive pulmonary impairment accompanied by scoliosis is one of the major problems in the treatment of scoliosis. The goal of this study is to evaluate the effect of scoliosis and its surgical correction on pulmonary function test, height and cobs angle.

Patients and Methods

From July 2018 to August 2020, 20 patients were admitted in Al karama teaching hospital, all patients had adolescent idiopathic scoliosis (AIS). Patients with non-idiopathic scoliosis and those not requiring surgical interventions were excluded from the study. 20 patients were included in a prospective study to evaluate the pulmonary function test PFT, the vital capacity estimated preoperatively, three months and one year following surgery for correction of spinal deformity, for the pulmonary function test we used the spirometer and the vitalograph. 18 were female and 2 were male. The age ranged from 13-20 years (mean if 15.1 years), the curve ranged from 45-80 degrees by Cobbs method. All patients had the pulmonary function test performed preoperatively and it ranged from 1-10 to 3.5 (mean of 2.32) and at three months and one year postoperatively. All the patient had the operations done in the same institute and by the same surgical team. None of the patients had been treated by brace preoperatively. All patients were reviewed for additional parameters such as height, weight, rib hump, radiological trunk imbalance and pelvic obliquity. 14 patients showed thoracic curve pattern while the rest had a thoracolumber curve pattern. The table below shows full informations regarding the patients:

Table 1: Patients Information's

No	Gender	Age	Height preop	Height postop	Cobb angle preop	Cob angle post op	PFT/VC preop	PFT/VC After 3 months	PFT/VC After 1 year
1.	M	14	150	153	53	26	3.4	4.27	4.30
2.	F	15	148	152	63	31	2.33	2.90	3.20
3.	M	13	140	142	60	30	1.22	1.65	1.80
4	F	20	154	156	50	24	1.89	2.40	2.70
5.	F	16	148	152	52	28	2.5	3.04	3.15
6.	F	14	150	154	56	26	2.4	3.09	3.20
7.	F	17	150	154	58	23	2.9	3.02	3.34
8.	F	14	145	149	60	28	1.1	1.87	1.90

9.	F	15	142	146	50	23	1.8	2.50	2.80
10.	F	17	150	153	51	25	2.0	2.50	2.70
11.	F	19	153	156	80	32	2.42	3.19	3.24
12.	F	13	140	144	70	30	2.7	3.57	3.80
13.	F	13	138	142	45	22	2.8	3.60	3.70
14.	F	15	150	154	50	25	3.0	3.40	3.60
15.	F	15	152	156	52	26	2.4	3.10	3.30
16.	F	14	148	151	50	22	2.2	3.08	3.20
17.	F	16	155	158	51	20	3.5	3.90	4.00
18.	F	18	158	162	56	28	3.0	3.50	3.70
19.	F	14	147	150	66	33	1.5	1.90	2.10
20.	F	13	138	142	70	30	1.1	1.50	1.80
	M/F 2/18	(13-20) 15.1	(138-158) 148.9	(142-162) 152.3	(45-80) 57	(22-40) 28	(1.1-3.5) 2.33	(1.5-4.27) 2.89	(1.8-4.3) 3.05

M=Male, F=Female, Pre-op=Pre-Operativ, Post-op=Post-operativ, PFT=Pulmonary Function test, VC = Vital Capacity.

Results

The vital capacity before operative intervention showed a mean of 2.33ml +/-0.67 9range 1.10ml to 3.50ml), and it improved postoperatively to mean of 2.89ml+/-0.75 (range 1.50ml to 4.2ml) and 3.05+/-0.73 (range 1.8ml to 4.30ml) in the three months and one year after the operation respectively as shown in the below table.

Table 2: Vital capacity

	N	Minimum	Maximum	mean	STD deviation
Vital capacity before surgery	20	1.10	3.50	2.33	0.67
VC after 3 months of surgery	20	1.50	4.27	2.89	0.76
VC after one year	20	1.80	4.30	3.05	0.73

Valid N (list wise) 20.

Table 3: Paired sample statistics

	Mean	N	Std. Deviation	Std. Error mean
Pair VC before surgery.	2.3295	20	.6660	.1528
1 VC after surgery	3.110	20	.6944	.1593

Table 4: Paired sample correlation

	N	Correlation	Sig
Pair VC before surgery & VC after surgery.	20	.972	.000

The height of the patient also showed a significant improvement, its mean was 148.9 cm (range 138 cm to 158) preoperatively. while the postoperative results as follow, mean height of 152,3 (ranged 142 cm to 162cm) this result also found to be found to be significant (P=0.038).

Table 5: Paired sample statistics.

	Mean	N	Std. deviation	Std. error mean
Pair height before	148.9000	20	5.6930	1.2730
1 Surgery. Height after Surgery.	152.3000	20	6.1599	1.3774.

Table 6: Paired sample correlations

	N	Correlation	Sig
Pair height before surgery & height after surgery.	20	.467	.038

The Cobb's angle preoperatively ranged from 45 -80 (mean 57) and after operative intervention ranged from 22 to 40 with mean value of 28. The correction in Cobb's angle found to be significant with P value > 0.05 as shown in the following table:

Table 7: P value

	frequency	percent	Valid percent	Cumulative percent
Valid 45.000	1	4.8	5.0	5.0
50.000	4	19.0	20.0	25.0
51.000	2	9.5	10.0	35.0
52.000	2	9.5	10.0	45.0
53.000	1	4.8	5.0	50.0
55.000	1	4.8	5.0	55.0
56.000	3	14.3	15.0	70.0
60.000	1	4.8	5.0	75.0

63.000	1	4.8	5.0	80.0
66.000	1	4.8	5.0	85.0
70.000	2	9.5	5.0	95.0
80.000	1	4.8	10.0	100.0
total	20	95.2	5.0	
Missing system	1	4.8	100.0	
total	21	100.0		

Table 8: Paired sample correlation

	N	Correlation	Sig
Pair Cobb's before surgery & Cobb's after surger	20	.979	.000

Discussion

The growth and development of pulmonary system is completed with the skeletal maturation of the spine 15-16 years in girls and 18-19 years of age in boys, while the growth in total number of alveoli ends around the second year of age and after the age of 35 years it starts to decline. The effect of surgical intervention have varied from an improvement in function after surgery, to no change, or to a postoperative decrease of pulmonary function our results go with the first group, in all of our patients although we are reporting in a smaller number and shorter period of follow-up. The results of tests performed more than two years postoperatively showed no improvement of pulmonary function irresponsive of the type of assessment used. The restrictive pulmonary function improvement that accompanies scoliosis correction is evaluated by the ratio of predictive vital capacity calculated from both vital capacity and body height. Hepper et al. in 1965 observed close correlation between arm span and height in 288 normal subjects (arm span height ratio 1.03 in males and 1.01 in females. And found statistical correlation between height and pulmonary function and this was the case in our study where the height showed significant improvement (P> 0.05) and correlation with the vital capacity as there is improvement in the vital capacity after that improvement in the height. Cobb's angle or the severity of the curve dictates the status of pulmonary function. It is among the most severely affected patients that the most important changes in pulmonary function after surgery are observed. Our study does support this view as the higher correlation and improvement in pulmonary function correlated with higher percent of correlation of sever curves. Our study results showed a significant increase in the third month postoperatively while the improvement at one year in comparison to 3 months was not significant.

Conclusion

1. There is restrictive pulmonary changes in patients with scoliosis.
2. The more severe the curve the more affection of pulmonary function.
3. There is higher improvement in the pulmonary function correlated with higher percent of correlation of more severe curves.
4. The height showed significant improvement and correlation with vital capacity after surgery.
5. There is significant increase in pulmonary function test in the third month postoperatively while the improvement after one year was not.

Recommendations

1. Early detection of scoliosis.
2. Early management of scoliotic patient.
3. We must calculate the pulmonary function, height and Cobb angle for those patients pre and post operatively.
4. We must follow up those patients and the above parameters.

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