PULMONARY FUNCTIONS IN IDIOPATHIC SCOLIOSIS

ÇITAK M., M.D. BENLİ T., M.D. KIŞ M., M.D.
AKALIN S., M.D. MUMCU E.F., M.D.

One of the main aims of scoliosis treatment is to improve the impaired pulmonary functions or if this is not possible, to sustain the present status of pulmonary capacity.

In this study results of pre and postoperative pulmonary function test of 62 patients, with idiopathic scoliosis and treated by Cotrel-Dubousset Instrumentation at the 1st Orthopaedics and Traumatology Clinic of Ankara Social Security Hospital between December 1988 and June 1991 in the 1., 3., 6., 12., 24.., and 36th postoperative months were evaluated. Spyrometry was used in measuring pulmonary functions. When all curve types were included, an improvement in pulmonary functions that started in the 1st month, accelerated in the 6th month and reached to a maximum in the 12th month was observed. Maximum improvement was noted in the flexible thoracal lordoscoliotic patients in which derotation a manoeuvre had been performed. In this group Vital Capacity (VC) improved an average of 13.1 % in the 1st month, 22.6 % in the 6th month and 36.9 % at the end of 12th month and no statistical difference was observed after the 24th month.

In view of these data, it is suggested that Cotrel-Dubousset Instrumentation technique significantly improves pulmonary functions and eventually carries out the primary aim in scoliosis surgery by correcting the chest deformity and bringing the sagittal contours to normal limits.

Key Words: *Idiopathic Scoliosis, Pulmonary Function Tests.*

INTRODUCTION:

Since Hippocrates, it is known that pulmonary functions are impaired by the scoliotic deformity. Hippocrates has stated that pulmonary expansion decreaseses and causes mortality due to pulmonary insufficiency in scoliotic patients. The deterioration of cardiopulmonary functions leads to secondary infections and the result can be fatal. Thus for an orthopaedic surgeon, better understanding of pulmonary functions and problems of the pulmonary system caused by scoliosis is very important (5, 8, 9). One of the main aims in idiopathic scoliosis surgery is prevention or improvement of pulmonary functions (8, 9).

Idiopathic scoliosis is a three dimentional complex deformity, with lordosis or kyphosis in the sagittal plane, rotational deformity in the axial plane and lateral curvature of the spine (13). By understanding the nature of the three plane scoliotic deformity, rigid systems that achieve correction in more than one plane are being increasingly popular (1).

Cotrel-Dubousset Instrumentation achieves correction in three planes and with multiple hooks double rods and a DTT that system provides a rigid rectangle. As this system does not need any postoperative cast or brace, it also eliminates iatrogenic restriction of pulmonary function (2, 7, 11, 12).

In this prospective study, differences in pulmonary functions of the 62 patients treated with the Cotrel-Dubousset technique were evaluated and the correlation between type of curve, rib hump and the changes in pulmonary functions were investigated.

PATIENTS AND METHOD:

Between December 1988 ad June 1991, 89 CD instrumentations were performed at the 1st Orthopaedic and Traumatology Clinic of Ankara Social Security Hospital. 62 patients with a late onset idiopathic scoliosis were included in this study. Average follow up was 26.0 months (10-42 months). Twenty seven (43-5 %) of the patients were female and 35 (56.5 %) were male. Mean age was 14.6 years (10-19 years).

In all of the patients detailed histories were taken and systemic and local physical examinations were made preoperatively.

The radiological examination consisted of antero-posterior, lateral and bending radiograms with the patients standing up. Cobb angles and sagittal plane contour angles were measured, the flexibilty and type of the curve was determined (21).

Pulmonary function tests were performed preoperatively. Vital Capacity (VC), Forced Expiratory Volume in the 1st Second (FEV1), Maximum Ventilation Volume (MVV), and Expiratory Reserve Volume

Ankara Social Security Hospital, 1st Clinic of Orthopaedics and Traumatology Ankara, TURKEY

(ERV) were measured. These values were divided by normal values and a percentage was obtained and then corrected with the "arm-span" method.

Pulmonary function tests were repeated at the postoperative 1st, 6th, 12th, 24th and 36th months. These were compared with the preoperative values using "Difference Between Means in Paired Observations" test. The correlation between these values and rib hump deformity and sagittal plane angle differences was investigated by "Correlation Matrix" test.

In all patients a one stage posterior instrumentation using standart Cotrel-Dubousset techniques and fusion with autologous bone grafts was performed.

RESULTS:

Preoperative radiological examination showed that 5 patients (8,1 %) had King Type I curves, 12 (19,4 %) had Type II, 39 (62,9 %) had Type III and 6 (9,6 %) had Type IV curves. No Type V curve was seen.

Preoperatively 20 (32,3 %) patients had a rib hump less than 3 cm, 25 (40,3 %) had a hump between 3-6 cam and 17 (27,4 %) had a hump more than 6 cm. A mean correction of 62,3 ± 26,9 % was obtained postoperatively when all types of curves were included. The correction amounts of the rib hump deformity for different curve types can be seen in Table I. As can be seen from the table, the maximum amount of correction was obtained in Type III curves in which a derotation manoeuvre had been performed ($p < 0.05$).

When the position of center of gravity in relation to the intergluteal crease was evaluated, 22 (35,5 %) had balanced curves, 23 (37,1 %) had less than 3 cm, 16 (25,8 %) patinets had between 3-6 cm and only one (1,6 %) patient had more than 6 cm of deviation from normal. Postoperatively the gravity line come to the intergluteal crease in 39 (62,9 %) patients. Twenty-one patients (33,9 %) had a residual deviation between 0-3 cm, and two (3,2 %) had a deviation more than 3 cms.

In the preoperative radiological assessment mean Cobb angle in the frontal plane was found to be 62,0° ± 13,0° in the lumbar and 44° ± 8,6° in the thoracal curves in Type I curves. When sagittal contours were evaluated, 22,1° ± 7,4° of hypokyphosis was determined in the thoracal region. An average decrease of 14,2° ± 4,3° of lumbar lordosis was observed.

Type II curves were divided in to two groups according to the thoracal curves' sagittal contour type. 7 had (11.3 %) a lordosis and 5 had a (8.1 %) hyperkyphosis. Preoperative mean Cobb angles of the thoracal and the lumbar curve, were 61,3° ± 11,5° and 28,3° ± 10,2° respectively in Type II lordotic patients. Thoracal kyphosis angle was averagely -4,7° ± 7,7°.

The mean Cobb angles in the thoracol and lumbar curves were 65,6° ± 16,7° and 31,2° ± 10,3° respectively in Type II curves with rigid hyperkyphosis. Thoracal kyphosis angle was averagely 69,6° ± 13,5°.

Preoperative mean Cobb angle in Type III patients was 49,9° ± 4,6° and mean thoracal kyphosis angle had decreased to 9,7° ± 11,4°. Lumbar lordosis angles were within normal limits.

Preoperative mean Cobb angle in Type IV curves was 48,8° ± 6,9°. Mean thoracal kyphosis angle and lumbar lordosis angles were 35,0° ± 6,1° and 29,7° ± 8,1° respectively.

Postoperative changes of the curves in the anteroposterior and lateral radiograms are seen in Table II and Table III. In the postoperative period averagely 32,5° ± 13,5° correction was obtained in the lumbar curve of the Type I curves and 42,2° ± 15,9° correction was achieved in the thoracal curve. In all patients normal physiological thoracal kyphosis was reconstituted but only 20 % of the patients were brought within normal lumbar lordosis limits.

The Cobb angles of the thoracal curve and lumbar curve were averagely corrected by 41,8 ± 7,4 % and by 21,7 ± 4,1 % respectively in Type II lordotic curves. In this group no significant change in the lumbar region was observed but all patients were brought to within –20° deviation limit from physiological thoracal kyphosis.

In patients with Type II curves with a hyperkyphosis pattern in the thoracal region, averagely 38,0° ± 4,8° and 22,8° ± 12,2° corrections were achieved in thoracal and lumbar curves respectively. Thoracal kyphosis angle was averagely reduced by 19,8° ± 6,9° and brought within normal limits in 80 % of the patients. In all patients of this group physiological lumbar lordosis was restored.

In type III patients 67,4 ± 14,3 % of correction was achieved in the Cobb angle, postoperatively. It was determined that this correction rate was higher than the correction rates in the bending radiograms and in all patients physiological sagittal contours were restored.

In type IV curves 53,8 ± 23,2 % correction was obtained in the frontal plane postoperatively. Although no significant difference in thoracal kyphosis and lumbar lordosis angles were observed, thoracolumbar junction angle was brought within normal limits in 66.6 % of the patients.

When all the curve types were included major

Table 1: Preoperative and postoperative values, amount of the correction values and percentages of correction, hight of rib hump deformites of the patients according to various curves
(PR: Preoperative, PO: Postoperative, PC: Percentage of correction, n: number of cases, A: Average, Sd: Standart deviation) (Numbers are cm at the column of PR, PO and AC)

Curve Types	PR	PO	PC	t p
Type I n = 5	2,5 ± 1,6	1,5 ± 1,1	33,6 ± 21,4	3,65 > 0,05
Type II Lordotic n = 7	7,9 ± 1,4	4,7 ± 1,3	41,5 ± 8,9	17,42 < 0,05
Type II Kyphotic n = 5	7,8 ± 1,4	5,9 ± 1,9	25,8 ± 10,2	7,75 < 0,05
Type III n = 39	3,9 ± 1,9	1,2 ± 1,1	76,0 ± 20,6	13,56 < 0,05
Type IV n = 6	3,3 ± 1,2	1,8 ± 1,8	51,3 ± 25,6	8,22 < 0,05
Total n = 62	4,5 ± 3,4	2,0 ± 1,9	62,3 ± 26,9	15,8 < 0,05

Table 2: Postoperative sagittal contour angles of different curve types. (T: Thoracal, L: Lumbar, n: number of cases, A: Average, Sd: Standart Deviation)

Type of the curve		Preoperative A ± Sd	Postoperative A ± Sd	Correction of Percantages	t p
King Type I n = 5	T L	44,0° ± 8,6° 62,0° ± 13,0°	26,4° ± 12,7° 42,0° ± 12,6°	42,2° ± 15,9° 32,5° ± 13,5°	7,67 < 0,05 5,65 < 0,05
King Type II Lordotic n = 7	T L	61,3° ± 11,5° 28,3° ± 10,2°	35,4° ± 6,2° 22,3° ± 8,5°	41,8° ± 7,4° 21,7° ± 4,1°	8,70 < 0,05 7,34 < 0,05
King Type II Kyphotic n = 5	T L	65,6° ± 16,7° 31,2° ± 10,3°	41,2° ± 13,4° 24,0° ± 9,2°	38,0° ± 4,8° 22,8° ± 12,2°	14,96 < 0,05 4,81 < 0,05
King Type III n = 39	T	49,9° ± 4,6°	17,0° ± 8,5°	67,4° ± 14,3°	33,71 < 0,05
King Type IV n = 6	TL	48,8° ± 6,9°	25,2° ± 12,3°	53,8° ± 23,2°	6,42 < 0,05
Total n = 62	M	53,2° ± 9,1	23,5° ± 13,4°	57,6° ± 19,1	29,13 < 0,05

curves were corrected by 57,6 ± 19,1 % the frontal plane postoperatively. The highest correction was obtanied in Type III curves in which a derotation manoeuvre had been performed, and this group was followed by Type IV and Type I and Type II curves respectively ($p < 0.05$).

Evaluation of the patients' pulmonary function tests are seen in Type IV. Preoperatively, especially in type II lordotic curves severe restrictive type of pulmonary impairment was observed. This group was followed by patients with Type III, Type I and Type IV curves.

In Type I patients, the vital capacity which was 70.7 % of normal preoperatively was corrected by 12.1 % in the 1st, 17.3 % in the 6th and 34.7 % in the 12th months ($p < 0.05$) and after 12 months there was no significant difference ($p > 0.05$). Other volume and capacity values were correlated with the vital capacity (Table IV).

In type II lordotic curves the vital capacity which was 41.3 % of normal preoperatively was corrected by 5,1 % in the 1st, 8,5 % in the 6th months ($p < 0.05$) and after this time no statistical difference was observed ($p > 0.05$). The other ventilatory parameters were similar. (Table IV).

In Type II kyphotic patients, the vital capacity which was 51.3 % of normal preoperatively was corrected by 2.3 % in the 1st month and later on, no significant change in vital capacity and other volume and capacity were noted ($p > 0.05$) (Table IV).

In Type III curves, the vital capacity which was 70,5 % of normal preoperatively was corrected by 13 % in the 1st, 22,5 % in the 6th, 36,7 % in the 12th months and after this date no significant difference was observed ($p > 0.05$). Differences in other volume and capacities were correlated with the vital capacity (Table IV).

In Type IV curves the vital capacity which was 83,6 % of normal preoperatively was corrected by 7,4 % in the 1st, 11,2 %, in the 6th and 15,7 %, in the 12th months and after this date remained the same. The other parameters were correlated with the vital capacity (Table IV).

A significant stastitical difference in pulmonary functions was observed between different curve types ($p < 0.05$). The maximum correction was obtained in the type III curves in which a derotation manoeuvre had been performed and the least correction was achieved in Type II kyphoscoliosis.

The amount of corrections in pulmonary functions were correlated with the amount of correction in the sagittal plane ($r = 0,793$, $p < 0,05$) and the correction rate of the rib hump values ($r = 0,799$, $p < 0,05$).

DISCUSSION:

Certainly one of the main aims of scoliosis surgery is to improve impaired pulmonary functions or if this is not possible, to prevent deterioration (5, 8, 9, 13). Because of the low success of Harrington rod system in correcting chest deformity, its ameliorating effect on pulmonary functions is negligable. There are a few reports suggesting that pulmonary functions are improved in patients treated with HRSF (3, 6).

In 1986 Shufflebarger, et al. reported the results of the pulmonary functions of 21 adolescent and 7 adult scoliotic patients treated with Cotrel-Dubousset Instrumentation. Vital capacity which was 2.3 liters (1,4-3,6) in adolescent patients improved 13,3 % by the end of the 1st month and 26 % by the end of the 3rd month, in adult patients the increase was 18 %. In light of these data, they suggested that the three plane corrective effect of the C.D. system and its effects on chest configuration played a role in the rapid improvement of vital capacity and maximum ventilation volume (11).

The same authors examined the pulmonary functions of 46 patients in which Cotrel-Dubousset Instrumentation had been performed and reported an improvement of 15 % in the 1st, 40 % in the 3rd month in vital capacity and 12,3 % increase in the 1st, 37 % increase in the 3rd month in maximum ventilation volume. Vital capacity which was averagely 2,03 preoperatively reached to a value of 3,1 lites by the end of the 12th month (12).

In 1987 Gepstein, et al. studied ventilation and perfusion capacities of 10 patients in which CDI had been performed. Using preoperative and postoperative 3rd month Tc99 scans they reported that CDI restored ventilation symmetry and increased pulmonary performance and perfusion (4).

In this study results of preoperative and postoperative pulmonary function tests of 62 patients in the 1., 3., 6., 12., 24. and 36th months with idiopathic scoliosis and treated surgically by Cotrel-Dobousset Instrumentation were examined. In all groups an improvement that started in the 1st month, accelerated in the 6th month and reached a maximum in the 12th month was observed. Maximal improvement was achieved in Type III curves in which a derotation manoeuvre had been performed. This group was followed by double major curves and thoracolombar curves. Minimum im-

Table 3: Distribution of mean correction values of thoracal sagittal plane angles in various curve patterns. (T: Thoracal,L: Lomber, A: Average, Sd: Standard Deviation, n: Number of the patients

Curve type		Preoperative A ± Sd	Postoperative A ± Sd	Correction of Percantages	t p
King Type I n = 5	T	22,1° ± 7,4°	34,0° ± 4,2°	11,8° ± 5,4°	4,93 < 0,05
	L	14,2° ± 4,3°	27,0° ± 7,4°	12,8° ± 5,7°	5,00 < 0,05
King Type II Lordotic n = 7	T	(-4,7)° ± 7,7°	12,0° ± 7,5°	16,7° ± 2,8°	15,7 < 0,05
	L	32,9° ± 8,9°	36,9° ± 7,4°	4,0° ± 3,2°	3,34 < 0,05
King Type II Kyphotic n = 5	T	69,6° ± 13,5°	49,8° ± 11,8°	(-19,8)° ± 6,9°	6,41 < 0,05
	L	38,2° ± 11,1°	38,4° ± 4,7°	0,4° ± 4,5°	0,19 < 0,05
King Type III n = 39	T	9,7° ± 11,4°	35,8° ± 4,7°	26,1° ± 9,4°	17,40 < 0,05
	L	36,1° ± 6,3°	39,6° ± 4,8°	3,6° ± 3,9°	5,59 < 0,05
King Type IV n = 6	T	35,0° ± 6,1°	38,5° ± 4,9°	3,5° ± 2,6°	3,31 < 0,05
	L	29,7° ± 8,1°	34,5° ± 7,2°	4,8° ± 1,9°	6,10 < 0,05

Table 4: Correction values and percentages of pulmonary function test in various curve patterns in the preoperative preiod and postoperative period and postoperative 1st, 6th, 12th, 24th and 36th months.
(All the values in the table are mean values and mean percentages)
(ERV: Pespiratory Reserv Volume, VC: Vital Capacity, FEV1: Forced Expiratory Volume in the first second, MVV: Maximum Ventilation Volume, PR: Preoperative, PO: Postoperative, CRV: Amount of correction, %:

		PR Value	PO 1. Month CRV %	PO 6.Month CRV %	PO 12.Month CRV %	PO 24.Month CRV %	PO 36.Month CRV %
Type I	ERV	86.3	6.9/7.9	11.2/12.9	17.1/19.8	17.3/20.0	17.3/20.0
	VC	70.7	8.5/12.0	12.2/17.3	24.6/34.7	24.9/35.2	24.9/35.2
	FEV1	89.3	9.4/10.5	16.1/18.0	26.3/29.3	27.1/30.3	27.2/30.5
	MVV	65.4	5.6/8.6	7.3/11.2	14.6/22.3	14.7/22.5	18.3/31.6
Type II-L	ERV	46.2	2.2/3.3	4.1/6.2	4.4/6.6	4.5/6.8	4.6/6.9
	VC	41.3	3.1/5.1	5.2/8.5	5.6/9.1	5.6/9.1	5.7/9.3
	FEV1	29.9	4.2/7.1	6.8/11.5	7.1/11.9	7.2/12.1	7.3/12.3
	MVV	31.9	2.1/4.0	2.2/4.2	2.2/4.2	2.3/4.4	2.5/4.8
Type II-K	ERV	56.2	1.1/1.9	1.3/2.3	1.2/2.1	1.3/2.3	1.1/1.9
	VC	51.3	1.2/2.3	1.2/2.3	1.2/2.3	1.2/2.3	1.1/2.1
	FEV1	39.3	0.9/2.3	1.1/2.8	0.9/2.8	1.1/2.8	1.1/2.8
	MVV	41.9	1.0/2.3	0.9/2.1	1.0/2.3	1.0/2.3	1.0/2.3
Type III	ERV	88.9	7.3/8.2	14.3/16.1	18.2/20.5	18.3/20.6	18.2/20.5
	VC	71.6	9.4/13.1	16.2/22.6	26.4/36.9	28.6/39.9	28.7/40.1
	FEV1	87.6	8.2/9.4	16.4/18.7	27.3/31.3	27.4/31.3	28.1/32.6
	MVV	57.9	4.8/8.3	10.1/17.4	18.1/31.3	18.6/32.1	18.3/31.6
Type IV	ERV	91.1	5.3/5.7	8.3/9.1	11.9/13.1	12.1/13.3	12.1/13.3
	VC	83.6	6.2/7.4	9.4/11.2	13.1/15.7	14.3/17.1	14.3/17.1
	FEV1	93.3	8.6/9.2	8.8/9.4	12.1/13.1	14.1/15.1	14.4/15.4
	MVV	69.7	6.1/8.7	7.2/10.3	9.6/13.1	11.2/16.1	11.1/15.9

provement or decrease in some patients in the 1st month is related to microinfarcts due to fat emboli during surgery. A rapid increase in pulmonary functions in the 6th month and thereafter is due to the corrective effect of CDI. In rigid thoracal lordoscoliosis approximately 10 % increase was observed in the first 6 months and remaied unchanged thereafter. No significant increase or deterioration was seen in rigid kyphoscoliotic patients (Type II kyphotic).

Differences in pulmonary functions were correlated with correction rates of physiloogic curves in the sagittal plane and rib hump.

In view of these data, it is postulated that CDI improves pulmonary functions especially in flexible thoracal lordoscoliosis patients and maintains the present status in rigid curves and eventually carries out the primary aim in scoliosis surgery by correcting the chest deformity and bringing sagittal contours to normal limits. Cotrel Dubousset Instrumentation improves pulmonary functions by:

1. Providing a rigid internal fixation and eliminating the need for postoperative immobilization by cast, thus avoiding an iatrogenic restriction in the ventilatory mechanism.
2. Bringing thoracal kyphosis to normal limits in the sagittal plane
3. Preventing pulmonary collapse by correcting the rib hump deformity and increasing chest radius with its derotational effect.

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