SPINAL IMBALANCE AND DECOMPENSATION PROBLEMS IN PATIENTS TREATED WITH COTREL DUBOUSSET INSTRUMENTATION

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Current principles of idiopathic scoliosis treatment are three dimensional correction and rigid fixation. Although it is accepted that the Cotrel - Dubousset Instrumentation (CDI) meets these goals, there is concern about the potential risk of trunk imbalance and spinal decompensation during the derotation manouvre. The results of 45 patients with idiopathic scoliosis treated with CDI between December 1988 and August 1992 were retrospectively analyzed. Mean age was 14.3 years and mean follow up wa 48.6 months. Average of 49.6% correction was achieved in the major curves. The best results were obtained in King Tip III curves with a 69.4% correction. Spinal imbalance was evaluated by measuring Lateral Trunk Shift (LT), Shift of Head (SH) and Shift of Stable Vertebra (SS). Decompensation was measured by the increases in secondary curves. When all curve types were included, the average preoperative LT value of 1.96 Vertebral Units (VU) was brought down to 0.91 VU postoperatively, achieving a 55.9% correction. Fourteen patients had a SH of zero preoperatively and remained balanced after instrumentation. Of the 41 remaining cases, 21 became zero postoperatively. When all cases were included the average preoperative SH was 1.0 VU and was corrected to 0.42 VU with CDI (69% correction). An average of 75.5% correction was obtained in SS, and the mean preoperative value of 0.73 VU was corrected to 0.19 VU. At the last follow-up visit a secondary curve had formed above the major curve in one case and three patients had a junctional kyphosis. Loss of correction in the frontal plane was corelated with loss in the correction of LT. The rigid and semi-flexible lumbal curves had a tandency to progress when they were not instrumented, especially in Type II curves. Junctional kyphosis could be prevented when concave laminar claws were used in the thoraco-lumbal region. It was concluded that spinal decompensation and imbalance could be minimized with careful preoperative planning, avoidance of over-correction and a long instrumentation in double major curves.

Key Words: *Idiopathic Scoliosis, Spinal Imbalance, Decompensation.*

INTRODUCTION

Scoliosis is a complex disorder of the spine, with lateral bending in the frontal plane and a rotation deformity especially in the apical vertebra (10, 13). Cotrel and Dubousset have proposed the concept of three dimensional correction of scoliosis, with the use of distraction, compression and derotation forces on the deformity (5, 6). The Cotrel-Dubousset Instrumentation and the prenciples of three dimensional correction and rigid multi-level fixation have been widely accepted. There are many studies on the correction effect of the instrumentation in all three planes (1, 3, 4). However, there have been reports in recent years postulating that the apical vertebra does not derotate in reference to the pelvis and the derotational effect is reflected to the neutral vertebrae (14, 16). Derotation causes formation of new curves or increase in secondary curves resulting in trunk imbalance (15).

The purpose of this study was to clinically and radiologically evaluate the spinal balance changes in 45 patients with adolescent idiopathic scoliosis treated with CDI.

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PATIENTS AND METHODS

Fourtyfive cases with adolescent idiopathic scoliosis treated by CDI at the Ankara Social Security Hospital, 1st Department of Orthopaedics and Traumatology between December 1988 and August 1992 were retrospectively analyzed. Minimum follow-up was 24 months and maximum was 68 months (Average 48.6 months). There were 32 females and 13 males. Mean age at the time of surgery was 14.3 (10-19) years.

Preoperatively, rib hump, shoulder and thorax asymmetry the distance of the weight line to the intergluteal crease was recorded. Standing and bending X-rays were taken and curves were grouped using the King Classification (8).

The patients were operated under general hypotansive anesthesia and standart CD techniques were used. The derotation monouvre was performed in single flexible thoracal curves (Type III curves) and in long flexible thoracolumbar curves (Type IV curves). Rigid

Type I and Type II curves were corrected with double rods on the concave side using mainly distraction and transverse traction. Autologous bone grafts were utilized in all cases. Patients were turned to their sides on the first postoperative day and mobilized on the third day.

Regular follow-up visits were performed on the 3rd, 6th, 12th, 12th and 24th postoperative months. Patients were clinically and radiologically evaluated with special emphasis on shoulder asymmetry, position of the weight line, formation of new curves or progression of secondary curves. Three radiological parameters on the preoperative, early postoperative and last follow-up visit (August 1994) X-rays were calculated. The three radiological parameters were Lateral Trunk Shift (LT), Shift of Head (SH) and Shift of Stable Vertebra (SS).

LT was measured as the distance of the apical vertebra of major curve to the mid-sacral line (MSL). SH was measured as the distance between the MSL and mid point of the seventh cervical vertebra. SS was measured as the distance between the stable vertebra and the MSL. All measurement were divided by the transvers diameters of the respective vertebra to account for the variations in X-rays magnification and patient size. Thus a new standardized measurements the "Vertebral Unit" (VU) was obtained to allow for comparison between patients. The thoraco-lumbar junction angle was measured and if present postoperative junctional kyphosis was noted.

RESULTS

Preoperative radiological evaluation revealed 27 cases with Type III curves, 12 cases with Type II and 6 cases with Type IV curves according to the King Classification.

The average pre and postoperative rib hump values, correction percentages and loss of correction at the last follow-up visit are seen in Table I. When all curve types are included a 78.9% average correction was achieved. The best results were obtained in Type III curves with a 84.7% average correction. The differences between the pre and postoperative values' were found to be statistically significant (t: 5.21, $p<0.05$).

The pre and postoperative frontal and sagittal Cobb angles, correction percentages and loss of correction values are seen in Table 2. When all groups are included, a 49.6% correction was obtained and this was found to be statistically significant (t : 6.71, $p<0.05$). The maximum amount of correction was achieved in Type III curves with 69.4% and the least correction was obtained in Type II curves with 39.1%. The sagittal contours were brought within normal limits in 59% of Type III cases and the rest were in the limits of 10° deviation from normal values.

Clinical and radiological balance values of all cases are seen in Table 3. Thirty one cases had shoulder asymmetry preoperatively. A total correction was obtained in 11 (35.5%) and a partial improvement was observed in 20 (64.5%) cases after surgery. No change was seen postoperatively in cases without preoperative shoulder asmmetry.

Pre and postoperative weight line values and correction percentages are seen in Table III. A 65.3% overall correction was obtained in all types of curves. The maximum amount of correction was obtained in Type III curves with 90%. No statistically significant correction was seen in Type IV curves. Type II curves had the most important amount of correction loss at the last follow-up visit.

The mean overall preoperative Cobb angles of the secondary curves were 23.9° and a 52.3% correction was obtained with CDI. A statistically significant correction was achieved in all secondary curves, except in patients with Type IV curves. These patients had almost half the amount of correction loss (9.6°±21.5°). Although only the thoracal curves were instrumented in Type II curves, a 4.5°±6.5° increase in secondary lumbar curves were noted contrary to the observations of King (8).

The secondary proximal curves in Type IV cases increased an average of 9.6° during the follow-up period. One patient in this group developed a new curve above the thoracolumbar curve.

Junctional kyphosis was present in 2 cases with Type IV curves before the operation and these could not be improved with surgery. Another patient with a Type IV curve developed a junctional kyphosis postoperatively.

Lateral Trunk Shift (LT) values improved significantly after instrumentation in all cases ($p<0.05$). The average preoperative LT was 1.96 VU and a 55.9% overall correction was obtained.

There were 14 cases with a normal SH value (ie: 0) preoperatively. All of them remained balanced after instrumentation and an additional 7 patients were corrected to zero, obtaining a total of 21 cases. A part from these patients 13 cases had a SH value less than 1 VU postoperatively, and although a radiological

Table 1. Pre (PR) and postoperative (PO) rib humb values, correction percentages (COR%) and loss of correction (L) at the last follow-up visit in patients with idiopathic scoliosis instrumented with Cotrel-Dubousset Instrumentation.

CURVE PATTERN	PR (cm.)	PO (cm.)	% COR	L (cm.)	T	p
TYPE II	4.27±2.86	1.73±1.42	65.9±25.9	0.46±0.93	2.63	p<0.05
TYPE III	2.60±1.57	0.60±0.99	84.7±26.3	0.45±0.81	4.81	p<0.05
TYPE IV	2.40±1.14	0.60±1.34	75.0±33.5	0.00±0.00	2.29	p<0.05
TOTAL	3.08±2.12	0.94±1.26	78.9±27.8	0.39±0.79	5.21	p<0.05

Table 2. Pre (PR) and postoperative (PO) frontal plane Cobb angles (F.COBB), thoracal (TK: Thoracal Kyphosis) and lumbar (LL: Lumbar Lordosis) sagittal contour angles, postoperative correction percentages (COR%) and loss of correction (L) at the last follow-up visit in patients with idiopathic scoliosis instrumented with Cotrel-Dubousset Instrumentation.

CURVE PATTERN		PRE	PO	COR%	L	T	p
TYPE II (n : 12)	F.COBB	74.5°±17.3°	46.5°±18.4°	39.1±22.0	10.2°±8.9°	3.68	p<0.05
	TK	28.7°±27.2°	35.1°±9.7°	-	2.3°±4.6°	-0.73	p<0.05
	LL	34.5°±20.7°	39.5°±9.3	-	2.6°±3.9°	-0.73	p<<0.05
TYPE III (n : 27)	F. COBB	48.2°±9.9°	18.2°±14.4°	69.4±14.1	4.3°±6.3°	6.45	p<<0.05
	TK	11.7°±19.6	26.1°±9.7°	-	3.5±6.4	-2.95	p<0.05
	LL	21.1°±14.7	34.8°±10.7°	-	2.6±6.9	-5.04	p<<0.05
TYPE IV (n : 6)	F. COBB	55.6°±17.2°	27.4°±11.3°	51.4±38.2	19.2°±23.3°	3.07	p<0.05
	TK	35.2°±16.6°	29.0°±23.0°	-	-0.4°±0.9°	0.49	p>0.05
	LL	29.6°±18.7°	39.0°±8.9°	-	1.0°±2.2°	-1.01	p>0.05
TOTAL (n : 45)	F.COBB	58.8°±18.9°	31.2°±17.6°	49.6±19.4	7.5°±11.3°	6.71	p<0.05
	TK	20.76°±22.7°	29.6°±12.1°	-	2.4°±5.3°	-2.15	p<0.05
	LL	25.6°±17.4°	36.8°±9.7°	-	2.2°±5.3°	-3.53	p<0.05

Table 3. Pre (PR) and postoperative (PO) clinical and radiological evaluation of patients with idiopathic scoliosis instrumented with Cotrel-Dubousset Instrumentation. (COR%: Correction percentages, WL: The position of the weight-line according to the intergluteal crease, S.Cobb: Cobb angle of the secondary curve, LT: Lateral Trunk Shift, SH: Lateral Shift of head, SS: Shift of Stable Vertebra, VU: Vertebral Unit).

CURVE PATTERN		PR	PO	COR%	L	T	p
TYPE II (n : 12)	WL (cm)	2.91±1.81	0.55±1.03	75.0±37.1	0.36±0.67	3.75	$p<0.05$
	S.COBB	42.2°±26.7°	21.1°±18.9°	61.4±28.9	4.5°±6.5±	2.13	$p<0.05$
	LT (VB)	2.53±0.58	1.53±0.61	39.3±24.2	0.18±0.35	3.76	$p<0.05$
	SH (VB)	1.47±0.71	0.79±0.37	50.2±12.4	0.74±0.57	2.23	$p<0.05$
	SS (VB)	1.33±0.79	0.41±0.34	54.0±38.0	0.15±0.33	2.82	$p<0.05$
TYPE III (n : 27)	WL (cm)	1.38±1.29	0.50±2.40	90.0±47.1	0.15±0.37	2.21	$p<0.05$
	S.COBB	17.5°±17.4°	7.7°±11.6°	60.2±40.4	1.8°±3.7°	2.09	$p<0.05$
	LT (VB)	1.54±0.53	0.62±0.42	59.7±22.9	0.23±0..61	6.29	$p<0.05$
	SH (VB)	0.62±0.43	0.21±0.31	85.4±27.1	0.38±0.30	2.16	$p<0.05$
	SS (VB)	0.27±0.33	0.02±0.05	92.2±23.3	0.01±0.03	2.26	$p<0.05$
TYPE IV (n : 6)	WL (cm)	1.00±1.73	0.60±1.34	25.0±43.3	0.00±0.00	0.41	$p<0.05$
	S. COBB	23.8°±22.1°	14.5°±18.2°	32.0±52.9	9.6°±21.5°	0.73	$p<0.05$
	LT (VB)	2.62±0.66	0.97±0.63	65.4±22.1	0.41±0.21	4.46	$p<0.05$
	SH (VB)	1.44±0.61	0.81±0.33	51.3±11.6	3.11±0.11	2.11	$p<0.05$
	SS (VB)	1.23±0.81	0.42±0.33	53.1±37.1	0.14±0.32	2.71	$p<0.05$
TOTAL (n : 45)	WL (cm)	1.79±1.66	3.03±1.66	65.3±45.6	0.19±0.47	2.41	$p<0.05$
	F.COBB	23.9°±23.5°	11.8°±15.6°	52.3±40.7	3.4°±8.6°	2.69	$p<0.05$
	LT (VB)	1.96±0.73	0.91±0.63	55.9±25.5	0.21±0.53	6.83	$p<0.05$
	SH (VB)	1.00±0.69	0.42±0.42	69.0±31.5	0.48±0.47	2.87	$p<0.05$
	SS (VB)	0.73±0.78	0.19±0.29	75.5±35.3	0.70±0.22	2.61	$p<0.05$

shift was present, these cases appeared to be clinically normal. Overall, the mean preoperative SH was 1.0 VU and a 69.0% correction was obtained. The average preoperative SS was 0.73 VU and a 75.5% overall correction was obtained.

The least amount of correction in LT was obtained in Type II curves with 39.3%. Patients with Type II curves also had the least amount of correction in SH (50.2%) and although a statistically significant correction was achieved in SS in the early postoperative period, cases in this group had the most loss of correction (0.15 VU) at the last follow-up visit.

Patients with Type III curves had a 59.7% correction in LT but improvements in SS and SH were significantly more than the other groups (85.7% and 925.25% respectively), and loss of correction was minimal. An average of 1.8° increase in secondary half compensatory curves was seen in this group. No new curves or junctional kyphosis was observed.

A high correction was obtained in LT in cases with Type IV curves but although statisticaly significant improvements were seen in SS and SH values, this improvement was less than the other groups. Secondary curves in Type IV cases were improved but this difference was not statistically significant and loss of correction at the last follow-up visit was much higher than other groups (9.6 VU). Junctional kyphosis in 2 cases could not be corrected with instrumentation, and one case developed a junctional kyphosis postoperatively.

DISCUSSION

Cotrele-Dubousset Instrumentation was developed in France between 1978-1983(6). The system consists of two rods, multiple hooks and cross links named DTTS. Popularized in 1988 by Denis, it has been widely used in patients with spinal deformities. This system has brought the concept of three dimensional correction in scoliosis with derotation in flexible curves and transverse traction in rigid curves. It has been postulated that, when the deformity in the frontal plane is corrected with derotation, physiological sagittal contours are also restored. There have been may reports on the high corrective effect of the system in the frontal, sagittal and transverse plane (1, 4, 5).

Nagata et al have obtained a 25.5% correction of the axial plane deformity in the apical vertebra with CDI in idiopathic scoliosis. They have shown that this correction is nearly three times of these achieved with Harrington, Harrington - DTT and Lugue systems (11). Akbarnia et al have found this value to be 22% and reported this correction obtained with derotation to be the main factor in the correction of rib hump and trunk deformity (1). We have reported in 1993 that a 20% correction could be achieved in the rotation of the apical vertebra using the CDI system (2). This derotational effect was diminished towards the end vertebrae. The maximum derotational effect was seen in hypokyphotic or lordotic Type III curves and was minimal in the lumbar spine.

The report of Transfeldt in 1989 raised a controversy about the derotational effect of CDI. They reported the concept of "en bloc" derotation of the spine. In their cases although the maximum derotation was seen in the apical vertebra, more derotation occured in the neutral vertebral than the in the vertebra adjacent to the instrumentation and especially in the thoraco-lumbar junction (14, 15).

Wood et al reported that when the pelvis was taken as the reference point, the overall derotation of the spine was very small, the greatest improvement was seen in Type II curves and the reflection of the derotation effect to uninstrumented vertebrae caused inbalance problems. They pointed out that imbalance problems were seen in the coronal and sagittal planes in Type II and IV curves and in the axial plane in Type III curves (16).

Gray et al. reported that the derotational effect was no corralated with curve type and was unpredictable (7).

Mason and Coranga found that decompensation was 4% in Harrington rod instrumented patients and 41% in patients operated with CDI (9).

In light of the above mentioned findings, 45 cases operated with CDI between 1988-1992 were evaluated for spinal imbalance and decompensation problems. An overall correction of 49.6% in the, frontal Cobb angles of major curves were noted. Although all improvements were statistically significant, the greatest correction was obtained in Type III curves in which a derotation manouever had been performed.

Sagittal contours were significantly corrected in Type III curves. Although not statistifically significant a major improvement was obtained in Type II and IV curves.

An overall correction of 65.3% in weight-line deviation and 78.9% in rib hump deformity was achieved. The greatest correction in rub hump deformity and weight line deviation was seen in Type III curves with 84.7% and 90% respectively. The weight-line deviation could not be corrected to statistically significant levels in Type IV curves.

A 52.3% overall correction was obtained in secondary curves and during the 48.6 months mean follow-up period, 3.4° loss of correction was observed. A new secondary curve was seen in only one case with a Type IV curve and this was due to incorrect pre operative planning.

A 61.4% and 60.2% correction was obtained in lumbar secondary curves in Type II and Type III curves respectively and this was statistically significant. No significant effect was seen on the secondary half curves in Type IV deformities. The greatest increase in secondary curves was seen in Type IV deformities (9.6°) followed by Type II curves (4.5°).

No change was seen with instrumentation in two patients with Type II curves and a junctional kyphosis preoperatively. One case with a Type II curve had a junctional kyphosis of 16° postoperatively.

A new standardized radiological system to evaluate trunk imbalance was developed and three parameters LT, SS and SH were measured.

An overall correction of 55.9% was seen postoperatively in LT and this difference was statistically significant for all curve types. The greatest correction in LT was seen in the most flexible Type IV curves with the derotation manouever but greatest loss of correction was also seen in these curves. The least amount of correction was obtained in Type II curves with 39.3%.

An overall correction of 75.5°% was achieved in SS and this difference was statistically significant for all curve types. The greatest correction and the least amount of correction loss was seen in patients with Type III curves in which a derotation manouever had been performed.

Anoverall correction of 69% was achieved in SH and this difference was statistically significant in all groups. The maximum amount of correction was obtained in Type III curves with 85.4%. Approximately, 50% correction was seen in Type II and IV curves. The mean preoperative SH of 1.44 in Type IV curves had increased 3.11 VU at the last follow-up visit. Patients with balanced curves constituted 31.1% of all cases before surgery, this value was increased to 46.7% with instrumentation.

Several points deserve emphasis in this study:

1. A high correction can be obtained in the frontal and sagittal using derotation in flexible curves and transverse traction in rigid curves.

2. One patient out of 45 developed a junctional kyphosis.

3. Derotation in Type III curves does not cause imbalance problems in the sagittal frontal planes, and the optimal balance of the head and stable vertebra was achieved in these curves. No subjective clinical complaints were seen regarding the presumed rotation of the pelvis post-operatively.

4. Secondary curves were significantly corrected in all groups.

5. Although the main corrective force was transverse traction and the lumbar region was not instrumented in Type II curves, a significant correction was seen postoperatively. Contrary to King's findings (8) these curves did not decrease, even increased in the follow-up period. Therefore it was concluded that Type II lumber curves greater then 40° should be instrumented to prevent decompensation to the left and provide lumbar lordosis as described by Richard et al (12).

6. Although significant improvements were obtained in the frontal plane, CDI was ineffective in the sagittal plane in Type IV curves. Over correction may cause shift of head and shift of stable vertebra, result in spinal imbalance and decompensation.

7. Problems of imbalance and post operative correction loss are mainly due to errors in pre-operative planning.

In the light of these findings it was concluded that CDI was effective in achieving high rates of correction in the frontal and sagittal planes frontal and sagittal inbalance problems in Type II curves can be avoided and minimized by good preoperative planning and avoidance of over-correction. Although derotation was used in Type III curves imbalance problems were minimal and high corrections in all three planes could be achieved.

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