THE RESULTS OF LATE ONSET IDIOPATHIC SCOLIOSIS TREATED WITH TSRH INSTRUMENTATION

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The purpose of this study was to determine the effectiveness of Texas Scottish Rite Hospital (TSRH) Instrumentation a recently developed system, in the treatment of late onset idiopathic scoliosis. From September 1991 to December 1993, 53 patients treated with TSRH for idiopathic scoliosis in the 1st and 2nd Department of Orthopaedics and Traumatology of Ankara Social Security Hospital were examined retrospectively. When all curve types were included, the mean preoperative Cobb angle of the major curve that was 59.8±15.6 was corrected by 58.8±19.9%. The highest correction rate was obtained in King Type III curves with a single thoracic flexible curve (mean 64.4%). In 67.9% of the patients physiologic thoracal kyphosis and in 43.4% physiologic lumbar lordosis was reconstitued. All patients had an improvement in pulmonary functions at 6 months follow-up. These results suggested that TSRH system is a one of the best choices in the surgical treatment of idiopathic scoliosis, as it has advantages such as providing high correction rates of the deformity and possibility of building a more rigid frame with cross-link plates.

INTRODUCTION

In recent years, the development of "three plane deformity concept" in scoliosis surgery has led to the popularization of the Cotrel-Dubousset Instrumentation (CDI) throughout the world. This system builds a rigid frame with multiple hooks placed on the strategic vertebrae, double rods and DTT system. In the frontal plane, especially in flexible thoracal lordoscoliosis, this system has high correction rates in all curve patterns. High success in reconstituting physiological sagittal contours and correction of rotational deformity by the derotation manoeuvre with minimal loss of correction at follow-up has been reported with this system (3, 5).

Surgeons of the Texas Scottish Rite Hospital developed a new spinal system which is basically a modification of CDI. The most important difference of TSRH system from the other systems is the elimination of elements such as connector and blocker and the hooks are connected to the rods with "three point locking system" (1). In 1994, they reported first results of treatment of adolescent idiopathic scoliosis (10). In our study, the results of 53 late onset idiopathic scoliosis patients treated with TSRH system are evaluated.

PATIENTS AND METHODS

The first TSRH Instrumentation in our clinic was performed in September 1991. From September 1991 to December 1993, 53 patients were instrumented with the TSRH Instrumentation in the treatment of idiopathic scoliosis at the 1st and 2nd Departments of Orthopaedics and Traumatology of Ankara Social Security Hospital. Mean follow-up period was 24.4±9.1 months (12-38 months). Thirty-one (58.5%) of the patients were female and 22 (41.5%) were male. Mean age the operation time was 14.8 (11-19).

Preoperatively, patients were evaluated in detail by clinical, radiological and laboratory examinations. Preoperatively, early postoperatively and at latest follow-up, anteroposterior, lateral and bending radiograms of the patients in erect position were taken, Cobb angles in both frontal and sagittal planes were measured and their correction percentages were calculated.

Curves were grouped according to King Classification (6). Appropriate TSRH planning was done according to the suggestions made by Herring and Johnson (1, 10). The distribution of patients according to King classification and type of the performed operations are seen in Table 1. All the patients underwent a posterior fusion with a mixture of autologous and allogenic bone grafts.

Autologous blood transfusion was done in all patients using the "cell-saver" (Electromedics) system. Wake-up test was performed in the first 20 patients. After it become available, the "somatosensory evoked potentials" (SSEP) were monitored in 33 patients using the (Cadwell-Quantum 80) system. For the last 10 patients of this study, SSEP and "Transcranial cortical

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Table 1. Distribution of cases according to King Classification and surgical procedure which performed (Post.: Posterior TSRH instrumentation, A + P: Anterior discectomy and release and posterior instrumentation, Ant.: Anterior release and anterior TSRH instrumentation).

TYPE of CURVES	POST.	A + P	ANT.	TOTAL	%
TYPE I	3	1	-	4	7.5
TYPE II	11	5	-	16	30.6
TYPE III	27	-	-	27	50.9
TYPE IV	4	1	1	6	11.3
TOTAL	45	7	1	53	100
%	84.9	13.2	1.9	100	

magnetic stimulation-motor evoked, potentials" (TkMMEP) were combined for neurologic intraoperative monitoring.

The patients were turned to their sides during the first postoperative day and were seated on the 2nd day. On the 3rd day, patients were encouraged to walk. No postoperative cast or brace was utilized. All patients returned for a follow-up visit at the postoperative 1st, 3rd, 6th, 12th, 24th months. Clinical and radiological examinations were repeated and pulmonary function tests were done.

The statistical evaluation was done using the "Difference Between Means For Paired Observations" test and the "Kruskall-Wallis Analysis of Variance" test.

RESULTS

A. Frontal and Sagittal Plane:

- Type I Curves:

In this group therewere 4 patients. One of the patients had one step anterior discectomy and posterior instrumentation remaining 3 had only posterior instrumentation. The thoracal curve (frontal Cobb angles: 39°-56°) was included both in fusion and instrumentation area in Type I curves.

The mean preoperative Cobb angle was 67.5° in the lumbar and 57.5° in the thoracal curve. In bending radiograms, 38.8% and 12.2% correction rate was obtained in thoracal and lumbar curves respectively. In the sagittal plane, three patients had hypokyphosis in the thoracal region (Table 2, 3).

Postoperative correction rates in the thoracal and lumbar curves were 55.9% and 50.1% respectively. The correction rates obtained postoperatively were higher than the rates measured in bending radiograms. Futhermore, it was statistically significant (t: 2.61, $p<0.05$; t: 3.27, $p<0.05$).

Preoperative thoracal kyphosis angle (mean 24.5 degrees) and lumbar lordosis angles (mean 20 degrees) were brought to 35° and 30.5° respectively. Thus, physiological thoracal kyphosis was restored in 4 (100%) and physiological lumbar lordosis in 2 (50%) patients (Table 4).

The Cobb angle which was averagely 16.3° in the secondary curves were brought to 0° postoperatively and no other secondary curves were observed. Body balance was provided in the frontal plane in all of the patients of this group. One patient had junctional kyphosis of 10° preoperatively and was corrected to 0° postoperatively.

- Type II Curves:

There were 16 patients in this group. 11 patients underwent only posterior instrumentation, remaining 5 underwent simultaneous anterior and posterior surgery. In four of the only posterior instrumented patients, correction was achieved with a technique similiar to CDI with two rods in concave side and transverse traction with TSRH "crosslinked plates". Sublaminar wiring was added to concave apical side and translation was performed in two patints. The remaining 5 patients with only posterior instrumentation in this group had distraction and derotation for the correction of the curves. In 11 patients with Type II curves with a lumbar curve more than 40°, the lumbar curve was included in the fusion and instrumentation to prevent decompensation. The remaining 9 patients had a large flexible minor lumbar curve, and a selective thoracic fusion and instrumentation was done.

Mean preoperative Cobb angle was 73° in the thoracic region and 39.8° in the lumbar region (Table 2).

Table 2. Preoperative (**PR**), side bending (**B**) and postoperative (**PO**) Cobb angles of major curves of the patients with idiopathic scoliosis treated with **TSRH** instrumentation and their correction percentages (**CP** %), correction loss (**CL**) values and percentages (**CL** %) in the frontal plane according to the different type of curves (±**SD** : standart deviation).

TYPE OF CURVES	PR	B	CP % (B)	PO	CP %	CL	CL %	t	p
Type I (n : 4)	67.5°±10.4°	63.8°±6.2°	38.8±14.6	38.3°±14.6°	50.1±18.6	6.0°±6.0°	8.9±7.1	3.27	<0.05
Type II (n : 16)	73.0°±15.9	65.6°±18.9°	37.3±17.1	37.3°±17.1°	50.1±17.9	6.0°±4.5°	8.2±4.2	6.11	<0.05
Type III (n : 27)	52.4°±11.2°	32.0°±14.3°	19.1±13.7	19.1°±13.7°	64.4±20.6	4.3°±3.6°	8.2±5.4	9.78	<0.05
Type IV (n : 6)	52.5°±10.5°	36.5°±14.1°	20.3±9.2	20.3°±9.2°	62.1±16.4	7.0°±6.3°	13.3±8.4	5.02	<0.05
Total (n : 53)	59.8°±15.7°	42.7°±21.5°	26.2±16.6	26.2°±16.6°	58.8±19.9	5.2°±4.5°	8.7±7.8	10.68	<0.05

Table 3. Pre (**PR**) and postoperative (**PO**) sagittal contour angles of different curve types. (T: Thoracal, L: Lumbar, n: number of cases, CL: Correction loss in the last follow-up visit, A: Average, Sd: Stardart Deviation).

		PR A ± Sd	PO A ± Sd	CL A ± Sd	t	p
Type I	T	24.5°±14.3°	35.0°±4.1°	0.5°±1.0°	(-1.42)	>0.05
n = 4	L	20.0°±20.7°	30.5°±5.3°	0.8°±0.9°	(-0.98)	>0.05
Type II	T	27.8°±25.9°	33.7°±15.7°	3.9°±5.2°	(-0.77)	>0.05
n = 16	L	23.3°±13.7°	29.1°±14.2°	1.4°±2.8°	(-1.16)	>0.05
Type III	T	21.9°±26.3°	34.9°±10.6°	5.3°±10.9°	(-2.39)	<0.05
n = 27	L	23.2°±15.1°	33.6°±10.8°	2.1°±5.6°	(-2.92)	<0.05
Type IV	L	15.6°±10.1°	26.2°±13.7°	26.1°±13.7°	(-0.90)	>0.05
n = 6	L	18.3°±10.1°	28.5°±5.4°	6.3°±6.4°	(-2.21)	<0.05
TOTAL	T	23.2°±24.9°	33.6°±12.4°	4.9°±8.9°	(-2.72)	<0.05
n : 53	L	22.4°±14.3°	31.4°±11.2°	2.2°±4.9°	(-3.60)	<0.05

Table 4. Distribution of cases according to deviation from physiological thoracal sagittal contours after instrumention with TSRH.

SAGITTAL CONTOUR	Type I	Type II	Type III	Type IV	Total
Within normal limits	4 (100%)	9 (56.3%)	19 (70.4%)	4 (66.7%)	36 (67.9%)
Deviation less than 10°	-	3 (18.8%)	6 (22.2%)	2 (37.3%)	11 (20.8%)
11°-20° deviation	-	3 (18.8%)	2 (7.4%)	-	5 (9.4%)
Deviation more than 21°	-	1 (6.2%)	-	-	1 (1.9%)
TOTAL	4 (100%)	16 (100%)	27 (100%)	6 (100%)	53 (100%)

in bending radiograms, we obtained 23.1% of correction in thoracal curves and 34.3% of correction in lumbar curves. The correction rate was statistically significant (t: 6.11, $p<0.05$). In this group, postoperatively, rigid thoracic curves decreased to 37.3 and a mean correction of 50.1% was obtained which was more than the correction rates measured in the bending radiograms. 42.6% of correction in lumbar curves was achieved.

We determined that preoperative sagittal contours in this group were lordotic, hyokyphotic or kyphotic. Preoperative mean thoracic kyphosis angle was 27.8° ((-18°) - 90°) (Table 3). Postoperatively mean thoracic kyphosis was 33.7°. In 12 (75%) patients this value was in the physiological sagittal range limits. In only 4 patients, it differed 10° of normal limits. Preoperative lumbar lordosis was 23.3° and became 29.1° postoperatively. Normal physiological lordosis was obtained in 8 (50%) patients in this group.

Cobb angle which was averagely 22.4° in the secondary half curves, was brought to 8.1° postoperatively. Thus, a significant correction was obtained in secondary curves. Futhermore, none of the patients had junctional kyphosis postoperatively.

- **Type III Curves:**

In this group, all of the 27 patients underwent to posterior surgery. Derotation manoeuvre was performed in all patients. Distal neutral vertebra was instrumented with a reverse hook with compression on the concave side to prevent decompensation.

Mean preoperative Cobb angle was 59.8°. In the bending radiograms, major thoracal curve was corrected by 40.8%. Postoperatively major thoracal curve was corrected 64.4% with a decrease to 19.1°. The correction rate achieved with surgery was statistically significant more than the bending radiograms (t: 2.04, $p<0.05$).

Preoperative mean kyphosis angle was 21.9° ((-15°)-90°) and mean lumbar lordosis was 34.9°. Postoperatively, mean thoracic kyphosis angles became to 34.9. In 19 (70.4%) patients, thoracic physiological kyphosis was restored. Postoperative mean lumbar lordosis was 33.6°. In 13 (48.2%) patients, normal physiological lumbar lordosis was obtained.

For secondary half curves, Cobb angles were 9.7° in upper curve, and were 12.4° in lower curve. Postoperatively correction rate of secondary curves were 77.4~ and 77.8~ respectively. In this group, no postoperative junctional kyphosis occured.

- **Type IV Curves:**

In this group, there were 6 patients. Four of them underwent only posterior instrumentation. Simultaneous anterior discectomy and posterior instrumentation was performed in one patient. The other patient had only anterior instrumentation.

Mean preoperative Cobb angle of thoracolumbar curves was 52.5° and decreased to 48.4% in side bending radiograms. Postoperative mean Cobb angle was 20.3° with a correction rate of 62.1%. This correction was statistically significant (t: 5.63, $p<0.05$).

Preoperative mean thoracic kyphosis angle was 15.7° which was corrected to 26.2° postoperatively. In 3 (50%) patients physiological thoracal kyphosis was obtained. Mean preoperative lumbar lordosis was 18.3° and came to 28.5° postoperatively. But, physiological lumbar lordosis was not achieved in any patients.

Mean preoperative Cobb angle of upper thoracic secondary curve was 19° and 59.6% of correction was obtained on side bending. Postoperatively, Cobb angle of secondary curve was brought to 9° with a correction of 28.2%.

Preoperative junctional kyphosis which was 3.3° averagely, decreased to 2.5° postoperatively. This correction was not statistically significant.

In 6 patients of this group, despite the three different methods utilized, no conclutaions can be reacher about the effectiveness of these methods because of the few number of cases. But in a patient who had 20° of junctional kyphosis. After the same day combined anterior discectomy and anterior instrumentation, junctional kyphosis angle decreased to 0°. Althought the significant correction of junctional kyphosis was obtained, was not as effective as on the correction of thoracal kyphosis and lumbar lordosis.

- **Overall Assestment:**

Preoperative mean Cobb angle of the major curves was 59.8°±15.6° and the correction rate for these curves was 58.8±19.9%. This rate was 38.4±43.9% and 35.8±38.2% for proximal and distal secondary curves respectively. The preoperative mean 23.4°°24.9° value of thoracic kyposis increased to 33.6°±12.4° postoperatively. Physiologic thoracic kyphosis was obtained in 36 of 53 patients. The preoperative mean 22.4°±14.3° value of lumbar lordosis was brought to a mean angle of 31.4°±11.2° and 23 (43.4%) of 53 patients had normal contours postoperatively. This concluded that correction rate in the sagittal plane was higher than the lumbar curves in the thoracal region.

B. Follow-up:

After a mean of 24.4 months follow up, the loss of correction in major curves for King Type I scoliosis patient was 6.0°±6.0° and it was 9.3°±8.1° for secondary thoracic curves. In the sagittal plane the loss of correction was 0.5°±1.0° for thoracic kyphosis and 0.8°±0.9° for lumbar lordosis.

For King Type II curves the loss of correction was 6.0°±4.5° for major curves and 8.6°±9.7° for secondary lumbar curves. This rate was 3.9°±5.2 for thoracic kyphosis and 1.4°±2.6° for lumbar lordosis.

For King Type III curves, there was no loss of correction for secondary curves while it was 4.3°±3.7° for major thoracal curves.

In King Type IV curves, the rate of correction loss was 4.0°±6.3° for major curves and 6.3°±6.4° for lumbar lordosis.

The overall rate of correction loss was 2.2°±4.5 for major curves, 6.4°±7.5° for lumbar secondary curves and 1.7°±1.5° for thoracic secondary curves while it was 4.9°±8.9° for thoracic kyphosis and 2.3°±4.9° for lumbar lordosis.

All patients had solid fusion mass. No pseudoarthrosis was seen.

C. Complications:

A complication 18.9% (10 patients) was seen. Six patients had hook dislodgement and one of them was revised with replacement of the hooks. The remainng five had a solid fusion mass, the implants were removed and no further surgery was necessary.

Two patients had deep wound infection and both were treated with implant removal and antibiotherapy. A revision surgery was not considered in a patient which 22° of correction loss after implant removal with Type II curve pattern as a solid fusion mass was observed at the second month control of this patient. The other patient who had implant removal had Type II curve pattern. In this patients reinstrumentation was planned but later was abondened because T12-L5 syringomyelia was diagnosed after Magnetic Resonance Imaging occasion revison would be risky was deemed to risky.

An incomplete paraplegia was noted in one patient at the postoperative third day and with recovered a with exception of slight dorsiflexion weakness at three months. An e

DISCUSSION

In the last decade, the three plane deformity concept of idiopathic scoliosis has led to the evolution of spinal instrumentations that correct the deformity in all three planes. Multiple level fixation with wires or hooks at strategic vertebrae, double rods and transverse connecting devices have become the state-of-the-art technology in addressing this complex problem (2).

Cotrel-Dubousset system has found a wide utilization in spinal surgery in the recent years and there are a number of reports suggesting its high correction potential in all planes when compared to other systems. With the derotation manoeuvre, correction of rotational deformity in the transverse plane which is a revolution in spinal surgery can be achieved (4, 5).

A rigid plate implant, which is connected to a spinal rod with an eye-bolt and locking nut, now available as the Texas Scottish Rite Hospital (TSRH) Crosslink was developed to bring the concept of rigid crossbracing to reality by Johnston and Ashman, after their studies on the rod migration problem in the Luque-SSI system. The axial stiffness of an SSI construct was significantly improved by the simple addition of cross-links (1, 10).

In 1987 Johnston et al. reported that although a significant amount of derotation could be achieved with the Cotrel-Dubousset Instrumentation, its resistance to torsional loads was not sufficient. Biomechanical testing showed that the CDI system's resistance to torsion could be increased significantly with TSRH cross-link plates (1).

In 1989 surgeons of Texas Scottish Rite Hospital developed the TSRH system which is basically a modification of CDI. Major advantages of the system are attachment of all elements to the rod by a three point locking system, all of the hooks are open and can be attached easily to the rods, the rods have 3 different types with varying hardness and 3 different screw designs. It has been reported that three point locking system has more rigidity than the rigidity achieved by breaking both screws on a closed CD hook (1). As all of the hooks are attached to the rod by the same system, it eliminates elements such as the connector, blocker and collar (1, 10).

One of the major advantages of TSRH is its ease of instrumentation and revision. In CD if the screws are broken, hooks can be removed only by cutting the rod. As placement of the nuts are lateral, cosmetic complaints due to te prominent hooks and rods under the skin aren't seen contrary to CDI (1).

In the study of Richards et al thoracic curve correction averaged 65% in those with Type III/IV curves and 54% in those with Type II curves inatients treated with TSRH (11). In our study, the highest correction was obtained in the King Type III curves (64.4%). In type II curves, 50.1% of correction was obtained.

Richards et al also stated that lumbar curve correction after instrumentation in Type I and II curves averaged 48% postoperatively (10). In tour study, 50.1% of correction was obtained in lumbar region.

In the study, it was noted that in the frontal plane, more correction was obtained in thoracal curves than the lumbar curves. It was concluded that low correction rates obtained in the lumbar region could be improved by the use of transpedicular screws and by anterior release in rigid curves.

Richards et al reported a 14% loss of correction in their series (10). Shufflebarger found no loss of correction using CD instrumentation (12). Puno found 12% loss of correction in King Type II curves and 8% loss in King II curves (8). When all the patients were included there was an 8.7% mean loss of correction in this study (Table 2). Both in Type II and III curves, there was a 8.2% loss of correction. The most significant loss of correction was in Type IV curves with an average of 13.3%.

Richards et al also reported 43% improvement in sagittal contours of hypokyphotic pienatients (10). In our series, when all patients were included, postoperative thorcal kyphosis was 33.6° and lumbar lordosis was 31.4° averagely. In 67.9% of the patients thoracal kyphosis angles were within physiological limits. The best corrections in thoracal kyphosis were see in Type III curves, in which a derotation maneouvre had been performed. 70.4% of these patients were in physiological limits in the postoperative period.

Trunk balance and decompensation after surgery with CD instrumentation has been critically evaluated over the past several years (7, 13). TSRH Instrumentation uses the same maneouvres as CD for the correction of scoliosis (distraction, compression, and rotation) and, therefore, is susceptible to the same problems of postoperative decompensation. Richards et al reported that imbalance problems were not seen in the single thoracal curves (10). Roye et al evaluating Type III and IV curves, also found optimum balance when fusion was stopped short of the stable vertebra (11).

In patients with King Type II curves, decompensation of the trunk to the left can be expected if a selective thoracic fusion is inappropriately performed. During preoperative surgical planning of patients with King II curves, the surgeon should be cautious when considering a selective thoracic fusion. Preoperative assesment of the flexibility of the lumbar curve, noted on side -bending radiograms, is by itself ineffective in predicting how the lumbar curve will respond to a selective thoracic fusion (10). If the lumbar curve magnitude exceeds 40° and if the center of the apical lumbar vertebra deviates substantially to the left of the center sacral line, then instrumentation in to the lower lumbar spine should be given serious consideration (7, 9, 11, 13).

In our study, no balance problems were seen in Type I curves. Type II curves that had been fused selectively demonstrated an increase in Cobb angles during the follow-up period. Rigid lumbar curves greater than 40° in Type II curves were instrumented and decompensation problems were minimized both the frontal and sagittal planes.

A high rate of correction in the sagittal and frontal plane was achieved in Type III curves in this study and no decompensation was observed. This was attributed to avoidance of overcorrection and the utilization of reverse hooks in distal neutral vertebra to achieve lumbar lordosis.

Imbalance problems were see mainly in Type IV curves. Althought high correction rates were obtained with posterior instrumentation in the frontal plane, a negligable amount of correction was seen in the sagittal plane. Although the anterior TSRH instrumentation is successful in correcting junctional kyphosis (14), its effect on restoring physiological sagittal contours is debatable.

A 18.9% complication rate was seen in this series. The infection rate was 3.8% and was comparable with other studies in the literature. One patient (1.9%) had an incomplete neurological deficit.

In light of these findings, TSRH instrumentation in the treatment of idiopathic scoliosis achieves (1) a rigid frame with multiple hooks, screw and cross-linked plates, (2) high correction rates in the frontal and sagittal plane, (3) low rates of complications and loss of correction. Frontal and sagittal imbalance problems can be minimized with the use of long construction in Type II curves, and distal concave reverse hook in Type III curves. The use of transpedicular hooks in the lumbar region can increase correction rates.

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