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Cotrel-Dubousset instrumentation for the treatment of severe scoliosis

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Abstract In a multicentric study, 36 cases (40 curves) of severe scoliosis were analysed; 19 were idiopathic and 17 neurological, Cobb angles ranged from 70° to 145°, all had undergone three-rod Cotrel-Dubousset (CD) instrumentation. The correction on the frontal plane achieved more than 50% of the preoperative angle (53.9% for idiopathic curves and 55.6% for neurological ones). On the sagittal plane the pathological shape of the spine was reduced and distinctly ameliorated. In ten patients, the authors successfully applied a technique, alternative to the original one, which was based on the use of two or three screws in the lumbar area, one supplementary pedicle transverse claw on the cranial area and two rods connected by a

domino, instead of a single rod (the longer one applied on the concave side). The main complications were: one case of infection, three of vascular compression of the duodenum, one of crank-shaft phenomenon and one laminar hook displacement. The excellent result achieved in both, idiopathic and neurological severe and stiff scoliosis shows the efficacy, reliability and versatility of CD three-rod instrumentation.

Key words Spinal instrumentation · Spinal fusion · Surgical treatment of scoliosis

Introduction

The Cotrel-Dubousset (CD) surgical technique [2, 3], used since the beginning of the mid 1980s has, over the past decade, represented the highest level achieved in correction of scoliosis by a posterior approach. This instrumentation left Harrington [6] and Luque [7] techniques behind, because it guarantees a better correction [5], allows recovery of kyphosis and lordosis [3, 4, 8], minimizes the neurological risk and eliminates postoperative cast or brace.

While the advantages of the CD technique are evident in the treatment of flexible and moderate curvatures, they are of particular value in treating severe and stiff ones, greater than 70°–80°, with evident trunk imbalance and

rotational kyphosis. For this specific group, Harrington tries correction by increasing the traction forces using two rods on the concave side, while the Luque technique is not advisable because of the increased neurological risk from sublaminar wires which, in this condition, pass dangerously close to the cord in the central part of the concavity.

As proposed by the authors, the CD technique [2–4] envisages a three-rod instrumentation, two of which are applied on the concave side creating distraction forces (a long one between the end vertebrae and a shorter one between the intermediate ones) and are approximated by two DTTs, thus opening the curvature and shifting its apex towards the middle line. The third rod, on the convex side, applies compression forces and, by means of an apical hook, allows pushing of the apex of the deformity from the posterior to anterior. Since there are various anchorage points, even in

these severe curves the instrumentation improves correction, regains the sagittal profile of the spine and eliminates the need for any postoperative cast or brace.

Using this three-rod technique over time, while not observing significant failures or complications due to material, we began to adopt some technical variations in order for the longer rod on the concave side to gain a more solid hold on the end vertebrae and in order to optimize recovery of the sagittal profile, to achieve greater intraoperative dexterity, to better distribute the corrective forces in all parts of instrumentation and, in this way, to minimize the theoretical neurological risks.

The first long rod, on the concave side, is divided into two parts interconnected by a sliding domino, which acts to open out the concavity of the curve: on the lumbar area we used two or three screws instead of hooks to regain a more effective lordosis by a rotating manoeuvre of the prebent rod; on the cranial one we used two pedicle transverse claws, instead of one, to increase the hold and to avoid the risk of concentrating corrective stresses on only one vertebra (Fig. 1A,B). On the long rod on the convex side we substituted the pedicle hook on the apical vertebra with one pedicle transverse claw (Fig. 1D) (sometimes two claws in the apical area – Fig. 1C), to avoid intrusion of this hook into the canal. Analysis of the 36 severe scolioses treated with three-rod CD instrumentation will provide us with useful information regarding the adaptability of the technique to the various patterns of the deformity, the rate of complications and the validity of our technical variations, which were applied in ten cases (Table 1: idiopathic cases 1–6, 9, 12 and neurological cases 1, 6).

Materials and methods

In a multicentric study, involving the orthopaedic and traumatology department at the University of Bari together with the two orthopaedic divisions of the Gaslini Institute of Genoa, 36 cases (Table 1) of scoliosis (40 curves), with Cobb angles ranging from 70° to 145° and treated using the technique of three-rod instrumentation, were analysed.

The scoliosis was idiopathic in 19 patients (13 females, 6 males) and 21 curves and neurological in 17 patients (11 females, 6 males) and 19 curves.

This second group comprises scoliosis following cerebral palsy ($n = 11$), arthrogryposis ($n = 1$), Friedreich's ataxia ($n = 1$), spinal amiotrophy ($n = 3$), and poliomyelitis ($n = 1$).

In the idiopathic scolioses, 13 curves were thoracic, 4 thoracolumbar, and 2 double curve (thoracic+thoracolumbar). The mean Cobb angle was 97.5° and bending 68°.

In the neurological scolioses there were 2 thoracic and 13 thoracolumbar curves, 1 double curve (thoracic + lumbar) and 1 double curve (thoracic + thoracolumbar). The mean Cobb angle was 106.8° and bending 71.6°.

Regarding sagittal contour and considering as normal [1, 10] values ranging from 26° to 44° for kyphosis, measured between T4 and T12, and those ranging from 42° to 57° for lordosis, measured between L1 and L5, there were 12 hypokyphoses (6 idiopathic and 6 neurological), 20 hyperkyphoses (11 idiopathic and 9 neurological) and only 4 normal kyphoses (2 idiopathic and 2 neurological). There were also 14 hypolordoses (9 idiopathic and 5 neurological), 10 hyperlordoses (4 idiopathic and 6 neurological) and 12 normal lordoses (6 idiopathic and 6 neurological). The diagnostic period ranged from neonates to 14 years.

Two-thirds of the subjects with idiopathic deformities had medium or serious respiratory insufficiency; in the neurological patterns, respiratory insufficiency was worse and in many subjects ($n = 11$) it was not possible to carry out this examination, due to lack of collaboration.

Fig. 1 **A** Preoperative planning of the first rod: two pedicle transverse claws in the upper area and the short rod on the lumbar region. The rod will be inserted into the three screws, and will then be rotated by 90°. **B** The two rods, after being firmly fixed onto the vertebrae, are inserted into the interconnecting domino, which allows easy distraction of the curve. Based on this first assembled rod, the horizontal traction system can act to bring the apex of the curve to the middle line. **C** On the convex side, two pedicle claws, one above and one below the apical vertebra, allow compression forces to be applied and at the same time allow the apex to be pushed forwards without risking apical hook intrusion into the canal. **D** On the convex side, instead of an apical hook, in order to avoid neurological risks it is more effective to use a pedicle transverse claw

Surgery was performed at between the ages of 8 and 42 years, with an average age of 16 years (16.1 years for idiopathic cases and 15.8 years for neurological ones).

For idiopathic scoliosis, Halo preparation was carried out for nearly 2 months in six cases, an elongation (Stagnara) cast in one case [10] and only traction and respiratory rehabilitation for 1 h/day for at least 2 months in 12. In the neurological deformities, Halo preparation was used five times.

The reasons why Halo was used were stiffness and severity of the curve (average value 113° in idiopathic and 128° in neurological cases), severe respiratory insufficiency and, in one case, the age of the patient (42 years) with consequent degenerative joint disease rigidity of the spine.

The fusion area comprised on average 14 vertebrae (min. 9 and max. 17); the upper end vertebra was usually T2 or T3 (in 15 cases of idiopathic and 11 cases of neurological scoliosis) and the lower end was usually L3 or L4 in idiopathic curves (14 of cases) and L4 or S1 in neurological scoliosis (12 of 17 cases).

Extension of the fusion area to the sacrum in neurological deformities was necessary to correct pelvic obliquity, which affected eight patients.

In two idiopathic and four neurological scolioses, anterior release was carried out with removal of five to eight discs at the thoracic or thoracolumbar area, to render the curvature more flexible during posterior instrumentation and to guarantee a circumferential solid fusion.

Anterior approach surgery was performed 2 weeks before the posterior one, and on average lasted 4 h. For fusion, iliac autogenous bone grafts were used in all cases, but in two neurological ones we were forced to add homologous bone grafts.

Postoperatively, standing position and deambulation were allowed when general clinical conditions permitted (4–15 days after the second operation).

In order to reduce mechanical stress on the instrumented vertebrae during the first postoperative weeks, a cast or brace was applied for approximately 3 months in 14 idiopathic and 12 neurological scolioses.

Surgery lasted on average 7 h 30 min, with no difference between the two groups, and varied between 6 and 9 h. Blood loss was measured from intraoperative suction and the weight of blood-soaked swabs. Autogenous blood was used in eight idiopathic and two neurological scolioses, while homologous blood was given in the remaining cases. Of these, five patients in the idiopathic group and 12 in the neurological group were deemed unsuitable for autotransfusion, due to age, weight and/or iron count.

In six cases the intra-operative wake-up test was carried out, while the others were monitored by SEPs.

Results

Results were evaluated postoperatively and at an average follow-up of 3.1 years for idiopathic deformities (min. 2 years, max. 5.2 years) and of 3.2 years for the neurological cases (min. 2 years, max. 6.5 years) (Figs. 2, 3).

In idiopathic cases (19 cases and 21 curvatures) a mean correction of 53.9% was achieved (initial curve angle of 97.5° reduced to 45°), while in the cases of scolioses with known aetiology (17 cases and 19 curvatures), mean correction achieved was slightly greater, at 55.6% (initial curve angle of 106.8° reduced to 47.4°). Mean loss of correction at follow-up was 2° for the idiopathic group and 2.6° for the neurological one.

Apical rotation (measured by Perdriolle's torsionmeter) in 10 idiopathic and in 15 neurological curvatures was

corrected by an average of 8.5° (range 37°–28.5°) for the former and 14.7° (range 42.3°–27.6°) for the latter.

The mean percentage of correction achieved in scolioses that underwent anterior release was 51.7%, which is close to the correction obtained in the other cases (53.9% idiopathic and 55.6% neurological). During the posterior approach, in cases with previous release, we observed a lesser stiffness of the curvatures and an easier corrective realignment.

Results on the sagittal plane show that the mean hypokyphosis of 13.6° found in six cases of 6 idiopathic scoliosis was improved to 21°; in cases of neurological deformity the initial mean hypokyphosis of 10.3° found in six patients changed to 27.3°. Normal kyphoses (two idiopathic and two neurological) maintained values within the normal range in three cases, while the fourth (neurological) changed from 38° to 50°. Mean rotational hyperkyphosis, found in 11 cases of idiopathic scoliosis, changed from 69.2° to 34°, while in the nine neurological cases it was reduced from 72.5° to 49.1°.

Hypolordoses, with a mean value of 31.6° in nine idiopathic scolioses and 33.2° in five neurological scolioses, remained at 35.1° and 32° respectively; normal lordoses maintained values within the normal range in the six idiopathic cases (46.5°–42.6°) and it was the same for the six neurological hypolordoses (44.5°–41.8°). Mean hyperlordosis in the idiopathic group (four patients), was reduced from 61.5° to 44.7° and in the neurological (six patients) from 64.8° to 40°.

Blood loss was on average 1450 cc in idiopathic cases and 1800 cc in the neurological ones, with minimum loss 800 cc and maximum 2850 cc.

Complications and failures

In one case (no. 11, idiopathic) operated at age 11, failure was due to the onset of crank-shaft phenomenon, which led to a 15° loss of correction for each curvature in the following 2 postoperative years, during growth spurt.

In one case (no. 7, idiopathic) we reported the displacement of a caudal hook, which led to reoperation after a few days and did not cause loss of angular correction. One case of infection (no. 4, neurological) led to removal of instrumentation after 6 months and consequently to a 30° loss of correction. One case of loosened stitches (no. 12, neurological) finished without consequences.

Vascular compression of the duodenum [9] occurred after anterior approach in two cases (nos. 12, 13, idiopathic), which resolved with medical therapy, while in a third case (no. 14, idiopathic) this occurred during preoperative Halo traction and explorative laparotomy was required, but the findings were negative.

Table 1 Details of the 19 idiopathic and 17 neurological scoliosis cases (*T* thoracic, *TL* thoracolumbar, *VCD* vascular compression of duodenum)**A Idiopathic scoliosis**

No.	Case	Sex	Age	Aetiology	Pattern	Preop treat- ments	Respiratory insufficiency	Scoliosis Cobb angle (°)				Kyphosis (°)		Lordosis (°)	
								Pre- op	Ben- dings	Post- op	F-Up	Pre- op	Post- op	Pre- op	Post- op
1	F.L.	F	42	Idiopathic	T	Halo	Severe	98	90	48	48	16	26	23	36
2	P.L.	F	13	Idiopathic	T	Halo	Severe	110	72	32	32	36	26	60	54
3	S.A.	M	16	Idiopathic	T	Halo	Severe	115	104	43	43	80	45	41	50
4	G.F.	M	13	Idiopathic	T	Elong. cast	Medium	80	52	38	38	18	25	36	36
5	M.R.	F	17	Idiopathic	TL		Medium	85	52	25	28	80	34	57	55
6	A.P.	M	15	Idiopathic	T		No	108	45	35	38	79	40	36	36
7	C.V.	F	16	Idiopathic	T		Severe	98	73	46	46	24	29	36	30
8	C.A.	F	12	Idiopathic	T		Medium	95	50	60	60	68	37	60	45
9	F.E.	F	15	Idiopathic	TL		No	112	60	48	48	49	24	68	50
10	G.C.	F	14	Idiopathic	T		No	80	68	50	50	40	32	43	35
11	L.S.	F	11	Idiopathic	T+TL		Medium	73–92	54–49	36–45	50–60	55	35	33	38
12	M.O.	F	15	Idiopathic	T	Halo	Medium	145	94	68	70	88	35	45	40
13	M.C.	M	15	Idiopathic	T	Halo	Medium	120	95	90	90	79	45	32	35
14	Z.K.	F	13	Idiopathic	T	Halo	Severe	90	63	55	55	–20	–10	28	30
15	G.G.	F	14	Idiopathic	TL		Slight	95	60	30	30	20	26	20	25
16	L.P.V.	M	18	Idiopathic	T		Slight	87	50	40	40	55	36	44	40
17	M.D.	F	16	Idiopathic	TL		No	82	52	20	23	24	30	58	30
18	N.E.	M	17	Idiopathic	T+TL		No	85–104	85–75	48–55	48–55	59	25	46	40
19	R.L.	F	14	Idiopathic	T		No	95	85	34	36	70	60	44	46

B Neurological scoliosis

No.	Case	Sex	Age	Aetiology	Pattern	Preop treat- ments	Respiratory insufficiency	Scoliosis Cobb angle (°)				Kyphosis (°)		Lordosis (°)	
								Pre- op	Ben- dings	Post- op	F-Up	Pre- op	Post- op	Pre- op	Post- op
1	M.S.	F	13	Friedreich At.	T	Halo	Severe	105	89	50	52	38	28	40	35
2	D.M.	M	21	Cerebral palsy	TL		Not cooperat.	95	80	52	55	–15	23	43	40
3	D.F.	M	16	Arthrogryposis	TL		Medium	93	75	56	58	55	15	45	40
4	Z.S.	F	32	Post-polio myel.	T+L		Severe	88–107	60–80	50–50	60–70	68	43	68	48
5	A.P.	F	12	Cerebral palsy	TL		Not cooperat.	107	72	56	59	18	28	68	40
6	C.C.P.	M	16	Spinal amiotrophy	T	Halo	Severe	116	98	50	53	12	35	28	26
7	C.C.	F	16	Cerebral palsy	TL		Not cooperat.	110	50	20	20	49	38	38	36
8	D.M.	F	17	Cerebral palsy	TL	Halo	Not cooperat.	170	90	42	42	45	28	44	38
9	D.C.	F	10	Spinal amiotrophy	T+TL		No	87–70	50–50	32–35	32–36	24	30	58	43
10	D.B.	F	8	Cerebral palsy	TL		Not cooperat.	117	94	80	80	8	20	22	27
11	F.B.	M	15	Cerebral palsy	TL	Halo	Not cooperat.	115	84	43	43	99	55	60	42
12	G.A.	F	12	Cerebral palsy	TL		Not cooperat.	120	85	60	60	110	140	70	40
13	G.D.	F	24	Cerebral palsy	TL		Not cooperat.	90	77	50	52	64	30	38	36
14	M.D.	M	12	Spinal amiotrophy	TL		Not cooperat.	98	25	40	40	88	46	43	40
15	P.M.	F	14	Cerebral palsy	TL	Halo	Not cooperat.	134	80	46	49	75	35	47	43
16	P.A.	M	19	Cerebral palsy	TL		Slight	110	68	50	50	38	50	65	27
17	P.D.	F	13	Cerebral palsy	TL		Not cooperat.	98	55	40	40	45	40	45	50

Rotation (°)		Posterior fusion area	Operating time (h/min)	Bone graft	Blood loss (cc)	Blood transfus	Anterior release	Operating time (h/min)	Cast of brace (months)	F-Up (months)	Complications
Pre-op	Post-op										
45	40	T2–L4	7	Autol.	1000	Autol.			2	48	
50	40	T1–L3	8	Autol.	800	Autol.			2	30	
20	15	T1–L3	8	Autol.	1200	Autol.				30	
25	15	T2–L4	7	Autol.	1300	Autol.				33	
		T2–L4	7	Autol.	1100	Autol.				24	
		T6–L2	8	Autol.	1000	Homol.			3	48	
		T3–L3	7	Autol.	1000	Homol.				30	Hook displacement
		T3–L2	7	Autol.	800	Homol.			3	44	
		T2–L4	8	Autol.	1700	Homol.				34	
		T3–L3	7	Autol.	1900	Homol.			3	32	
		T2–L3	7	Autol.	1900	Autol.			3	48	Crank-shaft phenomenon
		T3–L3	8	Autol.	2000	Homol.	T6–T12	4	3	40	VCD
		T3–L4	7	Autol.	1500	Homol.	T6–L2	3.05	6	38	VCD
		T2–L2	8	Autol.	1200	Autol.			3	30	VCD
45	30	T3–L4	7.30	Autol.	1900	Homol.			3	52	
40	30	T2–L3	7.30	Autol.	2500	Homol.			3	30	
20	20	T2–L2	7	Autol.	2000	Homol.			3	50	
25–80	25–50	T2–L4	6.30	Autol.	2100	Homol.			3	24	
20	20	C7–T10	6	Autol.	800	Homol.			3	62	

Rotation (°)		Posterior fusion area	Operating time (h/min)	Bone graft	Blood loss (cc)	Blood transfus	Anterior release	Operating time (h/min)	Cast of brace (months)	F-Up (months)	Complications
Pre-op	Post-op										
25	15	T3–L4	7	Autol.	800	Autol.				24	
		T2–L3	9	Autol.	1900	Homol.				36	
		T2–S1	9	Aut.+hom.	1500	Autol.				30	
		T2–S1	8	Aut.+hom.	2850	Homol.	T12–L4	5		30	Infection
45	20	T5–L4	6.30	Aut.+hom.	1500	Homol.				72	
60	45	T3–L2	7	Autol.	1200	Homol.			3	24	
50	30	T3–S1	8	Autol.	2500	Homol.			3	42	
80	50	T2–S1	8.30	Autol.	2400	Homol.			3	78	
15–25	10–15	T3–S1	7	Autol.	1800	Homol.			3	39	
50	25	T6–S1	6	Autol.	1300	Homol.	T9–L3	4	3	28	
50	25	T3–L4	7.30	Autol.	1850	Homol.			3	76	
50	35	T5–L5	7.30	Autol.	1700	Homol.	T9–L3	4	3	24	Loosened stitches
40	30	T6–L2	7	Autol.	1600	Homol.			3	32	
30	15	T4–L5	5.30	Autol.	2000	Homol.			3	36	
45	45	T2–S1	8	Autol.	2100	Homol.			3	30	
45	35	T2–S1	7	Autol.	2100	Homol.	T9–L3	4	3	24	
25	20	T6–L4	6.30	Autol.	1600	Homol.			3	28

◀ **Fig. 2** S. A. Right convex thoracic idiopathic scoliosis (115°) with associated rotational hyperkyphosis (80°), well corrected on both frontal (43°) and sagittal (45°) planes. The three-rod instrumentation technique was modified regarding the first rod (long rod in the concavity): we have two rods interconnected by a “domino device”, which avoids protrusion of the rod beyond the end hooks, since sliding of the two rods occurs in the central part of instrumentation. Moreover, using two pedicle transverse claws instead of one in the upper part of instrumentation and three screws in the lumbar region guarantees strong fixation of the rod and allows, without risk of hook dislodgment, effective traction of the second rod (short, in the concavity) towards the first

Fig. 3 P. L. Idiopathic thoracic scoliosis with a good correction on the frontal plane (from 110° to 32°). Note the pedicle transverse claw instead of the apical hook on the convex side. Sometimes, as in this case, the distraction force necessary to correct the curve on the frontal plane may reduce normal thoracic kyphosis

Discussion

Our results show that the outcome of CD instrumentation in cases of severe and stiff scoliosis is far more dependent

on biomechanical aspects linked to the deformity than to the aetiology of the scoliosis – in particular whether it is idiopathic or not. This study shows both groups achieved corrections of over 50% (53.9% for idiopathic curves and 55.6% for neurological ones), with only a 1.7% difference in the level of correction between the two groups.

Only the curve associated with arthrogryposis (case no. 3, neurological), in which rigidity is characteristic, showed a lesser degree of correction (40%), which may be related to aetiology.

The very low levels of loss of correction at follow-ups after 3 years (2° and 2.6° for idiopathic and neurological respectively) show the strength of three-rod instrumentation.

Another observation is that in order to obtain a more significant correction, anterior discectomy, even if only performed in serious cases, seems scarcely important when adopting a posterior instrumentation technique that develops such efficacious corrective forces.

In our study discectomy appears effective, and we still believe it is, but more for a quicker and easier instrumentation than to obtain a greater correction. In addition, discectomy is useful in cases of severe rotational kyphosis, in which a posterior approach may not always offer a solid and effective fusion, where it is better to have an anterior support.

On the sagittal plane, the three-rod CD instrumentation corrects hypokyphosis, hyperlordosis and rotational hyperkyphosis. However, while it does not worsen hypolordosis, nor does it correct it. The results of the cases in which we applied our technical intraoperative variations (Table 1) confirm their validity, since these permit us to regain a better lordosis (use of screws), facilitate instrumentation (two rods and a domino), reduce neurological risks (instead

of apical pedicle hook alone, we use pedicle transverse claw) and do not increase the rate of other complications.

Our study has highlighted the greater danger of infection in subjects with neurological scoliosis and crankshaft phenomenon, when we operate on very young subjects without also performing anterior fusion. Vascular compression of the duodenum appears to be caused by correction of the severe deformity of the spine by means of traction, since, in underweight patients with severe scoliosis [9], the angle between the aorta and the superior mesenteric artery is reduced. The three cases of vascular compression of the duodenum (two after anterior approach and one during Halo preparation) show that in these severe scolioses, apart from the fearsome neurological risks, abdominal risks are also not altogether rare.

Conclusions

In conclusion, this multicentric experience has shown that scoliotic curves greater than 70°–80°, regardless of aetiology, may be adequately corrected on the various planes with three-rod CD instrumentation.

The rate of complications is low in both the idiopathic and neurological groups and is of no statistical importance either regarding aetiology or severity of the curve. Only vascular compression of the duodenum appears to be a complication at times related to anterior approach surgery or to severity of the curve when associated with obvious thinness.

Our technical variations permit an easier, safer and effective correction of spine deformities that require major surgery.

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