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Posterior compact Cotrel-Dubousset instrumentation for occipitocervical, cervical and cervicothoracic fusion

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Abstract The authors report on 32 consecutive patients with instability at the craniocervical, cervical and cervicothoracic regions suffering from various pathologies, who were treated with posterior instrumentation and fusion using the posterior hooks-rods-plate cervical compact Cotrel-Dubousset (CCD) instrumentation alone or, in three patients, in combination with anterior operation. The patients were observed postoperatively for an average of 31 months (range 25–44 months) and evaluated both clinically and radiographically using the following parameters: spine anatomy and reconstruction, sagittal profile, neurologic status, functional level, complications and status of arthrodesis. All patients but one (who died) achieved a solid arthrodesis based on plain and flexion/extension roentgenograms. Cervical lordosis (skull–C7) and cervicothoracic kyphosis (C7–T2) was improved by instrumentation towards a physiological lateral curve by an average of 33% ($P<0.05$) and 28% ($P<0.05$) respectively. Anterior vertebralolisthesis was reduced in the craniocervical and cervicothoracic region, by 73% and 90% respectively. At final follow-up there was an improvement of the neurologic Frankel status by an average of 1.2 grades and of myelo-

pathy in 75% of the operated patients. Good to excellent functional results were seen in 77% of the operated patients, while acute and chronic pain was reduced by an average of 2.4 grades, on a scale of 0–3, in operated patients. No neurovascular or pulmonary complications arose from surgery. There was no significant change in lateral spine profile andolisthesis at the latest follow-up evaluation. There were no instrument-related failures. One patient requested hardware removal in the hope of reducing postoperative pain in the cervicothoracic region. The poor and fair results were related to the lack of improvement of neurologic impairment and myelopathy. The results of this study demonstrate that cervical CCD instrumentation applied in the region of the skull to the upper thoracic region for various disorders is a simple and safe instrumentation that restores lateral spine alignment, improves the potential for a solid fusion and offers sufficient functional results in the vast majority of the operated patients. However, the use of hooks in spinal stenosis is contraindicated.

Keywords Cervical spine · Craniocervical · Cervicothoracic · Cotrel-Dubousset · CCD

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Introduction

Instability of the cervical spine, whether traumatic, degenerative, rheumatic or neoplastic, may necessitate internal fixation. The location of the lesion and the pattern of the spinal instability should determine selection of anterior or posterior fixation procedure. From a biomechanical point of view, posterior fixation devices have an advantage over anterior devices for fixation of posterior instability, such as postlaminectomy instability, and for fixation of three-column instability, such as fracture-dislocation or circumferentially compromised vertebral metastases [2, 11, 24, 29, 36, 39, 40].

Since the first occipitocervical fusion in 1927 by Foerster [17], a number of posterior techniques for fusing the cervical spine using wire, metal, or methacrylate, with or without the addition of bone have been described [1, 2, 6, 8, 9, 12, 13, 16, 18, 19, 20, 21, 24, 25, 26, 27, 28, 30, 31, 38].

Abumi and Kaneda [1] first reported pedicle screw fixation in the middle and lower cervical spine in traumatic lesions. Based on comparative biomechanical studies of cervical fixation procedures, however, there is not much difference in stability between lateral mass screw-plate fixation and conventional non-screw fixation methods [1, 10, 22, 29, 37, 38].

Posterior upper cervical fusion with autogenous bone graft and wires has been advocated in the management of atlantoaxial instability in rheumatoid patients, with an improvement rate of 30–40% [9, 35], failure of fusion in 16–50% and a mortality rate ranging from 27 to 42% [12, 16, 35].

There have been only a few reports in the literature on the spinal disorders of and surgical approach to the cervicothoracic junction [1, 2, 7].

The purpose of this study is to report the use of the posterior cervical hook-rod compact Cotrel-Dubousset (CCD) instrumentation in the skull to the upper thoracic spine region in 32 patients suffering from different diseases in order to investigate the versatility and the successful use of the system. Specifically, the operated patients were examined for changes in neurologic function, spine stability, maintenance of spine alignment, and complications after using this fixation technique.

Materials and methods

Thirty-two patients with acute and chronic spinal lesions (Table 1) located in the region from C1 to T2 were managed by the first two authors using posterior cervical CCD instrumentation and fusion in two affiliated spine units between 1994 to 1997, using the same surgical technique and evaluation protocol. The indications for surgery were: presence of acute or chronic instability, presence of neurologic deficit, and iatrogenic instability. The indications for surgery are shown in Table 1. There were 24 men and 8 women, and their average age was 54 ± 20 years (range 18–84 years). Fourteen patients suffered from chronic cervical spine diseases and 18

from fresh traumatic lesion of the cervical and upper thoracic spine (Table 1). In 7 of the 32 patients, fusion involved the occipito-cervical junction; in 11 of the 32 patients, the cervicothoracic junction was included in the instrumentation; and in 14 of the 32, the instrumentation was limited to the cervical (C1–C7) region (Table 1). Impaired single or multiple vertebrae were variously distributed across the occipitocervical region to the cervicothoracic junction. Single- or multisegmental instability was mostly caused by the cervical lesions themselves, and instability was obvious, so that functional roentgenograms were either not necessary (vertebral bone deficiency due to metastasis or primary tumor: cases 1, 2, 3, 14) or theoretically dangerous for iatrogenic neurologic lesion (facet subluxation, dislocation, vertebral body fracture: cases 4, 6, 15–32). Alternatively, the instability was caused by extensive laminectomy for spinal cord decompression (cases 7–12) (Table 1). Only in one case (case 13) were preoperative flexion/extension roentgenograms needed to document postlaminectomy instability.

In all patients, cervical CCD was used for cervicothoracic fusion combined with conventional CD. The patients were re-evaluated at 2, 6 and 12 months after surgery, and thereafter once a year.

Implants

The cervical Compact Cotrel-Dubousset (Cervical CCD, Sofamor-Danek, USA) instrumentation (Fig. 1) was inspired by the Compact CD and derived from cervical and occipitocervical applications of the reduced-size CD implanted since 1983. This instrumentation is of stainless steel and was designed for treatment from the occiput to the thoracic junction, using the posterior approach, in trauma, degenerative disease, instability, tumor, and iatrogenic instability. Cervical CCD instrumentation is not limited to a single screw, plate, or rod, but may be adapted to a specific anatomy and diversity of pathologies using implants of different anchorage, shape and dimensions. The implants have been designed to obtain increased mechanical resistance values. The construct comprises two rods and one transverse link device for immediate and long-term stability. A domino connector [4] is also available, in case of extension of the instrumentation. The transverse link device is user friendly, strong (bending strength 183 N) and of small size [4]. The axial slippage of the hooks on the rod is estimated to be 2225 N and the force required for hook rotation on the rod is approximately 2.8 Nm [4]. The locking mechanism enables easy removal of the construct without bone damage during explantation. Each step and each maneuver during the operation is facilitated by multifunctional instruments adapted for the cervical spine. The screwdriver is universal. The hooks have accurate shape, low profile in the spinal canal, are compact and of minimal inventory (open-closed and large-small groove), their handling and insertion are easy. The rods have a reduced volume (5 mm diameter) compared to the original Cotrel-Dubousset instrumentation, are resistant but easy to contour in an appropriate shape for the cervical, occipitocervical, cervicothoracic spine and are connectable to the thoracic level. The occipital fixation may be obtained using screws or hooks. Compression and/or distraction is possible using appropriate instruments. Claw configuration between adjacent vertebrae is usually performed. The occipitocervical junction is instrumented with a combination of hooks and 3.5-mm screws penetrating both cortices of the skull [34].

Surgical procedure

All patients with dislocations underwent halo traction until reduction was achieved. After intubation, patients were placed prone on a frame and a horseshoe-type head holder or halo traction device. The head was taped to the head holder with the cervical spine

Table 1 Clinical data on 30 patients who underwent posterior cervical fusion using cervical compact Cotrel-Dubousset (CCD) instrumentation (*lamin* laminectomy, *radiculop* radiculopathy)

Case	Age	Sex	Pathologic condition for operation	Posterior operative procedure	No. of segments fused	Additional anterior operation	Pain ^a		Neurologic (Frankel grade)		Follow-up (months)	Complications	Result
							Preop	Postop	Preop	Postop			
1	72	F	C2 hemangioma	Lamin C0-C4	5	No	3	0	D	E	41	No	Good
2	42	M	Aneurysmal bone cyst T1-T2	Lamin C5-T7	10	C7-T3 resection & fusion	2	0	D	E	35	No	Good
3	28	M	Osteoblastoma T1 lamina	Resection C6-T3	5	No	3	0	E	E	29	No	Good
4	44	F	Congenital dislocation C1/C2 & myelopathy	C0-C5 fusion	6	Transoral dens resection	3	0	C	E	25	No	Good
5	54	F	Rheumatoid spondylitis C1-C4	C0-C5 fusion	6	No	3	0	E	E	26	No	Good
6	61	M	Odontoid pseudarthrosis & myelopathy	Lamin C0-C7	8	No	3	0	C	E	31	No	Excellent
7	68	M	Myelopathy	Lamin & C4-C7 fusion	4	No	2	1	C	C	29	No	Poor
8	76	M	Myelopathy	Lamin & C3-C7 fusion	5	No	2	1	C	D	37	No	Fair
9	66	M	Myelopathy	Lamin & C3-C6 fusion	4	No	2	0	D	D	25	No	Good
10	72	M	Myelopathy	Lamin & C3-C7 fusion	6	No	2	0	C	D	37	No	Good
11	75	M	Myelopathy	Lamin & C4-C6 fusion	3	No	2	0	D	E	37	No	Good
12	71	M	Myelopathy	Lamin & C3-C6 fusion	4	No	2	1	C	D	25	No	Fair
13	48	F	Postlaminectomy instability	C4-C7 fusion	4	No	3	1	E	E	42	No	Excellent
14	71	M	Metastatic prostate T1-T3	Lamin & C5-T7 fusion	14	No	3	0	C	E	44	No	Excellent
15	18	M	C1-C2 dislocation	C1-C2 fusion	2	No	3	0	D	E	31	No	Excellent
16	25	M	C5-C6 bilateral facet dislocation	C5-C6 fusion	2	No	3	0	D	E	28	No	Excellent

Table 1 (continued)

Case	Age	Sex	Pathologic condition for operation	Posterior operative procedure	No. of segments fused	Additional anterior operation	Pain ^a		Neurologic (Frankel grade)	Follow-up (months)	Complications	Result
							Preop	Postop				
17	19	F	C4-C5 subluxation	C4-C5 fusion	2	No	3	0	E	25	No	Excellent
18	31	M	C5-C6 unilateral dislocation	C5-C6 fusion	2	No	3	2	C	33	No	Fair
19	75	F	Jefferson & type II dens fracture	C0-C4 fusion	4	No	3	0	E	30	No	Excellent
20	26	M	C6-C7 subluxation & facet fracture C6	C6-T2 fusion	4	No	3	0	E	25	No	Excellent
21	74	M	Dislocation C5-C6	C5-C6 fusion	2	No	3	death	A	2 days	Death, vasc. cerebral	death
22	36	F	Dislocation C5-C6, lamina fracture	C4-C7 fusion	4	No	3	0	radiculop	resolved	No	Excellent
23	54	M	Fracture/dislocation C6-C7	C5-T2 fusion	5	No	3	2	E	30	Pain due to hardware	Good
24	49	M	Dislocation C6-C7, lamina fracture	C4-T2 fusion	6	No	3	0	radiculop	resolved	No	Excellent
25	84	M	Dens II, lamina fracture C5-C7	C0-T2 fusion	10	No	2	1	C	26	No	Fair
26	55	M	Fracture body of C6	C5-C7 fusion	3	Titanium mesh & plate	3	0	E	40	No	Excellent
27	80	M	Dislocation C6-C7	C6-C7 fusion	2	No	2	0	radiculop	resolved	No	Good
28	25	F	Jefferson & dens III	C0-C5 fusion	6	No	3	0	E	28	No	Excellent
29	41	M	Dislocation C7-T1	C5-T6 fusion	9	No	3	1	C	25	No	Poor
30	50	M	Fracture T2 & dislocation T2-T3	C6-T6 fusion	8	No	3	0	E	29	No	Excellent
31	43	M	Dislocation T1-T2	C5-T6 fusion	9	No	3	0	A	32	No	Poor
32	78	M	Dislocation T1-T2	C5-T6 fusion	9	No	3	0	D	26	No	Good

^aPain scale of 0-3, graded according to the criteria developed by the Hospital for Special Surgery

Fig. 1 Schematic demonstration of the compact Cotrel-Dubousset (CCD) hardware in situ

maintained in a neutral position, and the shoulders were pulled caudal by a heavy bandage for intraoperative lateral radiographic imaging of the lower cervical spine. With a median skin incision, the paravertebral muscles were dissected laterally to expose the laminae and the articular masses in the cervical and upper thoracic vertebrae and the transverse processes at the upper thoracic region. The laminar hooks were inserted at sites of the laminae that were prepared by blunt dissection or after partial excision of the ligamentum flavum or partial laminotomy. They formed a claw between adjacent vertebrae, and were assembled to two longitudinal rods. The longitudinal rods were augmented with the transfixation device (Fig. 1, Fig. 2C), representing a quadrilateral fixation that can counteract forces that act on different planes: axial loading, flexion-extension, and torsion. In case of instrumentation of the skull, it was subperiosteally prepared up to the occipital notch. The craniovertebral junction was instrumented using the premodeled CCD rods and four 3.5-mm screws that penetrate the cranial wall and are bilaterally inserted about 1.5 cm below the occipital notch and at about 2 cm laterally with respect to the median line. The type of material used allows for "in situ" contouring of the rods by means of special benders. This CCD implant can be considered as a "dynamic" fixation device, because the hooks, in contrast to screws, do not offer absolutely rigid fixation, since some movement at the lamina-hook interface can theoretically occur. It is also possible to apply limited force during surgery (distraction and compression forces) to obtain a better realignment of the skeletal components. In general, the reduction was performed before surgery by means of halo traction, and thereafter it was controlled intraoperatively using lateral plain roentgenograms. However, as pointed out earlier, it is also possible to apply limited force during surgery to compact the metal construct. After meticulous decortication of the posterior spinal elements and the skull (air drill with a diamond burr for preparation to craniovertebral fusion) posterior fusion was carried out using iliac cortical cancellous autogenous bone graft. In the three patients (patients 2, 4, 26) where a combined approach was necessary, the posterior operation was performed first, for better alignment of the spine, and it was followed

by the anterior operation. Anterior operation was indicated in case of extensive anterior pathology that caused immediate or potential severe instability which was not possible to be managed posteriorly only. Postoperative immobilization varied according to the number of the spinal segments fixed, the patient's general condition, and the extent of osteoporosis. In principle, a soft collar or a short Philadelphia collar was applied for 3 months. All patients except the neurologically impaired were permitted to ambulate or sit up in the bed the day after surgery, unless contraindicated by their general condition.

Clinical and functional evaluation

The pain level of the patients, their neurologic status and function and the complications after surgery were recorded in detail preoperatively through to postoperative follow-up. Pain status (on a scale of 0–3) was determined using the criteria developed at the Hospital for Special Surgery [33]. The pain grades were: none (0), mild (1), moderate (2), and severe (3). Neurologic status was determined using the Frankel classification (A to E); the preoperative neurologic status was graded as A in two, C in ten, D in seven and E in ten patients. Three patients suffered from radiculopathy. Preoperative pain level averaged 2.7 ± 0.5 (range 2–3) and was graded as 3 in 23 patients and as grade 2 in 9 patients (Table 1). During the follow-up period the improvement of the neurologic function, the existence of pain and disability, the success of fusion, and the restoration of the normal alignment of the cervical spine (tested radiologically with static and dynamic radiographs) were taken into account to determine the final outcome of each patient.

Follow-up information was obtained clinically and radiologically, and a rating of excellent, good, fair, or poor was assigned. If a complete recovery and return to previous activities occurred, the result was considered excellent; good if occasional pain, return to gainful activities, and intermittent use of mild analgesics occurred; fair, if partial recovery, frequent use of analgesics, and modified activities occurred; and poor, if no relief of original symptoms, constant pain and need for full-time support occurred [2].

Radiographic evaluation

Radiographic assessments were made before and after surgery in all patients (Fig. 2, Fig. 3, Fig. 4). Plain roentgenograms and bilateral oblique plain films were taken to evaluate the fusion process, and computed tomography (CT) and magnetic resonance imaging (MRI) were performed preoperatively. Fusion status was assessed radiographically by the presence of bridging trabeculae with homogeneous fusion mass and by lateral flexion/extension radiographs to evaluate motion at the fusion site (as physiological segmental motion is considered to be less than 2° according to Chan et al. [9]). To estimate sagittal plane correction within the instrumented spine and alignment of the cervical and cervicothoracic spine, we compared preoperative with postoperative values of (1) cervical lordosis [5] (skull–C7) in the 21 patients who underwent instrumentation at any level from the skull to C7, and (2) cervicothoracic junctional kyphosis [5] (C7–T2) in the 11 patients who underwent instrumentation and fusion at the cervicothoracic junction. Measurements were made as follows.

1. Cervical lordosis (average normal = -44.2° according to Bridwell [5]) is the angle formed by a line drawn from the posterior occiput to the clivus and a second line on the lower endplate of C7 (Table 2).
2. Cervicothoracic junctional kyphosis (average normal = 5° according to Bridwell [5]) is the angle formed by a line drawn on the upper endplate of C7 and the line drawn on the lower endplate of T2 (Table 3).

Table 2 Sagittal plane alignment in patients who underwent occipitocervical and cervical CCD instrumentation

Parameters	Preoperatively Mean (range)	Postoperatively Mean (range)	Follow-up Mean (range)
Skull–C7 lordosis (degrees)	–30.9 (–10 to –42)	–40.9 (–36 to –44)	–40.4 (–34 to –44)
Vertebral translation (mm)	1.5 (0 to 3)	0.4 (0 to 2)	0.4 (0 to 2)

Table 3 Sagittal plane alignment (C7–T2) in patients who underwent cervicothoracic CCD instrumentation and fusion

Parameters	Preoperatively Mean (range)	Postoperatively Mean (range)	Follow-up Mean (range)	<i>P</i> -value
C7–T2 kyphosis (degrees)	7.6 (5–12)	5.3 (4–7)	5.3 (4–7)	<0.05
Vertebral translation (mm)	3.55 (0–12)	0.4 (0–12)	0.4 (0–1.2)	<0.01

Fig. 2A–C Case 17. **A** Lateral roentgenogram of the cervical spine, showing a unilateral dislocation of C5–C6. **B** Lateral plain roentgenogram 25 months after surgery, demonstrating excellent reduction and fusion using CCD hooks. **C** Anteroposterior roentgenogram showing the CCD instrumentation in situ with the transverse connector

3. Sagittal vertebral translation (Fig. 2) was measured on lateral roentgenograms of the cervical spine, preoperatively, postoperatively and at the latest follow-up, as the amount (mm) of slipping of any vertebral body on the adjacent lower vertebral body (Table 2, Table 3).

Statistical methods

Statistica software and the paired and unpaired *t*-test were used to evaluate and to compare the results.

Results

There was one death in the early postoperative period because of acute vascular cerebral hemorrhage (Table 1). Thus 31 of the 32 patients were available for the follow-up evaluation. The follow-up averaged 31 ± 6 months (range 25–44 months). The operated patients with primary tumors and prostate metastasis were still alive at the latest follow-up evaluation. Operation time and intraoperative blood loss for the posterior procedure were measured exclusive of the anterior or combined surgery. Average operation time for the posterior operation was 120 min, (range 90–180 min), including the time for laminectomy and tumor resection, and average intraoperative blood loss was 300 ml, (range 60–1500 ml). Perioperative blood transfusion was not needed. The number of segments fused averaged 5 ± 3 (range 2–14). For fusion within the region from skull to C7, an average of 4 ± 2 segments were fused, whereas the average number for the cervicothoracic junction was 8 ± 3 segments. There was no

Fig. 3A,B Case 6. **A** Lateral roentgenogram showing odontoid pseudarthrosis with posterior dislocation associated with myelopathy. **B** Lateral roentgenogram of the cervical spine 31 months postoperatively after C1–C3 laminectomy and occipitocervical fusion using the CCD hook-plate system

Fig. 4A,B Case 2. **A** Computed tomography (CT) scan showing severe destruction of T2 on the right side. **B** Lateral roentgenogram of the cervicothoracic junction after staged anterior tumor resection and plating-grafting and posterior CCD instrumentation, 35 months after surgery. Note the combination of the cervical CCD with the CD instrumentation at the cervicothoracic junction, using the special “domino” connectors

neurologic deterioration in this series. Thirteen patients improved their preoperative Frankel status by an average of 1.2 grades, (range 0–2) (Table 1). Of the eight patients who had preoperative myelopathy, six improved by at least one Frankel grade (improvement rate of 75%) and the other two patients remained at the same Frankel grade

(Table 1). Radiculopathy in three patients resolved completely in the first 3 postoperative months. There was a neurologic improvement in 53% of the operated patients. At the latest follow-up, all 31 patients who had undergone bone grafting had solid bony union. There were no patients with failure of implant components or connections,

screw loosening, or lucent zone formation around the screws penetrating the skull. One patient (patient 23, Table 1) had constant complaints in the midthoracic region at the lower end of the rods, and he underwent a second operation 1 year after the index operation for removal of the hardware. The fusion area under and around the hardware was solid, without signs of pseudarthrosis.

The pain, on a scale of 0–3, improved in all patients by an average of 2.4 grades (range 1–3). The excellent and good results (overall 77%) were recorded for 18 of the 21 patients with instrumentation within the region skull–C7 and 8 of the 11 patients who underwent instrumentation at the cervicothoracic junction. The fair and poor results were due to associated neurologic impairment or myelopathy, and were observed in 4 of the 21 patients with fusion in the region skull–C7 and in 3 of the 11 patients with stabilization of the cervicothoracic junction (Table 1).

The operation improved significantly ($P < 0.05$) the sagittal profile of the cervical spine (Table 2) by reducing any kyphotic deformation, and offered a cervical lordosis (skull–C7) that was close to the physiological. Vertebral translation in the region skull–C7 was significantly ($P < 0.01$) reduced postoperatively and remained unchanged at the latest follow-up evaluation (Table 2). There was an average of 73% reduction of the anterior displacement of the vertebrae in this region. At the cervicothoracic junction, the operation significantly ($P < 0.05$) reduced pathologically increased kyphosis, which remained unchanged at the latest follow-up (Table 3). There was an average of 90% reduction of the ventralolisthesis of any vertebra at this junction.

Discussion

The present study showed that cervical CCD applied in the craniovertebral, cervical and cervicothoracic spine for various conditions offered immediate stabilization of the spine, significant reduction of vertebralolisthesis, maintenance of its reduction until the latest observation, restoration of the lateral profile of the spine in the craniocervical, cervical and cervicothoracic region, relief of acute and chronic pain, improvement of neurologic impairment and myelopathy and excellent and good functional results in the vast majority of the operated patients. However, several cases included in the present series received multi-level fusions even when one- or two-level pathology existed. This was performed because the CCD, as a hook and rod system, requires longer instrumentation because of:

1. Use of the “claw” configuration at the two uppermost and two lowermost levels of fixation
2. Extension of instrumentation above and below any levels of prior laminectomy(-ies), and
3. The need to avoid using hooks at the levels of significant spinal canal stenosis

These are theoretically the limitations and demerits of the CCD system in comparison to the recently developed spinal fixation devices [32, 37] of lateral mass screw and pedicular systems.

However, a recent clinical-neurophysiological study [4] in cadavers (without spinal stenosis) showed that cervical CCD hooks can be used with safety and reliability without neurologic complications during and after surgery. One cadaveric study [14] showed a close anatomical relationship with the dura and spinal cord, with a mean cervical CCD hook intrusion into the spinal canal of 27% of the diameter; however, they found no evidence of deformation of the spinal cord.

Bueff et al. [7] performed in 1995 a comparative biomechanical study between three instrumentation constructs (posterior Synthes lateral mass plate, cervical Cotrel-Dubousset rod-hooks and anterior Synthes plate), applied at the destabilized cervicothoracic junction, and showed that the posterior instrumentation had more stiffness than the anterior plate, and the stiffness of the posterior Synthes plate is the same as that of CCD.

The first preliminary report on successful use of a new rod-screw instrumentation, applied posteriorly for stabilization of the occipitocervical, cervical and upper thoracic spine, was that of Jeanneret [23] in 1996.

There are only a few articles reporting on the use of the Cotrel-Dubousset rod and hook system in the cervical spine applied for different disorders, mostly for occipitocervical instability [15, 22, 33], and all reported stable bony fusion in all cases, no surgery-related morbidity or mortality and no hardware failure.

Olerud et al. [32] recently published the results of their screw-rod posterior system, applied in 30 patients with various conditions. They reported good results in all but one patient, one neurologic deterioration, two cases of loss of fixation, two infections and one hematoma.

Sasso et al. [37] reported their results in occipitocervical fusions with posterior plate and screw instrumentation in 32 patients. They reported no pseudarthrosis, and an improvement or no change in the preoperative neurologic status in the operated patients.

In this series, there were no patients with pseudarthrosis, no cases of skull screw loosening and no rod breakage, in spite of early ambulation without postoperative rigid external support.

Regarding postoperative immobilization, Chan et al. [9] recommended a halo vest, and Ranawat et al. [35] observed that the more stable the fixation obtained during posterior cervical spinal fusion, the more satisfactory the fusion. Early series showed fusion rates ranging from 50 to 94% [9, 16]. The fusion rate in this series was 100% without use of rigid postoperative orthoses, and it therefore seems that cervical CCD is sufficiently stable to secure solid fusion.

The few poor and fair results were due to myelopathy or to lack of neurologic improvement postoperatively.

The anatomy at the cervicothoracic junction is unique in that there is a change from cervical lordosis to thoracic kyphosis, and thus the cervicothoracic junction poses special concerns for posterior spinal surgical procedures, because it is an area of transitional anatomy [3, 7]. To the authors' knowledge there are no previous reports on the application of cervical CCD at the cervicothoracic junction. In all previous reports on fusion in the cervicothoracic region, no mention was made of anything that might suggest that the sagittal profile of the spine had been restored. In the present series the preoperative and postoperative measurements showed that the appropriate contouring of the Cotrel-Dubousset rods offers a sufficient

cervicothoracic transitional kyphosis that does not differ from that of a normal spine.

In conclusion, cervical CCD hook-rod instrumentation provided good clinical and radiological results in the vast majority of traumatic and non-traumatic lesions extending from the skull to the upper thoracic spine, without neurologic complications. This posterior instrumentation alone or in combination with anterior reconstruction provides excellent initial stability and safeguards solid fusion, maintaining the sagittal profile of the craniocervical, cervical and cervicothoracic spine. It is one of the potential procedures for posterior reconstruction of the cervical spine with various kinds of disorders.

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