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Cotrel Dubousset instrumentation in occipito-cervico-thoracic fusion

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Abstract There are today several techniques available for cervical fixation – all with inherent limitations and risks. In view of the drawbacks of wiring and screw fixation, which both presuppose good bone quality for stabilization, there is a need for a stable and safe fixation system that can also be used in osteoporotic bone. The objective of the present retrospective study was to assess the usefulness and safety of Cervical Cotrel Dubousset Instrumentation (CCDI), based on sublaminar hooks. The material comprises 60 consecutive patients, 28 men and 32 women, with a mean age of 57.3 years (range 17–84 years), operated on with CCDI. The diagnosis was trauma in 17 patients, rheumatoid arthritis in 16 patients, tumor in 20 patients and miscellaneous diagnoses in 7 patients. The material was dominated by severe pathologies, with neurological impairment in 17 patients (28%). Complications, subjective outcome and Frankel classification of neurological

status pre- and postoperatively was documented. The patient outcome evaluation was excellent in 46%, good in 34%, fair in 10%, and poor in 10%. The physician's assessment was similar: 56% excellent, 27% good, 10% fair and 7% poor. Two patients improved by two Frankel grades, 7 by one and 47 patients had the same Frankel grade as preoperatively. Two patients deteriorated by one Frankel grade, one by three grades and one patient by four Frankel grades. Except for a 10% deep wound infection rate, there were few complications, with no evidence of neurological injury from the hooks in the spinal canal. The results of this study show that the cervical CDI system can be safely used for stable cervical fixation without need for external support in severe pathologies of the cervical spine.

Keywords Cervical spine · Instability · Posterior instrumentation · CD system

Introduction

Since Hadra first described the time-honored technique of cervical wiring, several alternative fixation techniques have been developed, all with inherent limitations and risks.

In atlanto-axial surgical stabilization, the Gallie wiring technique is still the gold standard, but it has several limitations [15, 26]. Its mechanical stabilizing potential is

limited, it does not result in rotational or translational sagittal stability and additional external fixation is needed, which is a great disadvantage, particularly in rheumatoid arthritis (RA) and metastatic disease. Transarticular C2–1 screws with additional Gallie type wire fixation is biomechanically attractive, offering rotational and translational stability, but is technically demanding, with a risk of vertebral artery injury [8, 29, 40].

Wiring is also a traditional method of subaxial spine fixation [33]. Techniques based on wires through the

spinous process with [36] and without [6] transverse K-wires are simple and safe, carrying no risk of neurovascular injury [4]. Plates and lateral mass screws can be used in multilevel cervical as well as occipitocervical instabilities [3, 19]. As described by Roy-Camille, transpedicular C2 fixation can be used in cases of hangman's fracture [34]. Recently, the use of transpedicular screw fixation has been reported in the subaxial cervical spine as well [1, 2]. Systems based on rods and wires/cables, such as the Ransford loop, allow multisegmental cervical and occipitocervical fixation [11, 32]. Occipitocervical fusion, with or without [28] fixation, has been used in instabilities of the upper cervical spine since the description by Foerster in 1927 [14]. The traditional fixation to the occiput has been with wires [10, 16]. More stable fixations, such as the Ransford Loop and the Roy-Camille OC plate [34], may improve fusion and allow mobilization without external support.

There are few reports on the use of laminar hooks and rods in surgical fixation of the cervical spine. Combined screws and hooks are used in the hook-plate system developed by Grob and Magerl for single- or two-segment fixations [17]. Murphy [27] reported on the use of Harrington compression rods, hooks and wires in the cervical spine, and Mitsui [25] has reported on the successful use of a hook-rod based system with double transverse connectors, called the one-piece cervical device (OPCD).

In view of the limited stability, particularly in osteoporotic bone, of systems based on wires, anterior plates and posterior lateral mass screws, and the technically demanding pedicle screw technique, there is a need for a stable and safe fixation system that can also be used in complex cervical instabilities with multisegmental instability.

Cotrel Dubousset instrumentation (CDI) based on rods and hooks has proven to be versatile and safe in the thoracic and lumbar spine. In an experimental study of the cervical spine, Fagerström et al. [12] reported on the relation between sublaminar hooks and the neuraxis, and found no evidence of spinal cord deformation exerted by sublaminar hooks, although the safety margin was limited. Pham et al. [30] reported good results of cervical CDI in a series of 30 patients with RA. No surgery-related deaths were reported, and all patients improved regarding both pain and neurological deficits. Heidecke et al. [20] reported on 14 patients with mixed upper cervical pathologies, all operated with occipito-cervical fusion using a horseshoe-shaped plate rod, with generally good results and no immediate surgery-related morbidity or mortality.

Cervical CDI has several potential advantages, such as immediate stability without need for external fixation. It allows multisegmental fixation including the occiput and the thoracic spine, and the fixation is based on cortical bone. A potential disadvantage is canal encroachment with cord or nerve root injury. The purpose of the present report was to investigate the outcome and safety of the cervical CD system based on hooks in the cervical spine.

Materials and methods

The material comprised 60 consecutive patients operated on with cervical CDI (CCDI) in the cervical spine. There were 28 men and 32 women, with a mean age of 57.3 years (range 17–84 years). There were 17 patients with traumatic injury, 16 with RA, 20 with tumors and 7 with miscellaneous disorders of the cervical spine.

The indications for surgery were neurological deficit or severe pain. In all patients there was radiologically demonstrated instability of the cervical spine. Eleven instrumentations were monosegmental, 8 multisegmental, 17 occipito-cervical, 20 cervico-thoracic and 4 occipito-cervico-thoracic. The distribution of the different types of constructs in the different diagnostic groups is shown in Table 1.

Except for a transoral extirpation of the dens on three patients with RA, no additional anterior approach was used. Postoperatively, external fixation (soft or semi-rigid collar) was intermittently used *ad libitum*, only for comfort and not for further stabilization.

The diagnoses and instrumented levels in the trauma group are specified in Table 2.

In the RA group, five patients had basilar invagination, eight had an atlanto-axial instability and five subaxial instability. Two patients had combined atlanto-axial and subaxial instability. Three out of five patients with basilar invagination had a transoral dens extirpation in addition to posterior surgery. Four out of these five patients also had a subaxial instability.

In the tumor group, 19 patients had cervical metastasis of various origins and one patient had a benign tumor, an osteoblastoma (Table 3).

The neurological pre- and postoperative status was classified according to the five-grade Frankel scale (A-E). Peri- and postoperative mechanical and general complications were recorded. Immediate postoperative and follow-up radiographs were examined for signs of loosening or pseudarthrosis. Nine patients died before follow-up. The cause of death was malignancy in seven patients, postoperative neurological deterioration in one and myocardial infarction 1 year postoperatively in one patient. The senior author (R.H.) or his assistant (T.F.) examined the patients at follow-up. The overall outcome was classified subjectively by the patient and by the physician into excellent, good, fair or poor. Ten patients considered themselves to live too far away or not to be in good enough physical condition to attend the evaluation. Of these ten patients, three were in the trauma group, three in the RA group and

Table 1 Type of instrumentation according to diagnosis in 60 patients operated on with cervical Cotrel-Dubousset Instrumentation (CDI) (RA rheumatoid arthritis)

	Total	Uni-level cervical	Multilevel cervical	Occipito-cervical	Cervico-thoracic	Occipito-thoracic
RA	16	4	1	10	1	0
Trauma	17	7	4	0	6	0
Tumor	20	0	2	5	9	4
Misc	7	0	1	2	4	0
Total	60	11	8	17	20	4

Table 2 Diagnosis and instrumented levels in 17 patients with cervical spine trauma operated on with cervical CDI

Pat. no.	Diagnosis	Instrumented levels
1	C7 fracture, epidural hematoma	C5–T2
2	C7 fracture, unilateral facet luxation C7–T1	C7–T2
3	Bilateral facet luxation C4–5	C4–5
4	Rupture of transverse ligament C1	C1–2
5	Fracture-luxation C6–7	C6–7
6	Posttraumatic kyphosis with subluxation C4–5	C4–5
7	Fracture-luxation C6–7, fracture T3–5	C4–T9
8	Fracture-subluxation and laminar fracture C5	C5–6
9	Dens fracture with rupture of dura	C1–2
10	Bilateral facet luxation C6–7	C6–T1
11	Teardrop fracture C5, burst fracture C6	C5–T1
12	Subluxation C6–7 sin	C5–7
13	Fracture C5 and subluxation C4–5, C5–6	C4–6
14	C7 fracture	C5–T2
15	C2 fracture	C1–3
16	Dens fracture	C1–2
17	Bilateral facet luxation C5–6	C3–7

Table 3 Diagnosis and instrumented levels in 20 patients with tumors, operated on with cervical CDI

Pat. no.	Diagnosis	Instrumented levels
1	Bronchial cancer	Occ–C4
2	Destruction NUD	C1–T3
3	Osteoblastoma	C3–5
4	Pulmonary malignancy	Occ–lower thoracic
5	Plasmocytoma	C2–7
6	Pulmonary malignancy	Occ–C4
7	Thyroid cancer metastasis	C1–T3
8	Osteoblastoma	Occ–C4
9	Pulmonary malignancy	C5–T8
10	Breast cancer	C5–T2
11	Breast cancer	Occ–T3
12	Adenocarcinoma (unknown origin)	Occ–T5
13	Adenocarcinoma (unknown origin)	C6–T7
14	Rectal cancer	C4–T5
15	Malignant teratoma?	C5–T12
16	Breast cancer	Occ–C5
17	Carcinoma (unknown origin)	Occ–T2
18	Breast cancer	Occ–C3
19	Colon cancer Duke C	C4–T4
20	Hypernephroma	C3–T6

four in the tumor group. Thus, 41 patients were available for outcome evaluation at a mean follow up of 18 months (range: 1–48 months).

Fig. 1 Case report 1. A 52-year-old man with rheumatoid arthritis (RA). Preoperative lateral view with a posterior atlanto dens interval (PADI) of 8 mm

Technique

In surgical treatment of cervical spine trauma, several considerations have to be made, including level(s), competence of anterior support and posterior tension band, degree of instability and osteoporosis. In the case of deficient anterior support, posterior fixation is not sufficient, and anterior surgery is recommended with or without added posterior fixation. In patients with posterior distraction injuries – typically uni- or bilateral facet dislocations – posterior instrumentation is biomechanically logical. With CCDI, a bilaminar claw is used. If there are associated laminar fractures or a laminectomy is required, the constructs must be extended to intact lamina. In seven cases with single-level pathology, however, single-level instrumentation was sufficient.

The rheumatoid patient offers a variety of pathologies to be treated. In the common case of atlanto-axial instability, a single C1–2 claw was used. In the case of concomitant dens migration into the foramen magnum and occipito-cervical pathology, the occiput has to be included in the fixation. In this series of patients, occipital fixation was performed with screws. In the patient with subaxial instability, fixation may be necessary into the thoracic spine. We did not experience any difficulties extending the CCDI system into the upper thoracic spine. Thus, connection to a thoracic system was not necessary.

In patients with metastatic disease, the patient is likely to be treated with postoperative radiation therapy. If this is the case, stability depends on the fixation alone, since no fusion is added, which obviously increases the demands on the system. In the present series, the fixations included occiput in 14 of 20 patients and were occipito-thoracic in nine patients.

Fig. 2A,B Case report 1. Flexion/extension view showing **A** a PADI of 10 mm in flexion, and **B** realignment in extension

Fig. 3 Case report 1. Preoperative magnetic resonance (MR) image showing pannus formation and signs of cord compression with cord edema

Three representative cases of typical applications of the CD cervical hook and rod system are presented.

Case report 1: occipito-cervical fixation

A 52-year-old man with RA presented with a 1-year history of numbness in his right leg and foot, and a 1-month history of bilateral numbness in the hands and fingers. At clinical examination, he showed signs of myelopathy with hyperreflexia in upper and lower extremities and ankle clonus. He had only slight neck pain, which was elicited by head rotation. Radiographs showed advanced destruction of dens and severe atlanto-dens instability. The posterior atlanto dens interval (PADI) measured 8 mm (Fig. 1). On flexion-extension view, the PADI was 10 mm in flexion, with realignment in extension (Fig. 2). Magnetic resonance imaging (MRI) showed extensive pannus formation and signs of medullary compression with cord edema (Fig. 3).

Surgery was performed with the patient in prone position with 5 kg halo traction. The occiput and the cervical spine were exposed to C4. Bilateral hooks were inserted in a claw formation, with supralaminar hooks at C2 and infralaminar hooks at C3. Bilateral wires were passed around the posterior arch of C1. The two separate rods were connected to the hooks, and each fixed to the occiput by three screws. The two C1 wires were then tightened around the rods. The neck was fixed in neutral position. One cross-link was added to provide rotational stability and to stabilize the hooks in the canal (Fig. 4). After decortication of the occiput, the posterior arches and the lateral masses, bone chips were obtained from the right posterior iliac crest and placed over the decorticated bone. Perioperative fluoroscopy showed good alignment between the dens and C1. A subcutaneous drainage tube was inserted before wound closure. A postoperative Philadelphia collar was used for 6 weeks. The patient showed regression of numbness in his upper extremities within the first postoperative days. At 3 months

Fig. 4 Case report 1. Postoperative lateral view. Fixation from occiput to C3

Fig. 5 Case report 1. Six months postoperative lateral view showing fusion mass and unchanged position of the implants

postoperatively, the patient had complete neurological recovery. At 6 months postoperatively, the patient had returned to his normal work. All neurological deficits were normalized except for a slight dysesthesia in his right hand, which disappeared approximately 1 year postoperatively. Radiographs at 6 months postoperatively showed unchanged position of the implant (Fig. 5).

Case report 2: cervical multilevel fixation

A 30-year-old woman with juvenile RA presented with bilateral weakness of her legs and arms and paresthesia in her hands. Movement of her cervical spine aggravated her symptoms. MRI showed degenerative changes of C3 to C7, with spinal stenosis at C4–5 due to a disc protrusion (Fig. 6). Plain radiographs showed a 3-mm anterior slip of C4 on C5 (Fig. 7).

She was operated on under general anesthesia with 2 kg halo traction in prone position. Hooks were introduced at C1–2 and C7–T1 in a claw configuration (Fig. 8). A laminectomy was performed at C3, C4 and C5. Pre-bent rods were positioned bilaterally and connected by two transverse connectors. The facet joints were decorticated with a high-speed drill, and the bone obtained from the laminectomy was used as a graft. Two sub-fascial drainage tubes were introduced. A Philadelphia collar was used 6 weeks postoperatively. At 5-month follow-up, the patient had no neck pain and showed complete recovery of arm weakness and paresthesia. The weakness in her legs has, however, persisted, most likely due to a MRI-verified lumbar spinal stenosis.

Fig. 6 Case report 2. A 32-year-old woman with RA. Preoperative MR image showing spinal stenosis at C4–5

Fig.7 Case report 2. Preoperative lateral view showing a 3-mm anterior slip of C4 on C5

Fig.8 Case report 2. Postoperative lateral view, showing fixation between C1 and T1

Fig.9 Case report 3. A 79-year-old man. Preoperative MR image showing spinal stenosis due to degenerative spondylolisthesis at C6-7

Fig.10 Case report 3. Computed tomographic (CT) reconstruction showing degenerative spondylolisthesis at C6-7

Case report 3: cervico-thoracic fixation

A 79-year-old man presented with progressive leg weakness and loss of walking ability. Cervical MRI (Fig.9) and computed tomography (CT) (Fig.10) showed a degenerative spondylolisthesis at C6-7 and a severe spinal stenosis at C5 through C7. With the patient under general anesthesia and his head fixed in a halo, the spine was exposed from C3 to T2. Hooks were inserted in claw formation at C3-4 and at T1-2. Complete laminectomies were performed at C5 and C6, and a partial laminectomy at C7. The right intervertebral joint at C6-7 was resected, and the seventh cervical root was decompressed by a foraminotomy. Rods were pre-bent and inserted bilaterally in the hooks. The system was fixed in

Fig. 11A,B Case report 3. One-year postoperative radiographs of the fixation between C3 and T2 show no signs of loosening. **A** Lateral view and **B** anteroposterior view

Table 4 Gender, age, operating time and blood loss in 60 patients operated on with cervical CDI, according to diagnosis

	<i>n</i>	M/F	Age: mean (range)	Op. time (min): mean (range)	Blood loss (ml): mean (range)
Trauma	17	13/4	44 (18–78)	170 (90–240)	750 (200–2500)
RA	16	2/14	70 (59–83)	268 (60–585)	803 (100–3200)
Tumor	20	10/10	62 (19–84)	227 (90–570)	1086 (200–6000)
Misc	7	3/4	49 (17–67)	251 (120–490)	679 (100–1800)
Total	60	28/32	56 (17–84)	229 (60–585)	830 (100–6000)

Table 5 Outcome at follow-up according to diagnosis in 41 patients operated on with CDI

	<i>n</i>	Patient classification				Physician classification				Mortality (<i>n</i>)
		Excellent	Good	Fair	Poor	Excellent	Good	Fair	Poor	
Trauma	14	8	4	1	1	8	4	0	2	0
RA	11	2	5	3	1	6	2	3	0	2
Tumor	9	4	3	0	2	4	3	1	1	7
Misc	7	5	2	0	0	5	2	0	0	0
Total <i>n</i>	41	19	14	4	4	23	11	4	3	9
%		46	34	10	10	56	27	10	7	15

slight compression. After decortication of remaining laminae and intervertebral joints, bone chips from the laminectomies were grafted to the raw bone surface. One sub-fascial draining tube was inserted. At 1-year follow-up, the patient was ambulatory without walking support and had no remaining weakness in his arms. He reported slight pain in the lower part of the neck. Plain radiographs 1 year postoperatively showed unchanged position of the implants (Fig. 11).

Results

The results are presented for the different constructs and for the different diagnoses.

Total material

Of the 60 patients in the material, 17 had traumatic injuries, 16 rheumatic disease, 20 tumors and 7 patients had miscellaneous cervical spinal disorders (Table 4). Eighty percent of the patients classified their outcome as excellent or good, and the physician classified the outcome as excellent or good in 83% (Table 5, Table 6).

Forty-seven patients had the same Frankel grade at follow-up as preoperatively, 9 had improved and 4 had deteriorated neurologically (Table 7).

In the total material, there were six general complications (10%), four neurological complications (7%), two

Table 6 Outcome as classified by the patient and by the physician according to type of instrumentation in 41 patients operated on with CDI

	<i>n</i>	Patient classification				Physician classification			
		Excellent	Good	Fair	Poor	Excellent	Good	Fair	Poor
Uni-level cervical	7	6	1	0	0	7	0	0	0
Multilevel cervical	8	4	4	0	0	4	4	0	0
Occipito-cervical	13	3	5	3	2	7	2	3	0
Cervico-thoracic	13	6	4	1	2	5	5	1	3
Total <i>n</i>	41	19	14	4	4	23	11	4	3
%		46	34	10	10	56	27	10	7

Table 7 Frankel classification of the 13 patients out of 60 in whom the neurological impairment changed from preoperatively to follow-up

Diagnosis	Preop.	FU	Improved no. of grades	Deteriorated no. of grades
Trauma	C	D	1	
	A	B	1	
	D	E	1	
	D	E	1	
	E	D		1
	E	B		3
RA	D	E	1	
	C	D	1	
	C	D	1	
	D	C		1
	E	A		4
Tumor	C	E	2	
	A	C	2	
Total	13	13	9	4

Table 8 General complications according to diagnosis in 60 patients operated on with CDI (*GI* gastro-intestinal)

	<i>n</i>	Cardio/pulmonary	GI tract	Pneumonia	Urinary tract infection	Vascular
Trauma	17	1	1	1		
RA	16					
Tumor	20				1	1
Misc	7	1				
Total	60	2	1	1	1	1

Table 9 Local complications, i.e. implant failure and deep wound infection in 60 patients operated on with CDI

	<i>n</i>	Implant failure	Wound infection
Trauma	17		1
RA	16	1	1
Tumor	20	1	4
Misc	7		
Total	60	2	6

implant failures (3%) and six wound infections (10%) (Table 7, Table 8, Table 9).

Neurological complications

Two patients (1 RA, 1 trauma) were reoperated due to neurological deterioration – Frankel E to A and Frankel E to B, respectively. Both were found to have epidural hematomas, which were re-operated with evacuation. No neurological improvement was seen in these patients. One further patient with bilateral C6–7 facet dislocation (Frankel E) had postoperative weakness in arms and legs. He slowly recovered, and at follow-up his neurological status was graded as Frankel D. Another patient with RA (Frankel D) experienced postoperative weakness in her left arm. Although this was most likely caused by aggravation of her severe left shoulder and elbow arthritis, a neurological cause can not be excluded.

Implant failures

In a patient with RA and cranial odontoid migration and anterior slippage of C3 and C4 operated on with fixation and fusion from occiput to C7, one hook at the end of the construct loosened. At reoperation, fixation and fusion was extended to T3. In one patient (patient 4, in the tumor group) one occipital screw loosened, which did not require revision.

Cervical fixation

Among the 11 patients with unisegmental fixation with various diagnoses there was no implant failure. One patient with posttraumatic kyphosis and C4–5 subluxation had an increased gibbus at follow-up, from 30° to 42°, which did not, however, cause any symptoms. A 66-year-old man with an odontoid fracture suffered from postoperative gastro-intestinal bleeding. There was no neurological complication in patients with unisegmental fixation.

Similarly, in the eight patients with multisegmental cervical fixation, there was no implant failure, no reoperation and no neurological complication. One patient had a postoperative deep wound infection and one had pneumonia.

Cervico-thoracic fixation

In the 20 patients with cervico-thoracic fixation, there was no implant failure. Three neurological complications occurred in the group. Five patients needed revision surgery. One patient with an acute C7 fracture and epidural hematoma was instrumented without claw fixation at the lower end of the construct. Postoperatively, the patient was hard to mobilize, and complained of neck pain, which was interpreted as secondary to an unstable instrumentation. After revision surgery with hook repositioning, claw technique fixation and extension of instrumentation, he was uneventfully mobilized. One patient had recurrent tumor growth and required a second operation. One instrumentation was extracted due to interscapular pain, one due to neck pain and one due to postoperative tetraplegia. There were five deep-wound infections. One patient developed postoperative pulmonary edema and one patient suffered a myocardial infarction with congestive heart failure. Five patients in the cervico-thoracic group died before follow-up.

Occipito-cervical fixation

Among the 17 patients with occipito-cervical fixation, there were three patients with deep wound infections. Thus, half the total of six deep wound infections occurred in this group. The only two implant failures in the entire material occurred in patients operated with occipito-cervical fixation. One patient in the occipito-cervical group deteriorated by one Frankel grade. One patient suffered a perioperative lower extremity arterial thrombosis and a ventricular ulcer. One patient had a urinary tract infection and one patient suffered from slight dysphagia, which was interpreted as secondary to the transoral odontoid extirpation. The mortality in the occipito-cervical group was 18% (3/17).

Discussion

In this retrospective study of the first consecutive 60 patients operated on with cervical CDI, we found no evidence of neurological complications caused by the laminar hooks. The postoperative neurological deterioration of two patients (to paraplegia and tetraplegia) was, at reoperation, considered to have been caused by epidural hematomas, with no radiological or operative signs of metal stenosis caused by the hooks. Thus, we have not been able to verify the widely held belief that hooks are dangerous in the cervical spine. Since hooks have been used safely in the thoracic spine for decades, this is, in our view, rather what one would expect.

Although no increased risk of neurological injury could be demonstrated in the present retrospective series of patients, the technique does, of course, have the potential for such complications. However, alternative tech-

niques based on wires or screws are not without risks either. The lateral mass screw is associated with a risk of nerve root and vertebral artery damage [2, 22]. Heller et al. [21] reported immediate radicular symptoms in seven patients (9%), cerebellar infarction in one and anterior horn infarction in one, in a series of 78 patients operated with posterior cervical plating with attempted bicortical lateral mass screw purchase. They recommended the use of somato-sensory evoked potential monitoring to avoid nerve injury. Abumi et al. [1] reported on a series of 13 patients with traumatic lesions in which pedicle screws were used with few complications, but they also concluded that the technique is technically demanding and associated with a potential risk of neurovascular injury.

Despite the fact that elderly patients dominated the material, with severe rheumatic disease and tumors (60%), the outcome was excellent or good in 80% of the patients. This can be compared to the 94% satisfactory results reported with the OPCD (one-piece cervical device) hook system used on less severely disabled patients [26]. The relatively high frequency of general complications must be interpreted in the light of the advanced age and the severe pathologies treated. Infections occurred primarily in occipito-cervical fusion on patients with RA, who might have an increased risk of infection due to immunosuppressive drug treatment. Possibly, the shaving of the back of the head and the less extensive coverage of the occipital region of well-vascularized muscle tissue are contributing risk factors for infection. The present series of patients has an associated learning curve, particularly regarding the occipital fixation, which has an obvious effect on operating time and, hence, risk of infection.

In atlantoaxial fusion, wires may cut through weak lamina in osteoporotic bone such as in RA. The passage of sublaminar wires in the upper cervical spine carries a potential risk of dural tear and cord damage, with neurological deterioration [37], and in some series high mortality rates – 27% in the series of Ranawat et al. [31] and 33% in the series of Crellin et al. [9]. Although no injury to the vertebral artery or the cord was reported in a large Swiss series of 161 patients reported by Grob et al. [18], transarticular C2–1 fixation is associated with a risk of lethal vertebral artery injury. Thus, neither wires nor transarticular screws are ideal solutions to C1–2 instability. In the present small series of C1–2 fusions, the clinical outcome was excellent/good in all patients and there were no complications. However, CDI seems unnecessarily bulky for C1–2 fusion, and crepitations were reported by one patient, suggesting the use of smaller implants.

The CD system offers different possibilities for occipital fixation. Two different rod-plates were used: the horse-shoe-shaped loop and a straight rod-plate. The latter can be fixed to the occiput either with screws or with two inverted hooks [13]. Logroscino et al. [23] proposed a single hook in the occiput and a specially designed hook in the foramen magnum.

In the subaxial spine one may choose between anterior and posterior fixation and combined front and back fixations. Anterior plates have been reported to offer a less rigid fixation than posterior constructs based on screws, wires and hooks [5, 7, 24, 38, 39]. In a human cadaver study, Bueff et al. [5] showed that the pediatric CD system with sublaminar hooks and a crosslink provided a larger increase in stiffness of the cervicothoracic junction (C7–T1) than posterior lateral mass plates and an anterior plate. Particularly in patients with osteoporotic bone, as in RA and ankylosing spondylitis, which are common patient categories in cervical spine surgery, the use of hooks resting on intact cortical laminar bone seems advantageous to screw fixation. Obviously, however, hooks should not be used at stenotic levels.

In trauma patients with good bone quality and single- or two-level pathology, anterior surgery is often preferable, since the exposure is less extensive and anterior support can be realized. In injuries at the cervico-thoracic level, however, an anterior approach is sometimes technically demanding, and posterior surgery may be the treatment of choice. In non-osteoporotic bone, anterior plate fixation is associated with few problems. Biomechanical studies have shown that bicortical fixation improves stability in cadavers [35], but whether this is sufficient in patients with low bone mineral density remains unclear, and a low bone density is a relative contraindication [41]. In anterior compression of the cord, anterior decompression, fusion and plating are of course mandatory.

In the rheumatoid patient, our results support the proposition that all pathologies, except when dens extirpation is indicated, can be addressed with a posterior approach.

Since these patients always have concomitant osteoporosis, hook-based fixations seem preferable, since they are based on cortical fixation points and therefore, most likely, are more stable.

In patients with metastatic disease in the cervical spine, the mechanism of compression can be either predominantly anterior or posterior and the choice of approach should be chosen accordingly. Since these patients, in general, will be subjected to either chemotherapy or radiotherapy or both, we do not try to accomplish fusion. Therefore, the mechanical demand on the implant is great. The results of our study indicate that CCDI offers good immediate as well as long-term stability. Out of 20 patients with metastatic disease, metal failure occurred in only one (with an inadequate number of screws inserted in the occiput).

The two implant failures in the present series were associated with technical errors. The occipital screws loosened in a patient in whom only three occipital screws had been used instead of the recommended five. The hook loosening occurred in a patient in whom the distal claw fixation had included three laminae instead of the recommended two. The observed rate of metal failure (2/60) compares well with failure rates reported with another hook system, the one-piece cervical device (OPCD), and with the posterior screw-plate systems [21, 25]. The low rate of implant failure observed in the present series shows that cervical CDI meets the mechanical demands on fixations used in the surgical treatment of advanced cervical instabilities. In conclusion, the study shows that laminar hook instrumentation in the cervical spine is not associated with any obvious neurological risk and results in a high success rate in severe cervical spine pathologies.

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