Acta Orthop. Belg., 2005, **71**, 604-609

ORIGINAL STUDY

Anterior cervical interbody fusion with radiolucent carbon fiber cages : clinical and radiological results

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The authors retrospectively evaluated 30 patients with an anterior cervical interbody fusion for cervical spondylosis or disc herniation. Open box carbon fiber cages were used at 45 levels.

The visual analogue scales (VAS), respectively for neck and for arm pain, and the neck disability index (NDI) improved significantly ($p < 0.001$). Fusion occurred in 87% of the operated levels. Subsidence of the cages into the endplates was observed in 49% of the operated levels, which increased to 54% when more levels were fused. No correlation between subsidence of the cage and clinical outcome or radiographic fusion was established.

The authors conclude that cervical discectomy and interbody fusion using an open box carbon fiber cage is a satisfactory treatment option for degenerative cervical disease causing neck pain and radiculopathy, despite the relatively high percentage of subsidence of this cage.

Keywords : cervical spine ; interbody fusion ; carbon fiber cages.

INTRODUCTION

Cervical spondylosis and disc herniation are frequent causes of neck and arm pain. Anterior cervical discectomy with decompression of the nerve root is a recognized treatment option (*3, 5, 9*). Interbody fusion with a structural support has been advocated, in order to avoid increase of the cervical kyphosis and loss of foraminal height (*1, 6, 12*). Allografts (*6, 15*), autografts (*6, 12*), polymethylmethacrylate (PMMA) (*2*) and cages have been used to this purpose (*8, 12*). However, a systematic review of the literature indicates that there is no gold standard for the treatment of degenerative cervical disease (*5, 13*). The popularity of cervical cages is increasing (*8, 13*), although long term studies are scarce. The objective of anterior cervical interbody fusion using a cage is to achieve a well-aligned segmental fusion with adequate neurologic decompression (*1, 5*). Cages perform well and are readily available, but they are relatively expensive (*12*). Various disadvantages have been described for the other implants as well. The use of a tricortical autologous iliac bone graft, for example, is associated with substantial donor site morbidity (*6, 10*). Allografts, mainly from the femoral diaphysis, are not available everywhere, and the use of PMMA often leads to pseudarthrosis (*2*).

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Table I. — Study population and measurements

patient nr.	gender	age	NDI pre-op / post-op	VAS neck : pre / post	VAS arm : pre / post	fusion level	fusion	subsidence	lordosis pre-post
1	f	50	76 / 80	8,4 / 8,4	7,9 / 8,6	C6-7 (1)	+	-	+ 3º
2	f	53	36 / 16	6,5 / 3,5	7,7 / 5	C5-6 (1)	+	-	+ 16º
3	m	49	74 / 68	6,3 / 6,8	6,2 / 3,7	C6-7 (1)	-	+	+ 6º
4	f	46	80 / 84	10 / 9	10 / 10	C5-6 (1)	+	-	- 1º
5	f	41	38 / 10	7,1 / 1,9	7,1 / 1,9	C5-6 (1)	+	-	- 12º
6	m	31	68 / 70	0,7 / 2,4	9,2 / 2,4	C6-7 (1)	+	+	+ 5º
7	m	54	36 / 4	7,6 / 0,4	7,4 / 0,2	C5-6 (1)	+	+	- 3º
8	f	48	84 / 58	6,8 / 2,4	8,2 / 3	C6-7 (1)	+	-	- 4º
9	m	37	24 / 4	4,2 / 0,1	5,2 / 0,1	C5-7 (2)	+ / +	- / -	+ 5º
10	m	49	98 / 6	7,8 / 0	8,4 / 0	C6-7 (1)	+	-	- 3º
11	m	47	14 / 12	5,1 / 0,5	0 / 2,2	C4-6 (2)	+ / -	- / +	- 10º
12	f	42	82 / 90	9,8 / 9,6	9,9 / 9,5	C5-7 (2)	+ / +	- / +	- 16º
13	m	58	80 / 46	8,2 / 2,9	7,6 / 0,4	C5-7 (2)	+ / +	- / -	- 15º
14	f	53	36 / 44	9,2 / 4,5	9 / 2,3	C5-6 (1)	+	-	- 9º
15	f	56	64 / 64	2,5 / 2,7	7,2 / 7,5	C5-6 (1)	+	-	+ 3º
16	f	64	100 / 84	10 / 7,8	10 / 7,8	C6-7 (1)	-	-	+ 4º
17	m	65	32 / 28	4,1 / 3,3	3,4 / 3,3	C4-6 (2)	+ / +	+ / -	- 2º
18	f	46	94 / 54	9,4 / 4,3	9,4 / 4,2	C5-7 (2)	+ / +	- / -	- 9º
19	m	57	36 / 2	0 / 0	10 / 10	C5-7 (2)	+ / -	+ / +	- 6°
20	m	55	68 / 60	5,8 / 7,3	6,7 / 1,3	C5-6 (1)	+	+	- 3º
21	m	71	26 / 16	7,8 / 1,5	7,8 / 0	C5-7 (2)	+ / +	+ / +	- 4º
22	f	60	58 / 66	4 / 6,5	4 / 6,5	C4-6 (2)	+ / +	+ / +	- 9º
23	m	56	72 / 60	9,9 / 4,7	9,8 / 2,8	C4-7 (3)	+ / + / +	+ / - / +	- 38º
24	f	74	66 / 66	0 / 0	7,4 / 7,8	C4-7 (3)	- / + / +	+ / + / +	+ 15º
25	f	41	74 / 64	7,6 / 8,9	8,8 / 8	C4-6 (2)	+ / +	- / -	- 11º
26	f	55	60 / 52	9 / 8,5	9,1 / 8,8	C5-6 (1)	+	+	- 2º
27	m	51	44 / 14	7,7 / 1,2	7,7 / 1,2	C5-7 (2)	+ / +	- / +	- 4º
28	f	37	80 / 52	7,7 / 7,9	9,8 / 0,1	C5-6 (1)	-	+	+ 4º
29	f	52	68 / 6	8,4 / 0,4	9 / 0	C5-6 (1)	+	-	+ 16º
30	f	36	38 / 32	6,8 / 6,5	7,4 / 6,5	C5-6 (1)	+	+	- 11º

PATIENTS AND METHODS

Thirty patients, operated in the Rijnstate Hospital, Arnhem, The Netherlands, for symptomatic cervical spondylosis or disc herniation between January 2000 and January 2002 were retrospectively evaluated. The study group consisted of 13 males and 17 females with a mean age of 51.1 years (range, 31-74 years) at surgery (table I). The mean follow-up period was 22.4 months (range, 9-39 months). Cervical nerve root entrapment was due to spondylosis in 14 patients and to disc herniation in 16 patients. A single-level fusion was performed in 17 patients, a two-level fusion in 11 patients and a three-level fusion in 2 patients. A total of 45 cages were implanted : 6 at C4-C5, 24 at C5-C6 and 15 at C6-C7. Nineteen patients were treated by an orthopaedic surgeon and 11 by a neurosurgeon.

An open box carbon fiber cage was used (cervical I/F cage, Depuy Spine, Amersfoort, The Netherlands), filled with autologous cancellous bone grafts from the iliac crest. Either an orthopaedic surgeon (PvL) or a neurosurgeon (RB) performed the surgery, according to the outpatient clinic where the patient was seen. Criteria for surgical treatment were arm pain due to cervical spondylosis or herniated disc with nerve root entrapment, that failed to respond to conservative treatment for at least three months.

Surgical technique

A standard anterior approach was used. A complete discectomy was performed. Under slight distraction, the disc, the dorsal osteophytes and the adjacent cartilaginous endplates were carefully removed. The subchon-

dral bone was preserved to minimize chances of subsidence of the implant into the trabecular bone. A bilateral decompression of the neuroforamen was performed. After determining the optimal size of the cage, the cage was packed with cancellous bone grafts from the ipsilateral iliac crest and implanted into the disc space. When distraction was removed, the cage was left under slight compression.

Clinical evaluation

Visual analogue scales (VAS), respectively for arm and for neck pain (*4*), and a "Neck Disability Index" (NDI) (*14*) were used retrospectively, in order to describe the clinical picture preoperatively and at the time of the last follow-up. The tests were supervised by an orthopaedic resident (IvdH), not involved in the surgery. The VAS had a range from zero to 10 (no pain versus unbearable pain), for neck pain and for arm pain. The NDI questionnaire evaluated disability in several aspects of everyday life. The maximum score was 50, representing the highest level of disability (100 percent). In addition, the postoperative questionnaire included items on overall satisfaction and readiness to undergo the initial operation again.

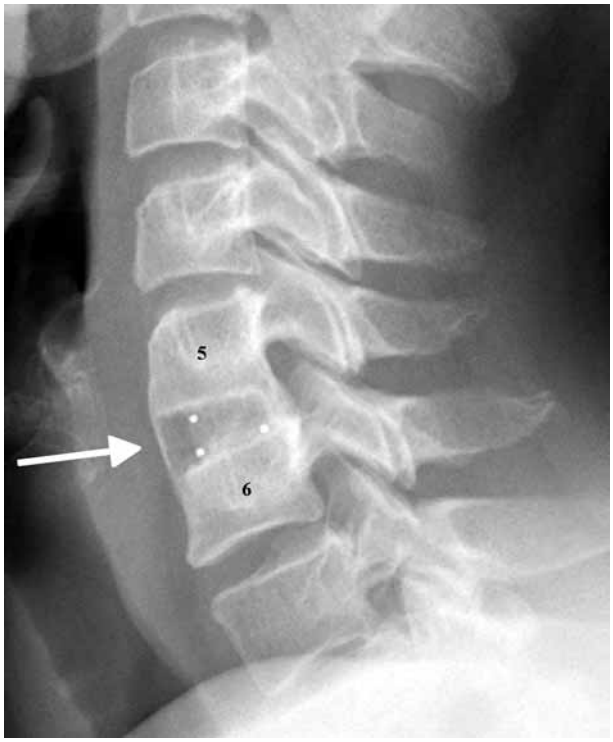

Fig. 1. — Lateral radiograph of the cervical spine, showing an anterior cervical interbody fusion C5-C6 with an open box carbon fiber cage. The tantalum beads indicate the position of the cage. A solid fusion is visible and the natural lordosis is restored. Note the arrow pointing towards the bony bridge between C5-C6 in front of the cage (sentinel sign), indicating solid fusion.

Radiographic evaluation

Antero-posterior, lateral and flexion-extension radiographs of the cervical spine were made preoperatively and at regular intervals after surgery. The preoperative lateral radiographs were analyzed to measure the inter-body angle between C4 and C7 (fig 2). The postoperative radiographs were used to assess fusion, possible subsidence of the cage into the vertebral endplates and evolution of the inter-body angle C4-C7. The following findings were seen as evidence for radiographic fusion : a "sentinel sign" (bridging bone anterior to the fusion cage seen on the lateral radiograph) (fig 1), and the presence of continuous trabeculae within the cage (*9*) in combination with loss of intersegmental motion on flexion-extension radiographs. Subsidence was defined as more than 1 mm penetration of the cage through the vertebral endplate. Restoration of sagittal alignment (cervical lordosis) was assessed by comparing the pre- and postoperatively measured inter-body angle between C4 and C7.

Statistical analysis

The Wilcoxon signed-ranks test, the paired Student's t-test, and the Mann-Whitney test were used for statistical analysis. P-values < 0.05 were considered significant.

RESULTS

Clinical results

VAS scores for neck pain decreased significantly from 6.6 (SD = 2.9) pre-operatively to 4.1 (SD = 3.3) ($p < 0.001$), and for arm pain from 7.7 (SD = 2.2) to 4.2 (SD = 3.5) ($p < 0.001$). There was also a significant improvement of the NDI from 60.4% (SD = 24.1) preoperatively to 43.8% (SD = 28.4) at the latest follow-up ($p < 0.001$). At the latest follow-up 8 patients (27%) were very satisfied, 16 (53%) were moderately satisfied and 6 patients (20%) were not satisfied. All patients that were not

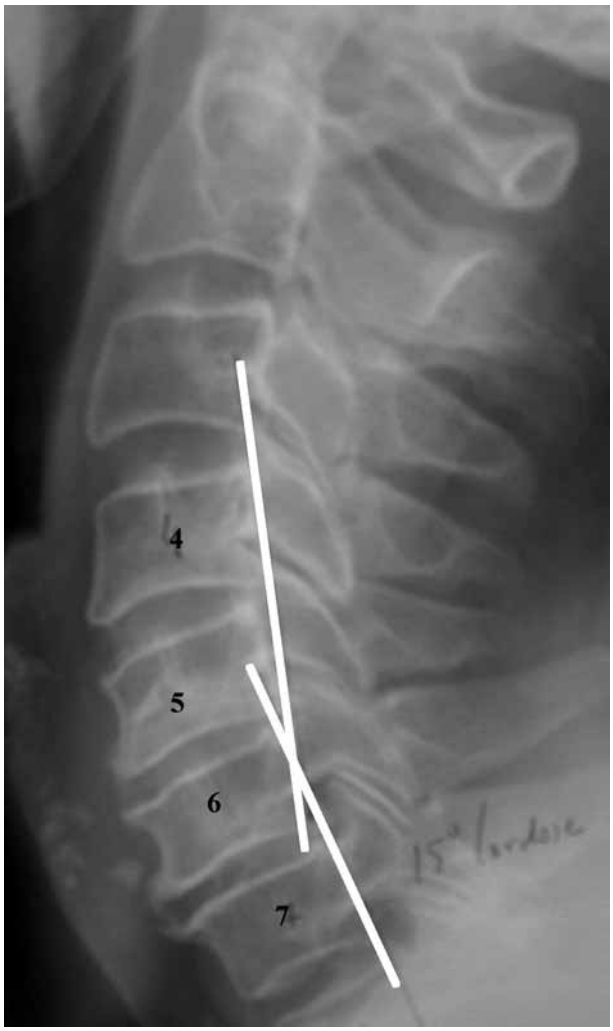

Fig. 2. — Lateral radiograph of the cervical spine showing measurement of the inter-body angle between C4 and C7.

satisfied had a two- or three-level fusion. Fourteen patients would undergo the initial operation again (47%), another 47% were not sure and 6% (two three-level fusions) would refuse the initial surgery.

Radiographic results

A sentinel sign was present in 4 out of 6 cages (67%) at the C4-C5 level, in 22 out of 24 cages (92%) at the C5-C6 level and in 11 out of 15 cages (73%) at the C6-C7 level. Trabecular continuity was observed in 5 out of 6 cages (83%) at the C4-C5 level, in 21 out of 24 cages (88%) at the C5-C6 level and in 12 out of 15 cages (80%) at the C6-7 level. The overall fusion rate was 39 out of 45 levels or 87%.

Subsidence through the vertebral endplate occurred in 4 out of 6 cages (67%) at the C4-C5 level, in 10 out of 24 cages (42%) at the C5-C6 level and in 8 out of 15 cages (53%) at the C6-C7 level. The overall subsidence rate was 22 out of 45 levels or 49% ; it reached 54% in multi-level fusions.

At the most recent follow-up a non significant decrease in inter-body angle between C4 and C7 could be established : from 10.3° pre-operatively to 6.9° ($p = 0.13$).

DISCUSSION

The use of cages as a substitute for iliac crest bone grafts to achieve interbody fusion after cervical discectomy has become popular. In a recent prospective randomised study, cages proved to perform equally well as tricortical autologous grafts for cervical interbody fusion, while avoiding comorbidity from the donor-site (*12*). In our study, neck and radiating arm pain from spondylosis and cervical nerve root entrapment also improved significantly after cervical discectomy and interbody fusion using a carbon fiber cage. The overall clinical results were fairly good. However, careful patient selection may allow further improvement. A flaw of this study was the fact that the visual analog scales and the neck disability index were assessed retrospectively. According to the literature, the clinical results tend to worsen when more levels are involved in the fusion (*3*). This was also confirmed by our study : 6 patients, all with a multi-level fusion, were not satisfied with the clinical result.

Fusion

A solid fusion was obtained in the vast majority of the cases. The fusion rate was as high as 39 out of 45 levels, or 87%, starting from strict radi-

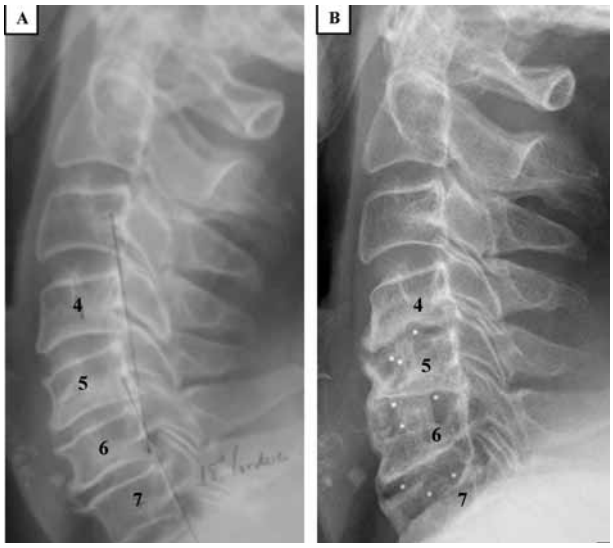

Fig. 3. — Pre- (A) and postoperative (B) lateral radiographs of the cervical spine, showing an extreme case of subsidence of implanted cages into the adjacent vertebral endplates. The natural lordosis was lost.

ographic criteria, such as the presence of a sentinel sign or bony bridging in the cage, which is the only absolute radiographic evidence for bony intersegmental fusion (*9*). A difference in fusion tendency between different intervertebral levels was also noted, with the highest fusion tendency at the C5-C6 level. Apparently, various biomechanical factors, which facilitate or inhibit interbody fusion, seem to play a role at each intervertebral level.

Subsidence

A substantial biomechanical influence of the cage on the adjacent vertebral endplates was also suggested by the surprising high percentage of subsidence : 49%. The risk of subsidence is a recognised phenomenon in spinal fusions with cages (*7, 16, 17*). Especially at the C4-C5 level and in multilevel fusions, relatively high percentages of subsidence of the cage were observed. Subsidence neither had a negative influence on the fusion potential of the involved level nor did it lead to a worse clinical outcome. Even when an increased risk of subsidence for specific intervertebral levels and in multiple-level fusions is acknowledged, the total rate of subsidence still remains high as compared to data reported with different implants in the literature (*8*). Most logically, both surgeon and implant related factors might play a role. As patients were randomly treated by an orthopaedic surgeon or a neurosurgeon, and both groups had similar subsidence problems, surgeon related factors seem to have played a minor role. It is, however, important to recognize that surgical technique is indeed extremely important to achieve a successful end result. In our opinion, chances of subsidence of the cage can be minimized by avoiding end plate destruction and over-distraction of the disc space. As to the design of the implant, one may speculate that relatively high contact pressures between the surface of the cage and the adjacent endplates can be held responsible for increased subsidence rates. It is probably important for the cage to have a contact surface that approaches the anatomical curvature of the involved endplate as much as possible. The generation of peak stresses can thus be reduced, and chances of subsidence minimized. In literature, only a few studies were found to compare different designs from this view-point (*8, 11*). The relation between a reduced risk of subsidence and a larger contact area at the implant-endplate interface has been described before (*16, 17*).

Cervical lordosis

Apart from fusion and subsidence, radiographic evaluation also included possible restoration of the cervical lordosis : the inter-body angle was measured between C4 and C7. One might object that the measurement should have been limited to the fusion area. Anyway, improved lordosis could be anticipated owing to the wedge shape of the cages. However, the authors had to conclude that surgery slightly reduced the pre-existent cervical lordosis, rather than improving it. This was probably due to the high amount of subsidence, rather than to insufficient wedging of the cages by their designer.

This study confirms that anterior cervical discectomy and interbody fusion using a cage is a good treatment option for incapacitating arm pain due to cervical spondylosis or disc herniation. The surgeon should preserve the endplates and avoid

overdistraction of the disc space. Multi-level fusion should be performed with caution because inferior results can be expected. The open box type of cage used in this study revealed a relatively high amount of subsidence, maybe due to relatively high contact pressure.

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