Mod Rheumatol (2004) 14:435–441
DOI 10.1007/s10165-004-0339-9

ORIGINAL ARTICLE

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Occipitocervicothoracic fixation using a hook and rod system for patients with rheumatoid cervical spine

Received: January 27, 2004 / Accepted: July 17, 2004

Abstract We retrospectively examined the outcomes of occipitocervicothoracic fixation using a hook and rod system for rheumatoid patients with cervical myelopathy in which decompression of the spinal cord and spinal fusion were performed simultaneously at multiple levels. There were 10 female patients with rheumatoid arthritis (ages 51–77 years, average 62.8 years; follow-up period 6 months to 3 years and 9 months, average 2 years and 8 months). Atlantoaxial subluxation was found in 5 patients, vertical subluxation in 4 patients, and subaxial subluxation in 8 patients. The progression of the disorder was assessed as class 4 stage 4 in 3 patients and class 3 stage 4 in 7 patients. The average time taken for surgery was 4 h 41 min, and the average volume of blood loss was 729 ml. There were no complications during surgery. One patient died of malignant lymphoma 1 month after surgery, and one patient died of heart failure 2 years and 3 months after surgery. The average Japanese Orthopaedic Association (JOA) score improved from 7.0 preoperatively to 9.5 postoperatively. Preoperative nuchal pain in 3 patients and difficulty in breathing on flexion of the cervical spine in 2 patients were improved after surgery. Good bony union was obtained in 9 patients. The exception being one patient who died of a disease unrelated to the surgery 1 month postoperatively. Occipitocervicothoracic fixation using a hook and rod system is an easy and safe procedure, and can facilitate not only good bony union, but also adequate decompression of the spinal cord with simultaneous laminoplasty because of the secure long fixation extending to the upper thoracic level and bilateral grafting of a considerable volume of bone.

Key words Cervical myelopathy · Hook and rod system · Occipitocervicothoracic fixation · Rheumatoid cervical spine

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Introduction

A patient with rheumatoid arthritis is often affected by cervical spondylotic myelopathy, in which the cervical spine becomes deformed at multiple levels and develops local instability in combination with osteoporotic change. In the surgical treatment for such patients, it is necessary to perform not only a procedure to decompress the spinal cord, but also a procedure to reduce the deformity and stabilize the spine. Recently, several types of spinal fixation procedures using specially developed spinal instrumentation have been performed.[1–15] However, some problems relating to the surgical method and fixation area remain unresolved. We have performed occipitocervicothoracic fixation using a hook and rod system[3,4] combined with laminoplasty, which simultaneously allows decompression of the spinal cord and spinal fusion at multiple levels. This study retrospectively examined the outcomes and limitations of our surgical methods.

Patients

Since 1999, 10 rheumatoid arthritis patients with cervical myelopathy have undergone occipitocervicothoracic fixation at our hospital. All the patients were women, and their ages at surgery ranged from 51 to 77 years, with an average of 62.8 years. The follow-up period ranged from 6 months to 3 years and 9 months, with an average of 2 years and 8 months, for 9 patients. These figures exclude one patient who died of a disease unrelated to surgery 1 month postoperatively. Preoperatively, atlantoaxial subluxation (the atlantodental interval was 5 mm or more on a flexion X-ray view) was found in 5 patients, vertical subluxation (the Ranawat value[16] was less than 12 mm) in 4 patients, and subaxial subluxation in 8 patients. On Steinbrocker's criteria for the progression of the disorder,[17] 3 patients were assessed as class 4 stage 4 and 7 patients as class 3 stage 4 (Table 1).

Table 1. Patient profiles

No.	Age	Sex	Duration (years)	Disorder (class, stage)	Follow-up	Deformity	C2–7 angle	JOA score	Bony union
1.	62	F	11	RA (4, 4)	2y 3m (death)	A, V, S	54 → 41	5.5 → 8	Union
2.	59	F	16	RA (3, 4)	3y 9m	S	40 → 17	7 → 10	Union
3.	57	F	16	RA (4, 4)	3y	A, S	23 → 20	10.5 → 11	Union
4.	51	F	24	RA (4, 4)	3y 7m	V	43 → 54	6 → 10.5	Union
5.	74	F	26	RA (3, 4)	3y 4m	V, S	22 → 15	7 → 9	Union
6.	77	F	20	RA (3, 4)	3y 4m	S	13 → 12	3 → 6	Union
7.	69	F	6	RA (3, 4)	3y 3m	A, S	39 → 5	7 → 10	Union
8.	66	F	20	RA (3, 4)	1m (death)	A, S	46 → 25	10 → 10	–
9.	58	F	11	RA (3, 4)	10m	S	5 → 10	6 → 9	Union
10.	56	F	10	RA (3, 4)	6m	A, V	11 → 13	11 → 12	Union

JOA score, Japanese Orthopaedic Association score; RA, rheumatoid arthritis; A, atlantoaxial subluxation; V, vertical subluxation; S, subaxial subluxation; y, years; m, months

Table 2. JOA score for cervical myelopathy

(1) Motor function of the upper extremities
- 4. Normal
- 3. Able to eat using chopsticks with slight difficulty
- 2. Able to eat using chopsticks with difficulty
- 1. Able to eat using a spoon only
- 0. Unable to eat unaided

(2) Motor function of the lower extremities
- 4. Normal
- 3. Able to walk without support with slight difficulty
- 2. Able to walk up and down stairs only with support
- 1. Requires support to walk even on level ground
- 0. Unable to walk

(3) Sensory function (the same in the upper and lower extremities and trunk)
- 2. Normal
- 1. Slight sensory disturbance or numbness
- 0. Distinct sensory disturbance

(4) Bladder function
- 3. Normal
- 2. Slight urination difficulty (pollakiuria, retardation)
- 1. Serious urination difficulty (residual urine, dysuria)
- 0. Urine retention

The neurological condition of the patients was assessed using the Japanese Orthopaedic Association (JOA) score for cervical myelopathy (Table 2), and the alignment of the cervical spine was assessed using the C2–7 lordosis angle, which is the angle made by two crossed lines drawn along the posterior margins of the C2 and C7 vertebral bodies.

Surgical method

The patient's cranium was fixed to the operation table by the Mayfield method. The positions of the head and trunk were carefully checked to avoid malformed fixation. From the cranial side, rotation was confirmed by comparing two imaginary horizontal lines: one was a horizontal line connecting the bilateral ears, and the other was a horizontal line connecting the bilateral posterior surfaces of the thoracic cage. Bending of the head was confirmed by alignment of the outer tubercle of the occiput, the spinous process of C7, and the thoracic spinous processes. The sagittal bony alignment from the cranium to the thoracic spine was confirmed roentogenographically.

The fundamental surgical procedure was as follows. After the posterior arch of C1 was resected and the lamina of C2 was reserved, tension-band laminoplasty[18] or double-door laminoplasty[19] was performed at the levels showing spinal cord compression. Cervical Cotrel–Dubousset instrumentation (CCD) (Medtronics, Memphis, TN, USA) is available for spinal fixation as a hook and rod system. The rod was configured with the same sagittal curve as the laminae. A compression force was applied between the lamina hook at C2 and the pedicle hook at C3 or C4. At any thoracic level between T1 and T6, a compression force was applied between the transverse hook at the cranial level and the pedicle hook at the caudal level. Finally, the rod was fixed at the occiput using screws, and the two rods were connected using two or three transverse bars. After making a horizontal notch at the occiput, the bent strut bone from the outer plate of the ilium was grafted between the horizontal notch at the occiput and the spinous process of C2. The strut bone was securely fixed by compression from the dorsal side using two threads which were connected to the

Table 3. Details of the surgery

No.	Hook level	Decompression area	Method	Operation time	Bleeding volume (ml)
1	C2/3, T5/6	C4–7	TBL	3 h 55 min	400
2.	C2/3, T3/4	C4–7	TBL	4 h 16 min	590
3.	C2/3, T3/4	–	–	4 h 10 min	920
4.	C2/3, T3/4	–	–	3 h 25 min	468
5.	C2/3, T3/4	C3–7	TBL	4 h 40 min	1840
6.	T2/3	C3–7	TBL	5 h 5 min	800
7.	C2/4, T1/4	C5–7	TBL	7 h 5 min	900
8.	C2/3, T3/4	–	–	3 h 45 min	680
9.	C2/3, T2/5	C3–7	DDL	5 h 3 min	630
10.	C2/4, T2/4	C3–7	DDL	5 h 30 min	770

TBL, tension-band laminoplasty; DDL, double-door laminoplasty

bilateral rods. Posterolateral fusion was performed at the subaxial levels using cancellous bone.

After surgery, a soft cervical collar was applied for 2 months.

Results

Laminoplasty was performed in 7 patients (tension-band laminoplasty in 5 patients, and double-door laminoplasty in 2 patients). The range of decompression was 3 laminae in one patient, 4 laminae in 2 patients, and 5 laminae in 4 patients (Table 3).

The levels of cervical hook fixation were C2–3 in 7 patients and C2–4 in 2 patients. The levels of thoracic hook fixation were T3–4 in 5 patients and T1–4, T2–3, T2–4, T2–5, and T5–6 in one patient each. In one patient, the posterior arch of C1 and the lamina of C2 were connected using lamina hooks at the first surgery. One month after surgery, laminectomy was performed because of fracture at the posterior arch of C1, and the occiput and the T2–3 were directly connected at the second operation (Table 3).

The average duration of surgery was 4 h 41 min (range 3 h 25 min to 7 h 5 min), and the average volume of blood loss was 729 ml (range 400–1840 ml) (Table 3). There were no complications during surgery.

One patient died of a malignant lymphoma (which was found by chance) 1 month after surgery, and one patient died of heart failure 2 years and 3 months after surgery. The average JOA score improved from 7.0 (3–11) preoperatively to 9.5 (6–12) postoperatively. Preoperative nuchal pain in 3 patients and difficulty in breathing on flexion of the cervical spine in 2 patients were improved after surgery (see Table 1).

Postoperatively, the C2–7 lordosis angle decreased by 14.6° on average in 7 patients, and increased by 6.0° on average in 3 patients. Overall, the average C2–7 lordosis angle decreased from 29.5° (range 5° to 54°) preoperatively to 21.2° (range 5° to 54°) postoperatively. Good bony union was obtained in all the patients except for the patient who died 1 month after surgery (Table 1).

Case study

A 74-year-old woman with rheumatoid arthritis (class 3, stage 4) combined with cervical myelopathy underwent decompression and fusion surgery. A preoperative X-p film demonstrated severe osteoporosis, vertical subluxation, and subaxial subluxation at C3/C4 and C4/C5. The Ranawat value was 8 mm. On a flexion X-ray view, the subluxation at C3/C4 had deteriorated (Fig. 1). Cervical CCD was fixed at between the occiput and the fourth thoracic vertebra (Fig. 2). Tension-band laminoplasty was performed between C3 and C7 (Fig. 3). After surgery, the patient's JOA score improved from 7 to 9, and the C2–7 lordosis angle decreased from 22° to 15°. MRI showed spinal cord compression at between C3 and C5, and an intramedullar T2-high lesion at C3/C4 preoperatively, and good spinal cord decompression postoperatively (Fig. 4). One year and 5 months later, there were no breakages or loosening of the instruments and good bony union had been obtained.

Discussion

Methods of spinal fixation and spinal cord decompression

In rheumatoid arthritis, not only the atlantoaxial joint but also subaxial joints are sometimes affected. As a result, cervical myelopathy is induced in combination with multilevel spinal deformity. In surgical treatments for these conditions, simultaneous wide-range decompression of the spinal cord and spinal fixation must be achieved. Although decompression and fusion via the anterior approach has been performed,[20] currently posterior spinal instrumentation is usually applied via the posterior approach.[1–15]

Several posterior spinal instrumentations are available, such as the hook and rod method,[3,4] the sublaminar wiring method,[6,8–11,13] the lateral mass screw method,[2,21] and the pedicle screw method.[1,7] The sublaminar wiring method is not indicated after laminectomy or laminoplasty because the wires cannot be anchored at the laminae. During the procedure of passing a wire under the lamina, the spinal cord may be compressed. After surgery, vertical translocation may occur because there is very little resistance against

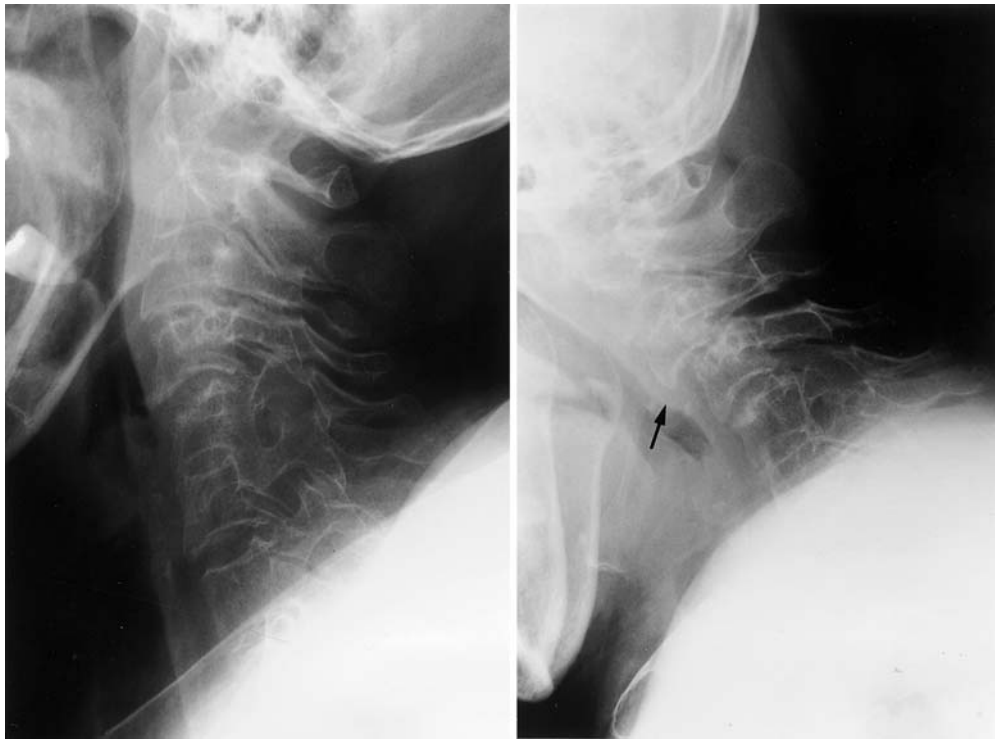

Fig. 1. Preoperative lateral X-p film (*left*) and the flexion X-p film (*right*). The preoperative X-p film showed severe osteoporosis, vertical subluxation, and subaxial subluxation at C3/C4 and C4/C5. On a flexion X-ray view, subluxation at C3/C4 was shown to have deteriorated (*arrow*)

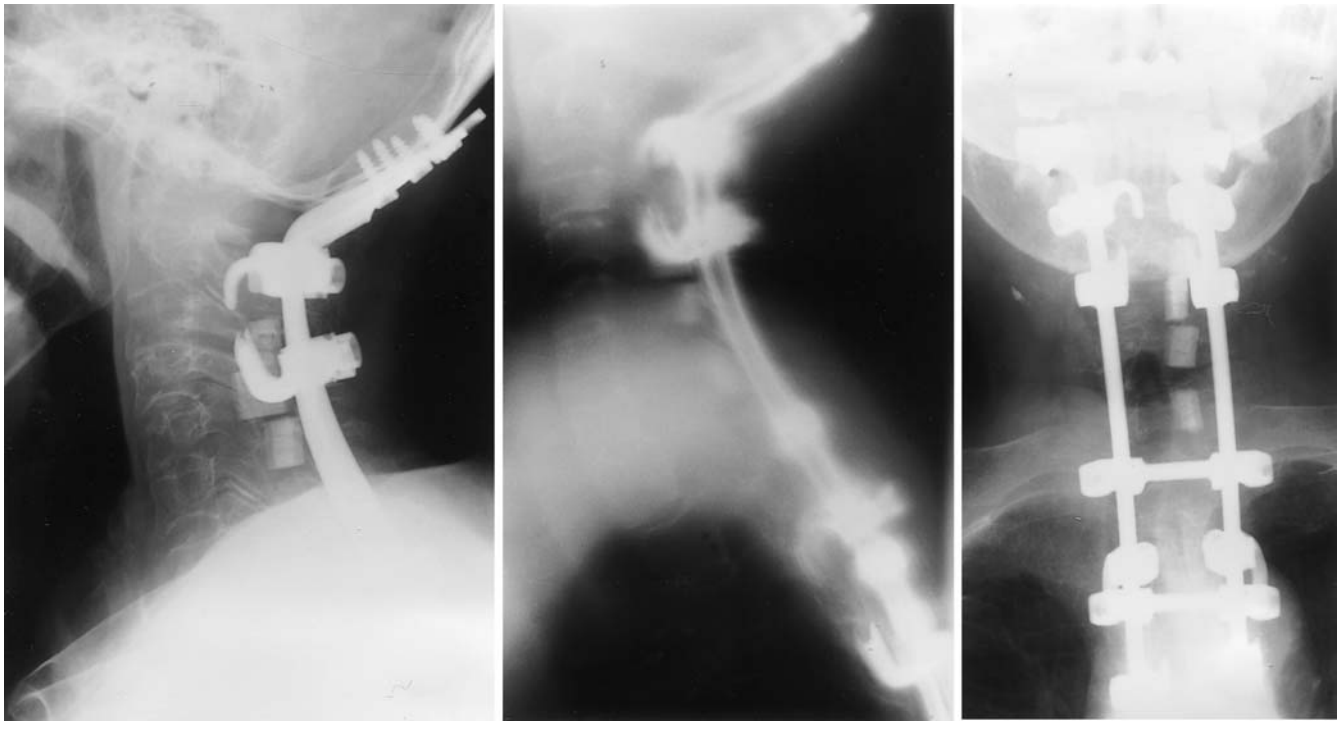

Fig. 2. Postoperative X-p films (*left*, lateral view; *right*, anteroposterior view) and tomography (*middle*). Cervical CCD was fixed at between the occiput and the fourth thoracic vertebra. A compression force was applied between the lamina hook at C2 and the pedicle hook at C3. A compression force was applied between the transverse hook at T3 and the pedicle hook at T4. The rod was fixed at the occiput using screws. Subaxial subluxation at C3/C4 and C4/C5 was reduced after surgery

shortening.[6,8,12] The lateral mass screw method has the disadvantage that the screws cannot be fixed securely in the lateral mass, especially in patients with osteoporosis.[2,21] In the pedicle screw method, the screws can be fixed securely to the vertebral body. However, there is the possibility of injuring nerve roots and the vertebral artery,[22,23] especially in patients with severe deformity and shortening of the vertebral body, invasion of the pedicle by pannus, and malalignment of the spinal column. In contrast, the hook and rod method is easier and safer, and is indicated in combination with laminoplasty. The hooks can be securely fixed at the pedicles and laminae with less possibility of injuring nerve roots and the vertebral artery. Care must be taken not to apply excessive compression force to the pedicle hook at the cervical level, especially in patients with severe osteoporosis.

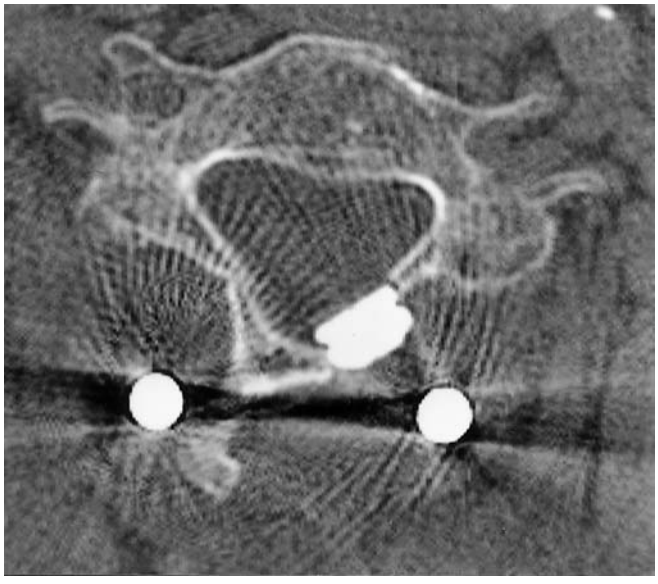

Fig. 3. Tension-band laminoplasty. The spinal canal was widened after tension-band laminoplasty using an intraspinous process spacer (*white quadrilateral area*) which was fixed at one side of the lamina. (The two *white circular areas* are rods)

However, fixation using only the hook and rod system is not sufficient to obtain good bony union. The important point is to make the bed as wide as possible, and to graft as much volume of bone as is possible. From this viewpoint, double-door laminoplasty is available in combination with the hook and rod system (Fig. 5). The bilateral rod can easily be fixed without intersecting the split laminae, and the grafted bone chips at the bilateral posterolateral portion of the laminae do not tend to drop into the spinal canal because the centrally split laminae are retracted bilaterally and symmetrically. Even in a rheumatoid cervical spine, the anteroposterior diameter of the spinal canal at the C2 level is wide, and as a result, in almost all patients, laminoplasty is performed below the C3 level. If laminoplasty must additionally be performed at the C2 level, the laminar hook cannot be fixed at the C2 level. In such a case, either Magerl's method,[7] in which the pedicle screw is inserted into the C2 vertebral body, must be performed, or the occiput and thoracic spine must be directly connected, followed by external support with a halo-vest.

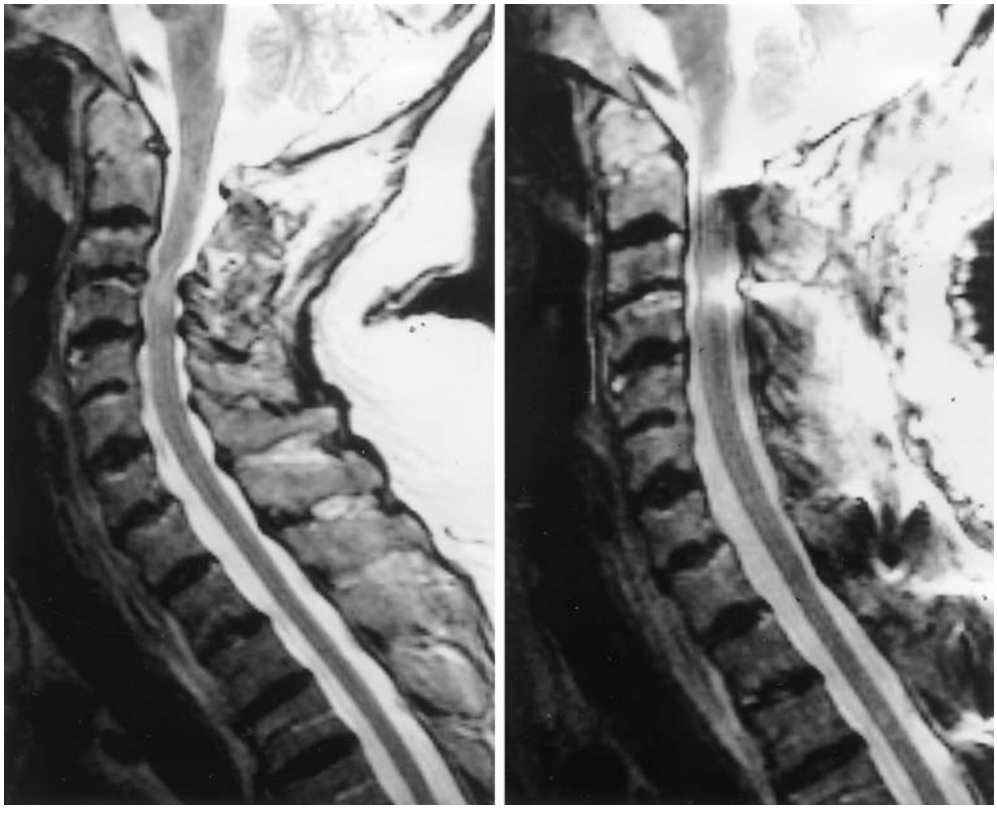

Fig. 4. Preoperative (*left*) and postoperative (*right*) MRIs. The preoperative MRI shows spinal cord compression between C3 and C5 and an intramedullar T2-high lesion at C3/C4. The postoperative MRI shows good spinal cord decompression. (The *black area* behind the spinal cord at the C2 level is artificial)

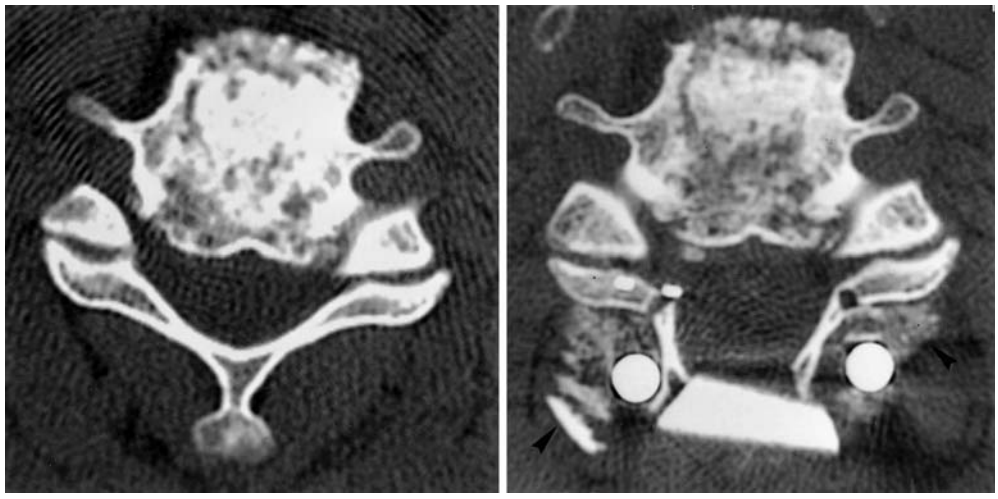

Fig. 5. Double-door laminoplasty. The preoperative narrow spinal canal (*left*) was widened after double-door laminoplasty using an intraspinous process spacer (*white trapezoidal area*) which was fixed centrally (*right*). The bilateral rod (two *white circular areas*) was fixed lateral to the split laminae. A large volume of bone chips (two wedges) was grafted onto the facet joints

The fixation areas

In occipitospinal fixation, locating the most caudal level of fixation is a problem. In the rheumatoid cervical spine, which tends to be associated with osteoporosis, occipitocervical fixation is fragile because of a short fusion and de novo spinal instability tends to occur at the adjacent level of fixation.[5,8,9] Therefore, we perform occipitocervicothoracic fixation as a long fusion[24] in which the most caudal level of fixation is the upper or middle thoracic level. The absolute indication for occipitocervicothoracic fixation is a patient with vertical subluxation and/or irreducible atlantoaxial subluxation with multiple-level spinal canal stenosis at the subaxial region, which must necessarily be decompressed. Certainly, the range of motion of the cervical spine is completely restrained after a long fusion. However, the vertebral body of the thoracic spine is bigger than that of the cervical spine, and as a result a stronger compression force can be applied between the pedicle and transverse hooks, which are securely fixed to the thoracic spine. Usually, the pedicle hook is fixed to T4 and the transverse hook is fixed to T3. As the thoracic spine is connected to the thoracic cage and is stable, there is an extremely low possibility of de novo spinal instability occurring at the level adjacent to the fixation. In this study, good spinal fusion was obtained in all the patients, except the one who died of unrelated causes 1 month after surgery.

The important technical points of occipitocervicothoracic fixation

The postoperative alignment from the cranium to the thoracic spine is permanently established at surgery. Therefore, care must be taken to avoid malformed fixation and ensure a proper alignment of the cervical spine. Before the incision, the rotation and lateral bending of the cervical spine are checked from the cranial side. The sagittal bony alignment from the cranium to the thoracic spine is confirmed roentogenographically. The alignment of the cervical spine is compared with that in the X-ray films that were taken preoperatively in a resting position. The sagittal bony alignment must also be confirmed roentogenographically during surgery after the reduction maneuver. Fixation of the cervical spine in an excessively flexed position is contraindicated to avoid obstruction of the trachea and difficulty in opening the mouth.

In conclusion, occipitocervicothoracic fixation using a hook and rod system is an easy and safe procedure and can facilitate not only good bony union, but also adequate decompression of the spinal cord with simultaneous laminoplasty, because of the secure long fixation extending to the upper thoracic level and bilateral grafting of a large volume of bone.

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