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Two asymmetric contoured plate-rods for occipito-cervical fusion

Received: 24 December 2002
Revised: 28 April 2003
Accepted: 16 May 2003
Published online: 8 January 2004
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Abstract The author presents a retrospective clinical study addressing the outcome after posterior stabilisation of the occipital-cervical spine using a new cranio-spinal implant. The range of surgical methods for operative treatment of occipito-cervical instability remains wide, and it is still a demanding technique that frequently requires improvisation by the surgeon. No previous studies have been published of occipito-cervical reconstructions using two contoured asymmetrical occipital plates interdigitating in the midline at the occiput and allowing various methods of cervical fixation, by means of different hooks, a claw device or screws. Nine patients with severe occipito-cervical instability and/or subaxial malalignment underwent reconstructive surgery with the new implants between 1998 and 2001. Seven patients suffered from rheumatoid arthritis (RA) including cranial settling. Two patients had widespread

cervical metastases. All patients suffering RA were treated by preoperative cervical traction for up to 28 days, and intraoperative traction, to try to restore the malalignment. Traction was also used, to diminish pain and to improve neurological symptoms. The lowest vertebra fused was T3. All patients were immobilised with an external orthosis or brace for 6 weeks or 3 months. A solid fusion was achieved in all patients. None of the patients deteriorated postoperatively. No serious complications occurred. One occipital screw broke and one hook loosened, needing a re-fixation. The simplicity of applying these cranio-cervical implants makes them practical for every orthopaedic or neurosurgeon with a special interest in cervical spine surgery.

Keywords Cranio-cervical instability · Atlanto-axial instability · Occipito-cervical fusion · Laminar hooks · Lateral mass screws

Introduction

Occipito-cervical fusions have been performed for more than fifty years. The procedure has been changed several times, and now a variety of techniques exist [1, 2, 12, 15, 16, 19, 22, 33, 39], none of which has gained widespread popularity. Bone-graft alone [8, 11, 30, 34] is no longer used because of the high failure rate. Bone grafting can be supplemented with wire [9, 13, 15, 16, 18, 24, 26, 27, 28, 36, 40, 44, 46], and sometimes with methylmethacrylate

[4, 5, 6, 42], though at present, improved metallic fixations (screws, plates, rods and hooks) are widely used for spondylodesis, because of their relative stability. However, transarticular and transpedicular screws in the cervical spine may be associated with some potentially life-threatening complications such as injuries to the neurovascular system, and insertion of sublaminar hooks can cause myelum compression. Many of these methods have also proved to be technically difficult because of pre-existing malalignment of the cervical spine. These problems are compounded by the complex anatomy of the occiput

Fig. 1 The Spine System Evolution Cervical (SSEC) system showing the two asymmetrical plate-rod construct. *Clockwise*: the claw construct, the single hooks, the C2-C1 transarticular and the lateral mass screws are shown

and the cervical spine and the biomechanical properties of the occipito-cervical junction. Not only must flexion, extension, lateral bending and rotation be neutralised, but cranial settling, as often occurs in rheumatoid arthritis, must also be prevented or treated. Fusion techniques are also frequently complicated by poor bone quality and the presence of pannus [3, 7].

During the past 5 years a relatively simple and rapidly implantable system for obtaining a sound spondylodesis has been developed. The system comprises two (asymmetrical) interdigitating plates screwed to the occiput in combination, with a stable fixation to the cervical spine, using various sizes and combinations of sublaminar hooks, claw-devices and screws.

The goal of this paper is to describe a new technique for occipito-cervical stabilisation and to present a retrospective review of the results.

Implants

The CE-approved plate-rod (Spine System Evolution Cervical, SSEC; Aesculap AG, Tuttlingen, Germany) is made of a titanium alloy (Fig. 1). Left-sided and right-sided asymmetrical implants are used in combination. There are three holes for occipital screw fixation in the left implant and four holes in the right. The occipital screws have a snap locking mechanism to ensure a perfect connection between plate and screws. For the cervical spine, lateral mass screws, transarticular screws, transpedicular screws and angulated hooks, in two different sizes and all made of the same titanium alloy, are available. The hooks are fixed to the rods by means of a nut using a nut centraliser. Hooks can be used either alone or as a clamp. A separate claw device is also available. The polyaxial screws for pedicle, transarticular or lateral mass screwing can be an-

Table 1 Clinical features, fusion level and length of follow-up per patient (*n.a.* not applicable)

Patient no.	Sex	Age	Radiologically affected levels	Preoperative pain ^a	Preoperative neurological symptoms ^a	Duration of preoperative traction	Instrumented levels	Follow-up period (months)	Postoperative pain ^a /neurological symptoms ^a
1	M	70	C0-C1, C2, C5-C6	1	II	2 weeks	C0-T1	53	0/I
2	F	61	C0-C1, C1-C2, C4-C5	2	II	2 weeks	C0-T1	52	0/I
3	F	46	C0-C1, C2	2	I	1 week	C0-T2	46	0/I
4	F	74	C0-C1, C2-C4	1	IIIB	4 weeks	C0-T1	40	0/II
5	F	41	C0-C1, C2	2	II	1 week	C0-C5	32	1/I
6	F	32	C1, C5, C6	<i>n.a.</i> ; +	<i>n.a.</i> ; None	Intra-op.	C0-C7	35	Breast cancer
7	F	74	C0-C1, C1-C2, C3-C4, C7-T1	2	IIIB	3 weeks	C0-T3	30	1/IIIA
8	M	60	C1, C2, C6	<i>n.a.</i> ; +	<i>n.a.</i> ; None	Intra-op.	C0-T1	20	Bronchial cancer
9	M	75	C0-C1, C5-C7	3	IIIB	3 weeks	C0-T2	20	1/IIIA

^a Pain and neurological symptoms were measured according to the Ranawat criteria (see Table 2)

Fig. 2 Patient 2. **a** Lateral radiograph showing an atlanto-axial subluxation with instability and a subluxation at C4-C5. **b** Magnetic Resonance (MR) image demonstrates the same subluxation. **c** Intraoperative photograph showing an occipito-T1 fusion. **d** Lateral radiograph (flexion) shows a solid fusion. The radiograph in extension was similar

gulated to 30°, while the transarticular C2-C1 screws can be angulated to 50°.

Materials and methods

Patients

Between 1998 and 2001, nine patients were treated surgically using this technique.

The clinical features are shown in Table 1. The mean age of the nine patients at the time of surgery was 57 years (range 32–75 years). The mean follow-up period was 36 months (range 20–53 months). Seven patients (five female and two male) were suffering rheumatoid arthritis (RA). Two had cervical widespread tumour metastases: one female patient suffered from breast cancer and one male patient suffered from bronchial carcinoma. All patients were examined by magnetic resonance imaging (MRI) and computed tomography (CT) of the cervical spine.

Cervical traction was used in all RA patients to realign the subluxations and to reduce cranial settling. Traction was also used to diminish pain and to improve neurological symptoms. The operation was planned when no further improvement could be achieved.

During the halo-traction several supportive measures were taken, such as decubitus prevention by using a special bed, counselling and intensive physiotherapy.

Control radiographs after the operation were performed at 2 and 12 weeks, 6 months and 1 year.

Surgical technique

The patient is placed in a prone position with the halo-ring resting on a horseshoe headrest, and traction of about 4 kg is maintained throughout the operation. Lateral image intensification is used whilst the occipito-cervical spine is adjusted as close as possible to a normal anatomical position to allow comparison with the post-operative situation. A midline incision from the occipital protuberance to the lowermost cervical (or thoracic) vertebra to be fused is performed. The squamous portion of the occipital bone is exposed as well as the spinous process, laminae and facet joints of the vertebrae to be fused. Particular care is taken to avoid damage to the vertebral artery whilst exposing the posterior rim of the foramen magnum and the posterior arch of C1. The cervical anchoring points are chosen, either for claw or hook placement or for screw insertion. It is possible to apply compression over one or several levels with the use of hooks or claws. Hooks can also be used to

Fig. 3 Patient 6. **a** Lateral radiographs show pathological compression fractures of C5 and C6. **b** Computed tomography (CT) scan shows an osteolytic left lateral mass of C1. **c** Anteroposterior (AP) radiograph shows the interdigitating plates at the occiput 1 year after surgery, and also shows the hooks at C2. **d** CT scan at the level of C7, showing that hooks can be safely applied without compromising the myelum

Fig. 4 Patient 7. **a** Lateral radiograph of the cervical spine showing osteoporosis and a slight subluxation at C1-C2 that proved to be stable in flexion/extension. **b** MR image shows destruction at the occipito-cervical junction with cranial settling and stenosis at C3-C4 and T1-T2. **c** AP radiograph shows hooks at C2, C5, lateral mass screws at C6 and hooks forming a claw at T2 and T3. **d** Lateral radiograph (flexion) 1 year after surgery showing a solid fusion with C3 and T1 laminectomy

obtain distraction. Being the most stable lamina of the cervical spine, C2 is secured whenever possible, but one or more distal laminae are usually also included in the construction. After positioning the hooks or screws, a template is used to aid cutting and bending the rod. Sometimes the occipital plate has to be bent or high spots on the occiput have to be flattened by burring. The first implant (mostly right-side) is positioned. The rod is loosely attached to the hooks, claws or screws by applying the nuts using a nut centraliser, and the drill holes for plate fixation are made in the midline and paramedian parts of the occiput, and the occipital screws inserted. Using distraction instruments, the occiput can be distracted from the cervical or even the thoracic spine to treat any cranial settling. The rod is then secured and the nuts are tightened. The same procedure is repeated on the opposite side. Cancellous chips and cortico-cancellous strips are taken from the iliac crest and placed on the decorticated occiput, laminae and spinous process around the instrumentation. Postoperative immobilisation is either in a Philadelphia collar or in a halo-vest, depending on bone quality, for up to 3 months.

Illustrative case reports

Patient 2

A 61-year-old woman (Fig. 2) was referred from an outpatients clinic with increasing neck and suboccipital pain. Neurological investigation showed Babinski's sign with hyperreflexia, but no other neurological deficits. She had been suffering from RA for 26 years and was classified according to the Ranawat criteria [35] for pain as grade 2 and for neurological assessment as class II (Table 2). Radiological investigation showed an atlanto-axial subluxation with instability and a slight cranial settling. There was also a subluxation at C4-C5. Cervical traction was applied for 2 weeks; the pain diminished and the neurological signs disappeared. She underwent an occipito-cervical reconstruction/fusion using two asym-

metrical contoured implants (SSEC) with a fusion down to T1. The laminae and lateral masses of C1 and C2 were partly eroded on one side by the rheumatoid inflammation, so they could not be incorporated in the reconstruction. Distraction between C0 and T1 was applied with simultaneous compression, by means of a claw device between C4 and C5. A cross-bar was not used because the decision had been made to immobilise the patient in a halo-cervical orthosis for 3 months. Four years after surgery, the patient is classified according to the Ranawat criteria for pain as grade 1 and for neurological assessment as class I.

Patient 6

A 32-year-old woman (Fig. 3) suffered from spinal cord compression due to metastases from breast cancer at C1, C5 and C6. After a halo-ring had been applied, the patient underwent a fusion between C0 and C7 with two contoured implants (SSEC). A cross-bar was used to improve the stability. Hooks were placed above the lamina of C7 and below the lamina of C2 to allow distraction. Postoperatively, the cranio-cervical spine was immobilised in a Philadelphia collar and the patient received radiotherapy. Three years after surgery there is still a solid cervical fusion, but the patient is now suffering from widespread tumour metastases.

Patient 7

A 58-year-old woman (Fig. 4) with RA was referred from another hospital. On admission there was an almost complete tetraparesis which had developed during the preceding 3 months. The patient was classified according to the Ranawat criteria for pain as grade 2 and for neurological assessment as class IIIB (Table 2). Radiological investigation showed an atlanto-axial instability with severe osteoporosis. Although there was only minor improvement in spinal alignment as a result of the traction, it was continued for 3 weeks

Table 2 Ranawat [35] criteria for pain and neural assessment

Pain assessment	
Grade 0	None
Grade 1	Mild; intermittent, requiring only aspirin analgesia
Grade 2	Moderate; a cervical collar was needed
Grade 3	Severe; pain could not be relieved by either aspirin or collar
Neural assessment	
Class I	No neural deficit
Class II	Subjective weakness with hyperreflexia and dysaesthesia
Class IIIA	Objective findings of paresis and long tract signs, but walking possible
Class IIIB	Quadriparesis with resultant inability to walk or to feed oneself

because of a logistical problem. A C0-T3 fusion was performed using two asymmetric contoured implants (SSEC). A laminectomy C3, C4, C7 and T1 was necessary, although it is normally avoided in RA, and lateral mass screws were used at C5. The patient was soon mobilised in a halo-vest. More than 2 years after surgery she can be classified according to the Ranawat criteria for pain as grade 1 and for neurological assessment as class IIIA.

Results

For all nine patients, at 6 months and 1 year the postoperative radiographic evaluation showed no displacement or instability on flexion/extension lateral radiographs.

There were no neurovascular injuries or cerebrospinal fluid fistulas. One superficial wound infection occurred (patient 7).

None of the patients deteriorated postoperatively. The patients were followed for 20–53 months. All patients are still alive.

Two implant failures have occurred. One patient (patient 4) with RA, suffering cranial settling and subaxial instability, showed, on routine radiological examination, a loose hook at the end of the construct, probably due to insufficient tightening of the nut that holds the hook to the rod. At reoperation the nut was tightened properly. In one patient (patient 2) an occipital screw broke during operation without any consequences.

The mean operation time was 170 min (range 95–235 min).

Discussion

Despite more than a half century of implant improvement, occipito-cervical fusion is still a challenge. Every surgeon is aware of the complications that can occur during the procedure, especially if the disease process, such as osteoporotic bone as in RA, or widespread tumour metastases, can compromise implant fixation [3, 7, 47].

Anatomical studies of the occipital bone have shown that the greatest thickness is at the level of the external oc-

cipital protuberance and in the regions of the internal occipital crest and the superior nuchal line [10, 17, 21, 38, 48]. Knowledge of the occipital morphology is of utmost importance to the surgeon. The superior nuchal line is not a good place for screw placement because plates and screws are then only covered by skin. A dense muscle mass is present below the superior nuchal line. This is the only appropriate cover for plates and screws. The lateral region of the squamous portion inferior to the inferior nuchal line is irregular in thickness, and is sometimes only 1–2 mm. This leaves the midline and the immediate paramedian bone below the occipital protuberance as the best place for plate fixation [10, 21], though more laterally placed screws can be very successful [41].

The presently available implants are usually in the form of an inverted U or a inverted tuning fork, frequently with only minimal midline fixation to the skull [2, 12, 13, 14, 16, 19, 24, 28, 29, 32, 36, 39, 40]. These systems are fixed to the occiput either by screws, hooks or wires. Wiring and hook techniques can be difficult, and especially in older patients dural tears can easily occur with the entailed complications. Screws are placed in the midline, paramedian or bilaterally on the occiput. All the rods of these systems run parallel, with a fixed distance to each other in the cervical region. This means that it can be very difficult to adjust the rods for symmetrical positioning on the cervical spine. Fixation by wiring a lamina to a rod system, even when using a rough rod or a double-wiring technique, has showed some postoperative instability [2, 16, 29, 31, 44]. Occipito-cervical stabilisation can also be carried out, not using a loop construct, but using two bilateral plates or plate-rod constructs. These mostly require fixation to the skull in the thin bone lateral to the midline [22, 25, 33, 37, 41, 42, 43], though some can be contoured in such a manner that screws can be inserted close to the midline [25]. Custom-made designs are frequently not allowed anymore because they are not officially approved [23, 45].

The present system of two interdigitating plate-rods was designed to address these problems. It permits fixation to the strongest part of the skull and incorporates currently accepted fixation methods to the cervical spine, without a fixed distance from the cervical midline. It also permits appropriate distraction or compression. It is the simplicity of placing the two unilateral plate-rods that allows their use in almost every situation. The final aim of this implant is to obtain a bony bridging, because the strength of the construct is greatest at the time of operation and will finally be reduced until the bone mass supplement has grown, although Moskovich has suggested that adding bone around the construct may not be necessary [7, 29].

Holes in the occiput for screw fixation of plates may be drilled bicortically in the midline; slight penetration of a dural sinus should never lead to complications if the patient is in a prone position during the operation. Bleeding

can easily be stopped by using a screw that is a few millimetres shorter than the depth of the drill hole. The same applies to penetration of the dura; leaking cerebrospinal fluid can be stopped by simply inserting a screw. In general, the pullout strength for bicortical screws is 50% higher than the pullout strength of unicortical screws, though unicortical screwing with a bone thickness of more than 7–8 mm is as strong as bicortical screwing [17, 38].

During preoperative planning of the anchoring points on the posterior cervical spine, the surgeon should be able to choose between sublaminar hooks, separate claw devices, polyaxial screws (transarticular, transpedicular or lateral mass screwing). Intraoperatively, if the chosen fixation is not practicable, the surgeon should have the possibility of changing the method of fixation, which is possible with the present system. Screw fixation can pose a danger to the neurovascular system, especially if the anatomy is abnormal. The incidence of complications incurred with lateral mass plating is noteworthy [20]. Hooks should not be positioned at places where MRI has shown a narrowing of the spinal canal, usually at the exact site of angulation or subluxation. Based on the MRI studies, proper

placement of hooks will hardly ever compromise the myelum.

Conclusions

To facilitate occipito-cervical fusion in patients with such diseases as RA or cervical metastases, a new implant comprising two asymmetric contoured and medially interdigitating plates, fixed to the skull with midline and paramedian screws and to the spine with various combinations of screws, hooks and clamps, was developed. The implant was used in nine patients and proved to be safe, relatively simple and effective.

It is always possible to avoid damage to neurovascular structures by appropriate use of hooks, claw devices and/or screws.

Acknowledgements I am grateful to Dr. M. Fidler MS, FRCS, for reading the manuscript critically, and I wish to acknowledge the contribution of Mrs M. Resink-Oosterloo in developing the system.

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