Magnetic resonance imaging–compatible posterior cervical implant for occipitocervical stabilization

Technical note


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Posterior cervical stabilization was accomplished in 30 patients (19 females and 11 males) by using sublaminar titanium cables and a new titanium bullet-shaped implant. Seventeen patients underwent occipitocervical fixation and 13 others were treated subaxially. These patients have been followed for 18 to 52 months (mean 36 months), and no implant has failed during the follow-up period.

Key Words • magnetic resonance imaging compatibility • spinal stabilization • posterior stabilization • cervical instrumentation

T here are two major problems involved in cervical spine stabilization: the first is achieving fixation without neurological compromise, and the second is obtaining satisfactory postoperative imaging of the neuraxis with minimal artifact. There are various types of fixation devices but basically they can be divided into two groups; those with screws and plates and those in which sublaminar wires and cables are fastened onto a preformed device that is often rectangular. Each type has its advocates, but it is fair to say that no single system is universally applicable.

The type of material used will influence greatly the quality of the postoperative image. Stainless steel has often been used because it is easily deformable to fit the exact contours of the spine and it is also relatively inexpensive, but it is ferromagnetic. Titanium has low ferromagnetic properties, but it is much more difficult to manufacture and it cannot be deformed as easily as stainless steel. There are some concerns about its durability and the possible shedding of titanium particles into the adjacent tissues over a long period of time. Not only is the type of material important, but the shape of the implant will also have an effect on the production of artifacts.

Because of anatomical constraints, very few kinds of implants can be used for occipitocervical as well as subaxial fixation. The Ti-Frame bullet-shaped rectangle fits well below the foramen magnum and, with minor modifications to standard techniques, conforms well and fixes firmly there as well as at lower levels. This paper presents the initial results of a 4-year experience with occipitocervical and subaxial fixation in which this device is used.

Materials and Methods

The Implant

The Ti-Frame is a bullet-shaped implant that has notches along the sides to receive sublaminar titanium cables; it has a flat cross-sectional area. It is available in three different lengths (4, 6, and 8 cm; Fig. 1 left). The implant is provided in three separate curvatures to allow for the best conformance in the individual spine (Fig. 1 right); it ranges from straight, slightly curved (7R), to more curved (5R). With these variations there are nine iterations in the full set of implants. Using a plate bender it is possible to modify the curve of an individual device slightly but because it is titanium there is a risk of weakening and fracturing the implant.

The implant is secured with titanium cables (Sof’wire), and details of this technology are documented elsewhere.

It is the clinical impression of our surgical team that the total construct is much more rigid and without any slippage, unlike our experience with round, cross-sectional devices (Hartshill Ransford implants).

Selection of Operative Procedures

A variety of ventral and dorsal procedures are used in our department to treat cervical instability. Anterior locking plates are used for subaxial instability, whereas posterior instrumentation is reserved for patients with kyphotic deformities and those with poor vertebral body bone quality. Cranio-cervical instability is managed with dorsal implants only in cases of atlantoaxial instability with good
bone quality; C1–2 transarticular screw fixation is our first choice.\(^6\)

Occipitocervical fixation is used for end-stage rheumatoid disease,\(^4\) carcinomatosis, and ligamentous laxity associated with rare congenital diseases such as Hurler’s or Hunter’s syndrome.\(^5\) In the United Kingdom, the preformed Hartshill Ransford loop (Surgicraft, Redditch, Worcestershire, UK) is the most popular.

**Methods of Fixation**

From the nine iterations, the rectangle that most closely conformed to the individual spine was chosen by length and curvature. In the subaxial spine the implant was placed with the pointed end cephalad (Fig. 2). For occipitocervical fixation the flat end was placed as snugly as possible to the foramen magnum; the bullet-shaped implant thus was pointing caudad (Fig. 3).

The cables were arranged around the implant to allow the highest and lowest lines to be “outside” the rectangle. At each laminar level the cable was directed, if possible, through a notch in the implant. Only the spinous process and ligamentum flavum were carefully preserved to minimize a subaxial kyphos formation.

The standard preparation for fixation included exposure of the lamina and decortication of the laminar bone by drilling in patients in whom a bone graft was inserted prior to the passage of the cables. Great care was taken to avoid touching the metallic retractors with the high-speed drill and to reduce possible ferromagnetic artifact. For similar reasons an aluminum suction tube was used instead of stainless steel. A flavumectomy performed using a blunt hook and 1- and 2-mm Kerrison rongeurs is essential prior to the passage of the cables; resistance may allow dural penetration and cause spinal cord injury.

Occipitocervical fixation with the Ti-Frame involved two 3-mm-diameter drill holes dorsolateral to the foramen magnum (Fig. 3). The dura was carefully dissected off the undersurface of the foramen magnum and a small notch or groove was cut into the bone of the foramen magnum on the line along which the cable would lie. A single (end-leader type) titanium cable was carefully threaded through on each side. If this was difficult, a threaded blunt-ended needle was passed in and out and the thread loop was used to pull the soft end of the cable through the hole.

In a situation in which the rim of the foramen magnum also caused compression, this rim was removed with the air drill. The placement of the occipital bone was controlled by the thickness of the occipital bone. Unless there was strong bone available to hold the cable, this form of fixation had to be abandoned.

**Bone Grafting**

In keeping with our previously published work,\(^17\) iliac crest cancellous bone graft was obtained in all patients for whom fusion was desirable. In children, our preference is for parietal bone obtained through a coronal incision. In patients with end-stage rheumatoid disease or carcinomatosis no attempt was made to effect a fusion, and therefore in eight of the 30 patients in this series no bone graft was inserted.\(^12,17\)

**Somatosensory Evoked Potential Monitoring**

Somatosensory evoked potentials were routinely monitored during the procedures by using a technique we have previously described.\(^18\)

**Patient Population**

Between February 1993 and December 1995, 30 patients (19 females and 11 males) who required cervical spine stabilization underwent posterior cervical fixation by means of a titanium rectangle secured with titanium cables. They ranged in age from 12 to 85 years (mean 46 years of age, Table 1). Approval was obtained from the Hospital Ethics Committee prior to the insertion of the Ti-Frame device or Sof’wire cables.

In the follow-up protocol, all patients were assessed clinically and radiographically on an outpatient basis by our team at 1, 3, and 6 months postsurgery. For those living far away, written and telephone requests were made for information on their clinical condition and plain x-ray films were obtained at 6-month intervals. Prior to submis-

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**Fig. 1.** Photographs of the cervical implant. *Left:* Three lengths are displayed (8, 6, and 4 cm). The device has a flat end and a pointed bullet-shaped end. *Right:* For each of the three lengths there are three curvatures (from bottom: ST = straight, 7R = slightly curved, and 5R = more curved).
of this paper, all patients were contacted and additional radiographs were obtained.

Radiological Studies

Preoperatively, plain radiographs were obtained in all patients. In all upper cervical cases in which screw fixation might have been an option, computerized tomography (CT) scans were obtained to determine lateral mass bone quality. All patients underwent preoperative MR imaging with a 1.5-tesla magnet,10,11 and gradient echo and fast spin–echo sequences were used in the axial and sagittal planes.

Postoperatively, radiographs were obtained in all patients immediately after surgery and at the time of final analysis of this data. All patients underwent early (within 1 month) postoperative MR imaging. Further MR studies were obtained later in the review process if there were any new symptoms.

Results

Clinical Findings

Of the 30 patients, 12 had rheumatoid arthritis, six had fracture dislocations, two presented with primary tumors, and three with metastasis (Table 1). No bone graft was used in eight patients, all of whom had rheumatoid arthritis; the other 22 received bone grafts. One patient with metastasis died of her disease 4 months postsurgery (Case 21), but all the other patients are still alive. The follow-up period ranged from 18 to 52 months, with an average of 36 months.

No patient developed a new permanent neurological deficit after the implant was placed. One patient with a large craniovertebral chordoma exhibited a sudden drop in somatosensory evoked potential amplitude during manipulation of the cable around the C-1 lamina. The waveform returned to normal the day after surgery. This patient suffered from dysesthesia in his right hand and reduction of fine finger movement for some weeks. He was later able to resume his professional duties as a dental surgeon.

Radiological Findings

The shortest segment undergoing fixation was C1–2, and the longest fixation was occiput–C7. In all, 112 motion segments were immobilized (average length of fixation 3.5 vertebrae), and the total number of titanium cables used was 276 (Table 1). There have been no broken implants, no broken cables, and no pull-out or implant migration.
Magnetic resonance imaging–compatible posterior cervical implant

In some of the patients with rheumatoid arthritis there was some movement on flexion and extension of the implant but considerably less than had been present prior to surgery. Furthermore, there has been no implant or cable failure associated with the movement, and this is similar to our experience in patients with rheumatoid arthritis in whom other implants were in place during a longer time period.

In terms of bone grafting, solid bone fusion has been confirmed in 18 of the patients. However, in keeping with our previous publication, we found it extremely difficult to be certain about bone fusion in each case, but have inferred that sound fusion exists in those in whom there is no movement. In some but not all patients, CT scans have been obtained that demonstrate bone fusion.

The 17 patients with occipitocervical fixation have had a most satisfactory outcome, and there was no pull-out of the cables from the occiput in these patients.

In the postoperative MR studies, all patients were asked specifically about discomfort in the neck during MR imaging; none reported heat or pain.

Discussion

For the long-term management of complex spinal deformity, spinal tumors, and cervical spinal cord compression it is essential to ensure that high-definition postoperative images can be obtained. There is a distinct disadvantage in using ferromagnetic implants for this very reason, and, although the image quality in the presence of stainless steel can be improved, the artifact is such that careful follow-up review is impractical without CT myelography. Thus, at present, we recommend the avoidance of ferromagnetic implants in the cervical spine if possible.

Other technical problems encountered in MR imaging of implants include artifacts caused by eddy currents generated within a closed loop and heating of the implant and surrounding tissues. With regard to the second issue, no patient in our study complained of discomfort or neurological symptoms.

With regard to image artifacts, although the use of a closed loop of titanium held down by multiple closed loops of titanium cable created some artifact, its level was considerably less than had been predicted on a theoretical basis. The notches in the implant designed to capture the cable and hold it firmly in position might also have caused image artifact, but these did not obscure any soft tissue images.

In terms of clinical results, we were gratified by the firm fixation afforded by the notched implant and the titanium cables. We found absolutely no migration, in contrast to that seen with Luque’s or Hartshill’s rectangles or other plain loop or rectangle devices. There was a very firm fixation that was clinically reminiscent of a lateral mass plate and screw device, although the laboratory confirmation of this clinical impression has yet to be reported.

Whereas the advocates of plate and screw fixation doubtless would have used such devices for some of the pathological conditions included in this series, our team, which also uses a great deal of “plate technology,” has reservations about using it in cases in which normal anatomical alignment cannot be achieved. In these circumstances we believe that sublaminar cable technology and implants are safer. Although the implant is most often attached to an intact lamina, a cable can be passed through a facet to secure that level to a Ti-Frame, but usually this is not necessary when only one level has undergone a laminectomy.

Occipitocervical fixation is always a difficult problem and whenever possible it is our practice to spare the occipitoatlantal joint. The fact that we have hundreds of patients with rheumatoid arthritis but only dozens with non-rheumatoid disease in whom occipitocervical fixation has been used attests to this principle. Until recently we have used the stainless steel Hartshill Ransford loop to achieve such fixation and accepted the quality of the postoperative image. Titanium Ransford loops are available but we have no clinical experience with them. However, the titanium implant Ti-Frame has allowed postoperative imaging and appears to be equally satisfactory as a fixa-

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**TABLE 1**

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs)</th>
<th>Sex</th>
<th>Disease</th>
<th>Level</th>
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<th>Frame</th>
<th>AA</th>
<th>Bone Graft (mos)</th>
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* AA = anterior approach; BI = basilar invagination; dis = fracture dislocation; met tum = metastatic tumor; Oc = occiput; OI = osteogenesis imperfecta; RA = rheumatoid arthritis; ST = straight; 5R = more curved.

† Patient died of her disease.
tion device, although it was not originally designed for this task.

There has been no implant failure or cable breakage in our patients, and this is in line with our previous experience with stainless steel cables and monofilament wires in a long-term implant study in rheumatoid arthritis. Moskovich, et al., found only an 8% failure rate over a decade and in their studies no bone had been inserted (unpublished data). Fixation without fusion is always a controversial point, but it is our view that the demands of patients with end-stage rheumatoid arthritis or carcinomatosis are such that the implant “survives” much longer and better than would have been predicted theoretically based on lumbar spine experience only. Whether there will be flaking from the implant and staining of the adjacent tissues as has been noted in long-term studies of titanium hip implants has yet to be evaluated.6

Based on our preliminary studies we recommend this titanium implant for further evaluation as a device that provides very firm fixation, significantly better than plain titanium implant for further evaluation as a device that allows good postoperative imaging.

Acknowledgments

Dr. Ahmed Tammam is a lecturer in neurosurgery from Al-Azhar University, Cairo, Egypt, and is currently working as a research fellow in our Department of Surgical Neurology.

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Disclaimer

Mr. Crockard has severed his ties with Codman Shurtleff Co., and any remuneration from the Ti-Frame is paid to Hillway Surgical, a small company in the United Kingdom in which he holds only a minority interest. No money is paid directly to Mr. Crockard, and he has no direct access to the funds of Hillway Surgical.

References


H. A. Crockard, A. Tammam, and N. Mendoza