Inverted-hook occipital clamp system in occipitocervical fixation

Technical note

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The authors describe an occipitocervical fixation procedure in which they use inverted occipital hooks inserted through a burr hole drilled in the squamous part of the occipital bone. Fifteen patients with unstable lesions of the occipitocervical junction underwent occipitocervical internal fixation. The mean follow-up period was 21 months (range 2–63 months). No implant failed, and postoperative immobilization was not required. The placement of a posterior occipitocervical graft (for which fusion is uncertain) can be avoided in certain conditions.

KEY WORDS • craniovertebral junction • occipitocervical fixation device • rheumatoid arthritis • occipital bone • craniocervical abnormality

Craniovertebral instability can be caused by malformations, degenerative disease, traumatic injury, tumor, or infection. Internal fixation of the occipitocervical junction is a corrective procedure performed separately (with or without fusion) or in association with anterior decompression via a transoral approach. Posterior or approach surgery is time consuming and difficult. Although many systems of occipitocervical osteosynthesis have been designed in recent years, the constructs often require postoperative immobilization and placement of a good-quality posterior bone graft (with screwed plates and tied frames) and/or are difficult to set up (occipital clamps under compression). In our early experience, occipitocervical plates were used systematically in association with a posterior bone graft. Once the use of rods and hooks allowed more sturdy constructs, postoperative immobilization and occipitocervical arthrodesis were discontinued. Because the positioning of occipital clamps under compression is difficult, however, the procedures are more complicated and require more time to perform.

Since April 1995, we have used an original occipital fixation technique involving two inverted hooks to perform this procedure without modifying the patient’s position intraoperatively. No postoperative immobilization is needed, and placement of a posterior graft can be avoided in patients in whom fusion is not possible or highly unlikely.

Clinical Material and Methods

Patient Population

Fifteen patients (four men and 11 women; mean age 48 years, range 23–77 years) harboring unstable lesions of the occipitocervical junction underwent occipitocervical fixation in which we used an original occipital catch system consisting of two inverted hooks (Table 1). In all cases surgery was performed in our department between April 1995 and May 2000. The mean follow-up period was 21 months (range 2–63 months). All patients suffered cervical pain, with associated occipital neuralgia in two patients (Cases 10 and 11). In seven patients neurological signs were secondary to upper cervical cord compression: five with paraparesis (Cases 2–4, 8, and 13) and two with paresthesia in the hands (Case 5) or all four limbs (Case 7).

There were no neurological deficits in the remaining eight patients. Preoperative radiological and neuroimaging assessment included standard radiography (frontal and lateral views) of the cervical spine, dynamic radiography (lateral views) during flexion–extension, and cervical computerized tomography scanning or magnetic resonance imaging depending on the type of lesion (for example, in cases of tumors). Angiography of the neck vessels was only required in one patient (Case 2) with a C-2 neurofibroma.

Indications for Surgery

All indications for occipitocervical fixation were relat-
ed to patent craniovertebral instability secondary to displaced or latent pathological fractures revealed on lateral dynamic radiography of the cervical spine or to surgery (tumor excision).

**Surgical Procedures**

Occiput–C3 fixation was performed in eight cases, Oc–C4 fixation in three cases, and Oc–C2, –C5, and –C6 in one case each. A double cervical clamp was adapted in one patient who underwent Oc–C7 fixation.

Only a single cervical clamp was necessary in 14 cases, but one patient (Case 15) required two cervical clamps on each side. Lamina–lamina clamps were always placed between the laminae of two contiguous vertebrae. In one patient (Case 13), the cervical construct involved three levels because the C-4, C-5, and C-6 laminae were fused. Only one occipitocervical arthrodesis was performed (Case 13). In two patients (Cases 6 and 8), C1–2 arthrodesis was undertaken to allow subsequent removal of the hardware after consolidation of the traumatic lesion, releasing the occipitoatlantal joint and providing better head mobility. A C-1 laminectomy was performed in nine cases and was supplemented in one case by C-2 and C-3 laminectomies. Occipital craniectomy was performed in four patients (Cases 3, 5, 7, and 8), supplemented in two cases by enlarging duraplasty (Cases 5 and 8).

**Surgical Technique**

Surgery is performed after endotracheal induction of general anesthesia. At the time of anesthesia induction, antibiotic prophylaxis is also administered (cefuroxime 1.5 g). The patient is placed in a ventral position, with his or her head fixed in neutral position in a Mayfield headrest, face down. A lateral control radiograph is obtained to ensure that the alignment of the cervical spine is clearly in a position of reduction. Thus, the head is placed in the ideal position for the patient, neither too flexed nor too extended. This position is not modified intraoperatively, and corresponds to the definitive fixation of the head on the cervical spine after internal fixation.

A midline skin incision is made along the spinous pro-

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**TABLE 1**

Summary of clinical data in 15 patients treated by occipitocervical osteosynthesis

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs)</th>
<th>Sex</th>
<th>Diagnosis</th>
<th>Pain Origin</th>
<th>Neurological Deficit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>50</td>
<td>F</td>
<td>C-2 metastasis of breast adenocarcinoma</td>
<td>cervical</td>
<td>none</td>
</tr>
<tr>
<td>2</td>
<td>53</td>
<td>F</td>
<td>neurofibroma of C-2</td>
<td>cervical</td>
<td>paraparesis</td>
</tr>
<tr>
<td>3</td>
<td>77</td>
<td>F</td>
<td>complex malformation of C-1 &amp; C-2</td>
<td>cervical</td>
<td>paraparesis</td>
</tr>
<tr>
<td>4</td>
<td>55, M</td>
<td></td>
<td>RA C1–2 dislocation, ascendant luxation of odontoid process</td>
<td>cervical</td>
<td>paraparesis</td>
</tr>
<tr>
<td>5</td>
<td>41</td>
<td>M</td>
<td>Arnold–Chiari os odontoideum &amp; syringomyelia</td>
<td>cervical</td>
<td>paresthesia in the hands</td>
</tr>
<tr>
<td>6</td>
<td>24</td>
<td>M</td>
<td>Jefferson traumatic C1–2 dislocation</td>
<td>cervical</td>
<td>none</td>
</tr>
<tr>
<td>7</td>
<td>63</td>
<td>F</td>
<td>RA C1–2 dislocation</td>
<td>cervical</td>
<td>4-limb paresthesia</td>
</tr>
<tr>
<td>8</td>
<td>24</td>
<td>F</td>
<td>traumatic Oc–C2 dislocation</td>
<td>cervical</td>
<td>paraparesis</td>
</tr>
<tr>
<td>9</td>
<td>23, M</td>
<td></td>
<td>C-2 metastasis of an osteosarcoma</td>
<td>cervical</td>
<td>none</td>
</tr>
<tr>
<td>10</td>
<td>42, F</td>
<td></td>
<td>C-2 metastasis of breast adenocarcinoma</td>
<td>occipitocervical neuralgia</td>
<td>none</td>
</tr>
<tr>
<td>11</td>
<td>38, F</td>
<td></td>
<td>C-2 metastasis of breast adenocarcinoma</td>
<td>occipitocervical neuralgia</td>
<td>none</td>
</tr>
<tr>
<td>12</td>
<td>70, F</td>
<td></td>
<td>RA C1–2 dislocation</td>
<td>cervical, shoulders</td>
<td>none</td>
</tr>
<tr>
<td>13</td>
<td>71, F</td>
<td></td>
<td>degenerative autosomal-dominant dystonic disease</td>
<td>cervical</td>
<td>paraparesis</td>
</tr>
<tr>
<td>14</td>
<td>63, F</td>
<td></td>
<td>C2–5 metastasis of breast adenocarcinoma or epidermoid lung carcinoma</td>
<td>cervical</td>
<td>none</td>
</tr>
<tr>
<td>15</td>
<td>39, F</td>
<td></td>
<td>metastasis of breast adenocarcinoma</td>
<td>cervical</td>
<td>none</td>
</tr>
</tbody>
</table>
cesses. At the occipital level, it is necessary to distinguish the upper nuchal line clearly, which is a significant anatomical landmark for drilling the burr holes.

The technique for placing the occipital hooks has been previously described.11 Some significant points, however, require emphasis. Two burr holes are carefully cut using a high-speed diamond drill, avoiding any tears in the dura mater. The position of the burr holes is determined relative to easily located anatomical landmarks (Fig. 1), 2 cm from the midline and 3 cm below the upper nuchal line. At this precise point on the squamous part of the occipital bone, the mean bone thickness is 2.5 mm. (We have previously used a caliper to obtain 200 measurements on 100 dry skulls [100 on the right and 100 on the left]. The thickness of the squamous portion differed from one skull to another [range 0.75–11 mm], and significant differences were found between the right and left sides of the same specimen [unpublished data].) The diameter of the burr holes corresponds to the width of the lamina of the hooks (5–6 mm). If the burr holes are too wide, the behavior of the occipital hooks may be affected. A spatula or a cervical laminar rugine is used to separate carefully the dura from around the burr hole. The laminae of the vertebrae into which the hooks are to be placed are then prepared. If necessary, laminectomy is performed before beginning placement of the instrumentation. The two occipital hooks used for this procedure, which are not specific to occipital squama, are closed cervical hooks with a large groove (Compact Cotrel–Dubousset; Medtronic Sofamor Danek, Memphis, TN), chosen to ensure a good purchase on the squamous of the occipital bone. In strict accordance with the anatomical landmarks, it is possible to drill the burr holes far enough from the transverse and occipital sinuses so as not to cause vascular injury. If occipital craniectomy is required, as was the case in four of our patients (Cases 3, 5, 7, and 8), the position of the occipital burr holes will be determined once craniectomy is performed. The burr holes are placed at least 1 cm from the edge of the craniectomy to avoid weakening the occipital squama purchase. The two hooks are placed at the same time, with their two blades inserted into the burr hole. The hooks are then repositioned vertically and blocked in the burr hole at the level of the groove (Fig. 2). Large-grooved hooks are preferable because they provide a broader contact area with the internal face of the occipital squama and, thus, better resistance to pullout. Once in place, the hooks are ready to receive the rods.

The open cervical hooks are then positioned to provide a lamina–lamina cervical clamp. Once all the hooks are in place, installation of the rods can begin. The rods are bent to follow the anatomical contours of the cervical spine, in accordance with the desired cervical lordosis. The rods can be curved 90° if necessary. The rod is inserted first into the occipital hooks and then into the cervical hooks. According to the length of the occipital portion of the rod, one of the following two techniques can be used.

1) If the rod is short, it can be inserted upward into the lower occipital hook and then into the upper occipital hook, while maintaining the cervical hooks in good alignment. This is the simpler technique.

2) If the rod is longer, it is inserted first into the upper occipital hook and then into the lower one. The rod needs to be rotated approximately 180° before being inserted into the cervical hooks.

It is then blocked in the cervical hooks to ensure com-
pression of the cervical grips on the right and the left. The occipital hooks are then tightened.

If the burr holes match the size of the laminae of the hooks, it is not necessary to create distraction between the hooks because simple tightening will be sufficient to block them. If any mobility of the occipital hooks occurs inside the burr hole, however, it is necessary to create distraction between them. To avoid any mobility on the frontal plane, the two rods are connected by a transverse linking device (Fig. 3). In our opinion, the construct is sufficiently stable not to require arthrodesis, but the follow-up duration was more than 2 years (range 24–63 months) only in six cases.

Closure is performed with systematic drainage, without a vacuum in the event that duraplasty is required. In our cases no external immobilization was proposed after surgery. Clinical follow-up examinations were supplemented with control anteroposterior and lateral radiographic evaluation (Fig. 4).

The stability of the occipitocervical fixation was always confirmed by dynamic lateral radiography, except in the patient in Case 14 who died during the 2nd postoperative month.

Results

The inverted hook-assisted occipital fixation technique has been used in our department since April 1995 in 15 patients. Table 2 provides a summary of the treatments as well as the clinical and radiological results. The duration of the operation depended on the inclusion of other procedures. Those involving tumor excision and duraplasty increased the duration considerably. The approximate time of the internal fixation procedure combined with C-1 laminectomy was 150 minutes.

Immediate Postoperative Course

No patient required external orthoses for immobilization. The mean hospital stay was 10 days (range 6–22 days), which commenced on the day of the operation.

Follow-Up Period

The mean follow-up period was 21 months (range 2–63 months). To date, five patients have died during the terminal phase of their disease (of cancer or RA). Preoperatively all patients experienced cervical pain, which in two cases was associated with occipital neuralgia. Complete resolution of cervical pain occurred at some time postoperatively in 11 patients and partial relief occurred in four (Cases 2, 4, 8, and 14).

No neurological deterioration was observed. In patients with preoperative neurological dysfunction complete improvement was observed in four patients (Cases 2, 3, 5, and 7) or partial improvement in three (Cases 4, 8, and 13). No infection-related complications or postoperative hematomas were demonstrated. There were no hardware failures at the occipital level.

Procedure-Related Complications

No serious complications occurred. In two patients (Cases 7 and 13) CSF leaks occurred when the burr holes were drilled, but these ceased immediately when the occipital hooks were inserted. There were no cases of postoperative CSF fistula or meningocele. These were the only complications concerning the occipital clamp system. At the cervical level, partial migration of one of the cervical hooks was noted during the 6th postoperative month in one patient (Case 10). This event was without clinical consequence, because the migration has not pro-
Occipital clamp in internal occipitocervical fixation

TABLE 2
Summary of procedures and clinical and radiological results

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Internal Fixation</th>
<th>Associated Op</th>
<th>Duration of Op (mins)</th>
<th>Clinical Course</th>
<th>Hosp Stay (days)</th>
<th>Follow Up (mos)</th>
<th>Residual Pain</th>
<th>Radiological Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Oc–C5</td>
<td>none</td>
<td>180</td>
<td>death</td>
<td>5</td>
<td>27</td>
<td>no</td>
<td>stable</td>
</tr>
<tr>
<td>2</td>
<td>Oc–C4</td>
<td>partial tumor removal, C-1 laminectomy</td>
<td>500</td>
<td>recovery</td>
<td>16</td>
<td>63</td>
<td>occasional (cervical)</td>
<td>stable</td>
</tr>
<tr>
<td>3</td>
<td>Oc–C3</td>
<td>C-1 laminectomy</td>
<td>210</td>
<td>recovery</td>
<td>14</td>
<td>45</td>
<td>no</td>
<td>stable</td>
</tr>
<tr>
<td>4</td>
<td>Oc–C3</td>
<td>C-1 laminectomy</td>
<td>190</td>
<td>death after improvement</td>
<td>11</td>
<td>12</td>
<td>yes (cervical)</td>
<td>stable</td>
</tr>
<tr>
<td>5</td>
<td>Oc–C3</td>
<td>craniectomy, C-1 laminectomy, duraplasty</td>
<td>240</td>
<td>recovery</td>
<td>8</td>
<td>34</td>
<td>no</td>
<td>stable</td>
</tr>
<tr>
<td>6</td>
<td>Oc–C3</td>
<td>C1–2 arthrodesis</td>
<td>210</td>
<td>favorable</td>
<td>8</td>
<td>35</td>
<td>no</td>
<td>stable</td>
</tr>
<tr>
<td>7</td>
<td>Oc–C3</td>
<td>craniectomy, C-1 laminectomy</td>
<td>140</td>
<td>recovery</td>
<td>9</td>
<td>24</td>
<td>no</td>
<td>stable</td>
</tr>
<tr>
<td>8</td>
<td>Oc–C2</td>
<td>craniectomy, duraplasty, C1–2 arthrodesis</td>
<td>210</td>
<td>improvement</td>
<td>22</td>
<td>14</td>
<td>none after hardware removal</td>
<td>stable</td>
</tr>
<tr>
<td>9</td>
<td>Oc–C4</td>
<td>C-1 laminectomy</td>
<td>170</td>
<td>death</td>
<td>6</td>
<td>11</td>
<td>no</td>
<td>stable</td>
</tr>
<tr>
<td>10</td>
<td>Oc–C4</td>
<td>C-1 laminectomy</td>
<td>120</td>
<td>favorable</td>
<td>6</td>
<td>18</td>
<td>no</td>
<td>stable</td>
</tr>
<tr>
<td>11</td>
<td>Oc–C3</td>
<td>none</td>
<td>90</td>
<td>favorable</td>
<td>8</td>
<td>12</td>
<td>no</td>
<td>stable</td>
</tr>
<tr>
<td>12</td>
<td>Oc–C3</td>
<td>C-1 laminectomy</td>
<td>180</td>
<td>death</td>
<td>8</td>
<td>4</td>
<td>no</td>
<td>stable</td>
</tr>
<tr>
<td>13</td>
<td>Oc–C6</td>
<td>C1–3 laminectomy, Oc–2 arthrodesis</td>
<td>140</td>
<td>improvement</td>
<td>13</td>
<td>5</td>
<td>no</td>
<td>stable</td>
</tr>
<tr>
<td>14</td>
<td>Oc–C3</td>
<td>none</td>
<td>90</td>
<td>death</td>
<td>9</td>
<td>2</td>
<td>yes (cervical)</td>
<td>stable</td>
</tr>
<tr>
<td>15</td>
<td>Oc–C7</td>
<td>double cervical clamp</td>
<td>90</td>
<td>favorable</td>
<td>12</td>
<td>5</td>
<td>no</td>
<td>stable</td>
</tr>
</tbody>
</table>

Discussion

The indications for occipitocervical fixation are few and relate to treatment of instability of the craniovertebral junction. In addition to the cervical pain involved, instability can cause spinal cord compression. This instability is infrequent in young patients but can be caused by trauma, os odontoideum, and malformation of the craniovertebral junction; in elderly patients and in those with lesions secondary to metastatic disease of the upper cervical spine, however, instability is more frequent. In patients with RA, occipitocoxial instability is a severe complication among those who live in a semibedridden state. In rare cases, instability is of iatrogenic origin, developing after resection of a tumor that had, for example, destroyed the lateral mass of the atlas.

We report our first series of 15 patients treated with an occipitocervical fixation procedure involving inverted hooks and a clamp; the patients were followed for a mean 21 months.

The technique was originally described in a case report in 1998,11 and other teams have used it and reported good results.2 The fact that there are numerous cervical fixation techniques, which involve various forms of hardware for internal fixations that are more or less adapted to this type of surgery, is one indication of the difficulties encountered by surgeons.1,3,8,24,26,30,37 Some surgeons use steel wires for internal fixations,26 which involves various forms of hardware for external immobilization. Others are complicated and require considerable technical ability. Often it is the experience of the surgeon that determines the final result. The problems encountered are anatomical and mechanical.26 Although cervical fixation is associated with few problems when screw/plate systems, metal wires, or hooks are used, the same is not true for occipital fixation. The authors of anatomical studies of the occipital bone have shown that the squama is thin and not very resistant, except on the midline,9,10,18,38 which accounts for shearing risks with steel wires or wrenching of screws, whether the process is uni- or bicortical.17 Moreover, authors of anatomical studies of the posterior fossa have shown that some areas are very well vascularized by the sagittal, lateral, and occipital venous sinuses—that is, precisely those in bone regions in which the squamous part of the occipital bone is thickest and in which osteosynthesis has the maximum effect. Thus, there is an ongoing dilemma between providing better osseous resistance and running a greater vascular risk (hemorrhage or thrombosis). Fixation involving unicortical screws is less dangerous, although it provides poorer tear strength17 than bicortical screws which, themselves, are associated with hemorrhagic complications such as subdural hematoma of the posterior fossa39 or CSF leakage (in fact, the latter is more frequent when hooping is performed with steel wires40). In our technique, occipital implants are positioned far from the lateral and occipital sinuses, in the squamous part of the occipital bone where risk of vascular injury is lowest. At this level, the squama is thinner, but the mean thickness of 2.5 mm determined after 200 measurements obtained in dry skulls (unpublished results) has been adequate in our experience to provide solid anchorage for the occipital hooks. The advantage of rigid fixation is to allow correction (often partial) of displacement of the craniovertebral junction and obtain immediate stability without any need for external immobilization.35 The mechanical stress exerted on occipital fixations is multiaxial.20 The movements involved in head flexion induce a wrenching of screws and steel wires,1,37 and rotation of the head can dislodge occipitocervical screw-fixated plates when they are not interlocked.29 This fragility of hardware anchorage has led some surgeons to perform postoperative immobilization by using a more or less rigid orthosis, depending on the hardware implanted for osteosynthesis.12,13,35,36 Systematic occipitocervical arthrodesis has also been recommend-
These grafting techniques are even more difficult when performed in osteoporotic bone, as in the case of RA. In such cases, however, it is necessary to ensure the solidity of the internal fixation for both short- and long-term stabilization. The indications remain exceptional in traumatology (two cases in 5 years in our experience). These indications relate to cases in which the deformity cannot be reduced or in those with very unstable lesions of the craniovertebral junction. In our technique, because the occipital anchorage is sufficiently solid, even in the event that osteoporosis occurs, not to require postoperative immobilization, the patient experiences greater comfort. The two rods are interlocked to ensure resistance to stress during rotation.

It was never necessary for us to remove the hardware in any of the six patients who received occipital constructs and who attended more than 2 years of follow up. The surgical techniques described in the literature always concern an intact squamous part of the occipital bone. Some of these techniques are quite interesting, but it is unclear how the surgeon is to proceed when occipital craniectomy needs to be performed together with stabilization, for instance, in the treatment of an Arnold–Chiari malformation.

In our series, occipital craniectomy was needed in four cases, which required us to change the usual entry point for the occipital hooks while remaining at some distance from the venous sinuses. This modification of the entry point did not alter the course of the operation. In fact, the adaptability of the system of rods and hooks to anatomical conditions is one of the main advantages.

Presently, with existing hardware, this technique cannot be proposed as an application in children because the hooks positioned in the occipital squama are too prominent. Thus, other techniques are preferable. The search for new hardware must be directed to the construction of true occipital implants to which rods, steel wires, or occipitocervical plates can be fixed. Even though the indications for this technique remain exceptional, craniovertebral internal fixation should be included in the therapeutic arsenal of the spine surgeon.

Conclusions

Occipital fixation, as described here, facilitates occipitocervical internal fixation and osteosynthesis, which is regarded as a difficult procedure, while providing good anchorage to an often fragile bone (for example, in cases of RA). The reliability of the construct allowed us to perform occipitocervical fixation without requiring postoperative immobilization and, in some cases, without arthrodesis.

The adaptability of the construct to the requirements of surgery (for example, occipital craniectomy) is a significant advantage when performing this surgical technique. Future modifications to the shape and size of the hooks are necessary to develop a true occipital implant and facilitate insertion of the osteosynthesis rod.

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References

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32. Paquis P, Lonjon M, Grelletier P: [Use of the CCD (Sofamor-Danek) rod plates for instabilities of the craniospinal junction.] Neurochirurgie 44:101–104, 1998 (Fr)


37. Vale FL, Oliver M, Cahill DW: Rigid occipitocervical fusion. J Neurosurg (Spine 2) 91:144–150, 1999


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