Use of MR imaging-compatible Halifax interlaminar clamps for posterior cervical fusion

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Twenty-one patients requiring posterior cervical fusion were treated with magnetic resonance (MR) imaging-compatible Halifax interlaminar clamps for internal fixation. Various levels were involved: the C1-2 level in eight cases, the C4-5 level in four, the C5-6 level in three, the C6-7 level in three, the C4-6 level in two, and the C5-7 level in one. Bilateral clamps were used in 18 cases and unilateral clamps in three. Autogenous iliac bone grafting was performed in all cases but one. Follow-up periods ranged from 1 to 18 months (average 9.2 months), with no complications or mechanical failures occurring thus far. Follow-up diagnostic studies revealed rigid fixation and fusion in all cases. The MR imaging-compatibility of the clamps allowed excellent follow-up studies with minimal artifact. Because of their ease of use, rigid stabilization, good results, lack of complications, and compatibility with MR imaging, the Halifax interlaminar clamp with bone grafting provides an ideal method for posterior cervical stabilization.

KEY WORDS • clamp • spinal fusion • spinal stabilization • magnetic resonance imaging

Various methods are available for posterior cervical fusion.1,3,4,7,17 In most of these methods stainless steel wire is used as the internal fixation agent with or without methyl metacrylate or iliac bone grafting. As cervical sublaminar wire can lead to certain complications,9 alternative techniques such as intraspinous or interlaminar wiring have been developed. Tucker16 introduced the concept of an interlaminar clamp and Holness, et al.,10 subsequently reported their experience using stainless steel clamps. Recently, eight cases were reported using Halifax interlaminar clamps for posterior C1–2 arthrodesis.4 The interlaminar clamp avoids the hazards of passing sublaminar wires. In addition, it allows secure fixation without the potential complication of wire breakage or pulling through bone such as can occur with sublaminar, interlaminar, or intraspinal wiring.

The past decade has seen the development of magnetic resonance (MR) imaging as a primary diagnostic modality, particularly in the treatment of the cervical spine where it is well established as an indispensable tool for evaluation of both traumatic and nontraumatic pathology.5,7,12,15 Despite its unquestionable potential value, MR imaging has remained of limited use in patients who have undergone posterior stabilization of the cervical spine. This limitation is due to ferromagnetic artifacts created by the stainless steel internal fixation devices (wire or clamps). A recently developed titanium alloy clamp* is currently available and offers both the advantage of an interlaminar clamp and MR imaging compatibility. This report describes our experience with 21 patients treated with these interlaminar clamps for posterior fixation in combination with autogenous iliac crest bone grafting for posterior cervical spine stabilization.

Clinical Material and Methods

Patient Population

This series includes 21 patients undergoing posterior cervical spine stabilization procedures at the Neurosurgery Service of The University of Texas Medical Branch (UTMB) during an 18-month period beginning in December, 1988. The patients ranged in age from 14 to 76 years (average 36.8 years).

Three patients presented with quadriplegia, one with mild myelopathy, and six with transient radiculopathies; the rest were neurologically intact. The clinical characteristics of the patients in this series are outlined

* Titanium alloy clamp manufactured by Codman and Shurtleff, Inc., Randolph, Massachusetts.
TABLE 1
Clinical findings and procedures in this patient series*

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs)</th>
<th>Sex</th>
<th>Clinical Presentation</th>
<th>Etiology</th>
<th>Pathology</th>
<th>Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>25</td>
<td>M</td>
<td>C-5 radiculopathy</td>
<td>trauma</td>
<td>C4-5 post ligamentous instability, anagulation</td>
<td>bilat C4-5 HIC, iliac bone graft</td>
</tr>
<tr>
<td>2</td>
<td>66</td>
<td>F</td>
<td>neck pain, dizziness, shoulder discomfort, occipital neuralgia</td>
<td>rheumatoid arthritis, gunshot wound</td>
<td>C1-2 ant subluxation, C1-2 ant subluxation</td>
<td>bilat C1-2 HIC, iliac bone graft</td>
</tr>
<tr>
<td>3</td>
<td>27</td>
<td>M</td>
<td>neck stiffness</td>
<td>trauma</td>
<td>C4-5 radiculopathy</td>
<td>bilat C4-5 HIC, iliac bone graft</td>
</tr>
<tr>
<td>4</td>
<td>16</td>
<td>F</td>
<td>neck tenderness</td>
<td>trauma</td>
<td>C4-5 unilat locked facet, C-5 body compression fracture</td>
<td>C4-6 HIC on rt, C4-5 HIC on lt, iliac bone graft</td>
</tr>
<tr>
<td>5</td>
<td>14</td>
<td>M</td>
<td>neck pain</td>
<td>trauma</td>
<td>C4-5, C5-6 post ligamentous instability, C-5 body compression fracture</td>
<td>bilat C4-5 HIC, iliac bone graft</td>
</tr>
<tr>
<td>6</td>
<td>33</td>
<td>F</td>
<td>neck pain</td>
<td>trauma</td>
<td>C6-7 postligamentous instability</td>
<td>bilat C6-7 HIC, iliac bone graft</td>
</tr>
<tr>
<td>7</td>
<td>33</td>
<td>M</td>
<td>neck pain</td>
<td>trauma</td>
<td>C1-2 ligamentous instability</td>
<td>bilat C1-2 HIC, iliac bone graft</td>
</tr>
<tr>
<td>8</td>
<td>23</td>
<td>M</td>
<td>quadriplegia</td>
<td>trauma</td>
<td>C6-7 instability, it C-6 lamina fracture</td>
<td>C6-7 HIC on rt, iliac bone graft</td>
</tr>
<tr>
<td>9</td>
<td>50</td>
<td>M</td>
<td>post C-5 and C-6 radiculopathies on It following C4-5 &amp; C5-6 ant cervical fusions</td>
<td>cervical spondylosis</td>
<td>C4-5 &amp; C5-6 lat cervical spinal stenosis</td>
<td>extensive post foraminotomies with hemifacetectomies &amp; neurolysis at C4-5 &amp; C5-6, C4-5 HIC on rt open reduction of bilat locked facets, bilat C5-5 HIC, iliac bone graft</td>
</tr>
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<td>10</td>
<td>36</td>
<td>F</td>
<td>C5 radiculopathy</td>
<td>trauma</td>
<td>C4-5 locked facets, anterior subluxation</td>
<td>bilat C4-5 HIC, iliac bone graft</td>
</tr>
<tr>
<td>11</td>
<td>37</td>
<td>F</td>
<td>mild myelopathy, occipital neuralgia</td>
<td>os odontoidum, C1-2 instability</td>
<td>os odontoidum, C1-2 instability</td>
<td>bilat C1-2 HIC, iliac bone graft</td>
</tr>
<tr>
<td>12</td>
<td>34</td>
<td>F</td>
<td>C6 radiculopathy</td>
<td>trauma</td>
<td>C6-7 postligamentous instability with a C6-7 unilat locked facet &amp; hemilaminar fracture of C-6 on It</td>
<td>C6-7 HIC on rt, iliac bone graft</td>
</tr>
<tr>
<td>13</td>
<td>76</td>
<td>F</td>
<td>neck pain</td>
<td>trauma</td>
<td>Type II odontoid fracture</td>
<td>bilat C1-2 HIC, iliac bone graft</td>
</tr>
<tr>
<td>14</td>
<td>27</td>
<td>M</td>
<td>transient bilat C-5 radiculopathy</td>
<td>trauma</td>
<td>C4-5 post ligamentous instability</td>
<td>bilat C4-5 HIC, iliac bone graft</td>
</tr>
<tr>
<td>15</td>
<td>68</td>
<td>F</td>
<td>neck pain</td>
<td>trauma</td>
<td>Type II odontoid fracture</td>
<td>bilat C1-2 HIC, iliac bone graft</td>
</tr>
<tr>
<td>16</td>
<td>26</td>
<td>M</td>
<td>neck pain</td>
<td>trauma</td>
<td>C1-2 ligamentous instability</td>
<td>bilat C1-2 HIC, iliac bone graft</td>
</tr>
<tr>
<td>17</td>
<td>27</td>
<td>F</td>
<td>neck pain</td>
<td>trauma</td>
<td>C5-6 post ligamentous instability</td>
<td>bilat C5-6 HIC, iliac bone graft</td>
</tr>
<tr>
<td>18</td>
<td>61</td>
<td>M</td>
<td>bilat C-6 radiculopathies</td>
<td>trauma</td>
<td>C5-6 locked facets with disc sequestation, compression of spinal cord &amp; C-6 nerve roots</td>
<td>1) anterior disectomy, 2) bilat C5-6 HIC, iliac bone graft</td>
</tr>
<tr>
<td>19</td>
<td>73</td>
<td>F</td>
<td>neck pain</td>
<td>trauma</td>
<td>C1-2 ligamentous instability</td>
<td>bilat C1-2 HIC, iliac bone graft</td>
</tr>
<tr>
<td>20</td>
<td>43</td>
<td>M</td>
<td>quadriplegia</td>
<td>trauma</td>
<td>C5-6 &amp; C6-7 post ligamentous instability</td>
<td>bilat C5-7 HIC, iliac bone graft</td>
</tr>
<tr>
<td>21</td>
<td>19</td>
<td>F</td>
<td>quadriplegia</td>
<td>trauma</td>
<td>C5-6 locked facets</td>
<td>bilat C5-6 HIC, iliac bone graft</td>
</tr>
</tbody>
</table>

* Post = posterior; ant = anterior; unilat = unilateral; bilat = bilateral; lat = lateral; HIC = Halifax interlaminar clamps.

Table 1 illustrates various levels involved: the C1-2 level in eight cases, the C4-5 level in four, the C5-6 level in three, the C6-7 level in three, the C4-6 level in two, and the C5-7 level in one.

Radiographic evidence of posterior instability was demonstrated preoperatively in all cases but one (Case 9), in which instability followed bilateral facetectomies. Where indicated, plain cervical spine tomography, myelography with computerized tomography (CT), flexion-extension digital video fluoroscopy, and MR imaging (0.6-tesla unit) were performed (Figs. 1 and 2).

Surgical Technique

Awake nasotracheal intubation and general anesthesia were used in all cases. The patients were positioned prone in skeletal cervical traction on a Stryker frame. A posterior midline approach was used to expose the unstable level. The spinous processes were not removed.

The superior border of the superior laminae and the inferior border of the inferior laminae were freed of their ligamentum flavum attachments medially, and small rongeurs were used to prepare the clamp site. The laminae, spinous processes, and posterior surface of the facets in the region of the fusion were denuded of periosteum, and high-speed drills and rongeurs were used to roughen the bone until it was bleeding freely. The clamps (Fig. 3) were torqued until adequate alignment and immobility of the fused levels were achieved.

Cancellous bone chips (2 to 5 mm in diameter) were obtained from the iliac crest. These were wedged between the spinous processes and the clamps below the free edges of the clamps, or placed bilaterally over the prepared fusion sites.

Throughout the procedure, C-arm fluoroscopy was used to ensure complete reduction and correct alignment at the fusion site. A perioperative antibiotic (naf-
Halifax interlaminar clamps

cillin, 1 gm) was given every 6 hours for 12 doses to all patients. Philadelphia or soft collars were worn optionally for patient comfort for a variable period of time.

Results

Intraoperative Course

Of the 21 patients treated, 18 patients had no bone fractures; bilateral interlaminar clamps were placed in this group. Two patients (Cases 8 and 12) had unilateral lamina fractures and a clamp was placed contralateral to these fractures. In the remaining patient (Case 9) a unilateral clamp was placed following bisevel hemifacetectomies for lateral cervical spine stenosis where there were incomplete fusions following prior anterior cervical fusions at the same levels. In 18 of the 21 patients only one level was spanned by the clamps, and in the other three patients two levels were spanned. In Case 9, a clamp spanned C4–6 following the anterior fusions. In Case 5, instability was present at both C4–5 and C5–6; C5–6 was spanned with one clamp and C4–6 contralaterally with another clamp. In Case 20, bilateral clamps were used to span the space from C5–7. Iliac bone grafting was performed in all patients except one (Case 9).

Rigid internal stabilization was achieved in each case. This was demonstrated intraoperatively by axial rotation, flexion, and extension forces applied by a Kocher clamp.

Follow-Up Results

Follow-up periods varied from 1 to 16 months (average 9.2 months). Follow-up dynamic flexion-extension studies showed satisfactory alignment and stabilization in all cases. During the follow-up period no clamp dislocations or mechanical failures were encountered. Thus far, there have been no complications in this series.

Magnetic resonance images were obtained in nine cases at 1 to 16 months postoperatively. Axial and sagittal T1-weighted spin-echo images (5 mm apart) were obtained in all nine cases (Fig. 4); T2-weighted spin-echo images were obtained in three cases and T2-weighted gradient-echo images were obtained in six (Fig. 5). Signal-void areas were detected at the site of the interlaminar clamps in all imaging sequences; however, the size and position of the artifacts were such that excellent evaluation of the cord and adjacent structures, including neural canal and intervertebral foramen, was possible in all nine cases. The MR studies revealed abnormalities associated with the initial injury but demonstrated no pathology requiring additional surgery.
FIG. 4. Follow-up magnetic resonance studies in Case 10. A: $T_1$-weighted midsagittal image (TR 0.5 sec, TE 26 msec) revealing excellent evaluation of the spinal cord and adjacent structures. Note small nucleus pulposus herniations at C4-5 but no cord abnormalities. B: $T_1$-weighted axial image (TR 0.8 sec, TE 27 msec) demonstrating minimal signal-void artifacts posterior to the laminae (arrows), while the spinal cord, neural canal, and intervertebral foramen are well visualized with no significant signal distortion.

Discussion

Internal Fixation

It is well documented that stainless steel interlaminar clamps provide rigid internal fixation in patients with soft-tissue damage and cervical instability. With the new MR imaging-compatible clamps, satisfactory rigid intraoperative stability was achieved at the unstable level in all our cases. Despite Tucker's original report where only unilateral clamps were used, it is recommended that the clamps be placed bilaterally to assure posterior fixation at the unstable segment. In this series, bilateral clamps were used for all C1-2 fusions as well as at all other levels where posterior elements were intact. In the two patients with unilateral laminar fractures, a single contralateral clamp was used which provided equally satisfactory internal fixation.

It is claimed that Halifax interlaminar clamps can be used for rigid stabilization of a cervical spine where there is instability at multiple levels. In the majority of our patients (18 cases) only one level was spanned, but in the remaining three cases, two levels were spanned with satisfactory results. This method is well suited for all levels in the cervical spine, and we are in agreement with Cybulski, et al., that it is also a safe and effective alternative to sublaminar wiring for posterior C1-2 arthrodesis.

Fusion With and Without Bone Grafting

Originally, Tucker advocated the use of clamps without bone grafting and reported fusion across the facet joints in most patients. Holness, et al., reported radiologically documented anterior and/or posterior bone fusion in all patients followed longer than 4 years where only interlaminar clamps were used. Despite these results we believe that autogenous bone grafting in addition to an internal fixation device is mandatory to ensure an ultimate solid bone fusion. Therefore, iliac bone grafting was performed in all of our cases except one where the patient had previously undergone a bilevel anterior cervical discectomy with bone grafting, but had an incomplete fusion. Following posterior decompression and instrumentation, this patient developed a solid bone fusion that was demonstrated on follow-up radiographs.

The use of methyl methacrylate in posterior cervical fusion remains controversial. Although it has been applied with the Halifax interlaminar clamp in C1-2 arthrodesis, we did not use it in any of our patients. Since the interlaminar clamp provides adequate instant rigid stabilization, we believe that methyl methacrylate does not add to the immediate stability and definitely does not replace the need for bone grafting.

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Analysis of Results

Although the follow-up period has been short in our small series, we have had good results. No complications have occurred in any of our patients either from surgery or from mechanical failure. However, a longer follow-up period and a larger series would be necessary to address the questions of solid bone fusions and ultimate long-term stability, the use of unilateral or bilateral clamps, and clamps spanning more than one level.

Compatibility With MR Imaging

Since the introduction of MR imaging as a diagnostic tool, it has become mandatory to use MR imaging-compatible material for internal arthrodesis when follow-up MR studies will be required. Stainless steel used for posterior cervical fusion has been shown to exhibit ferromagnetic properties in the strong magnetic field of diagnostic MR units. This ferromagnetic property causes local distortion and signal loss to such an extent that critical evaluation of the cord and supporting structures is often not possible.\(^6\) Geisler, et al., addressed this issue by utilizing titanium wire for posterior cervical stabilization; titanium wire permitted undistorted images of the spinal cord immediately adjacent to the point of surgical fixation. Those authors described signal-loss areas in the vicinity of the titanium wire, which concurs with our findings when we used titanium alloy interlaminar clamps in this series. The focal signal loss results from local eddy currents created in response to changing magnetic fields (gradients). This phenomenon is seen in nonferromagnetic conductors. The small currents produce their own electromagnetic fields sufficient to distort the main magnetic field resulting in focal image degradation.\(^11\) Artifacts created by the titanium alloys in our series and in that of Geisler, et al., did not degrade the diagnostic quality of the MR images. We have found T\(_2\)-weighted axial images to be sufficient for follow-up examination in most cases. Sagittal T\(_2\)-weighted images may be of benefit when cord edema and/or hemorrhage are suspected. We have found the gradient-echo T\(_2\)-weighted sequence less useful due to a more pronounced artifact. This disparity is believed to be due to increased susceptibility to field nonuniformity in the gradient-echo sequence as compared to the spin-echo sequence.\(^5\)

Conclusions

The new MR-compatible Halifax interlaminar clamp system is a technically safe, easy, and reliable procedure that provides an attractive alternative to the conventional use of wire as an internal fixation agent in posterior cervical spine stabilization. In addition, MR compatibility allows a noninvasive life-long follow-up imaging option.

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References


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