The influence of transoral odontoid resection on stability of the craniovertebral junction

CURTIS A. DICKMAN, M.D., JACQUELINE LOCANTRO, M.D., AND RICHARD G. FESSLER, M.D., PH.D.

Department of Neurological Surgery, University of Florida College of Medicine, Gainesville, Florida

Twenty-seven cases of craniovertebral junction compression treated with transoral surgery were reviewed to assess the influences of pathological processes and surgical interventions on spinal stability. All patients presented with signs and symptoms of spinal-cord or brain-stem dysfunction. Pathology included rheumatoid arthritis in 11 patients, congenital osseous malformations in 11, spinal fractures in two, plasmacytoma in one, osteomyelitis in one, and a gunshot injury in one. Instability was defined as clear radiographic evidence of mobile subluxation in conjunction with clinical assessment.

Of 19 patients (70%) requiring internal fixation, nine underwent upper cervical fusion and 10 had occipitocervical fusion. When instability occurred, all subluxations were at the CI–2 level. There were no occipitoatlantal subluxations. Eight patients (30%) had preoperative instability of the craniovertebral junction due solely to their pathology, 11 patients (40%) suffered instability after transoral surgery, and eight (30%) were without clinical or radiographic evidence of instability (mean follow-up period 14 months).

Craniovertebral junction instability predominated among patients with rheumatoid arthritis: 91% required fusion and 45% presented with pre-existing instability. Among individuals with congenital osseous malformations, 45% required fusion and only one patient (9%) had pre-existing instability. Patients who required subsequent posterior decompression of a Chiari malformation were at risk for developing instability; three of four became unstable after posterior decompression.

Transoral resection of the dens, the anterior arch of C-1, and the lower clivus does not fully destabilize the spine; however, this operation may potentiate incipient pathological instability. The primary determinants of instability are the extent of pathological bone destruction, ligamentous weakening, and operative bone removal. Long-term follow-up monitoring is needed after transoral surgery to detect cases of late instability.

Key Words · transoral approach · odontoid resection · spinal fusion · rheumatoid arthritis · craniovertebral junction

The anatomical and functional relationships at the craniovertebral junction are the most complex and dynamic among any region of the spine. The occiput, atlas, and axis are interrelated physiological units; they are more closely coupled than simple "motion segments," which consist of two adjacent vertebrae and the associated intervertebral disc and ligaments.5,6,8,11,36,37 Half of all cervical rotation and a considerable amount of flexion, extension, and lateral bending occur at the craniovertebral junction.28,36,37 The wide range of motion within these segments may increase susceptibility to injury and instability.7,8,28,36,37

Transoral decompressive surgery for the treatment of extradural ventral midline pathology involving the dens, the anterior arch of C-1, and the lower clivus has become increasingly popular, safe, and effective.3,4,17,23-25.35 Over 70% of patients may require spinal fusion after transoral surgery;4,17,23-25 however, the risks of creating spinal instability with this surgical technique have not been fully delineated. This study examined the separate influences of underlying pathological processes and surgical interventions on subsequent spinal stability. This information is clinically relevant for determining an individual's risk of instability and the optimum timing and extent of surgical interventions.

Clinical Material and Methods

Case Material
Twenty-seven cases of transoral decompression of the craniovertebral junction performed at the University of Florida College of Medicine between 1988 and 1991 were analyzed retrospectively. The radiographic studies and medical records of each patient were re-
viewed. The cases were characterized according to patient age, sex, medical history, pathology, neurological deficits, symptoms, radiographic findings, extent of spinal instability, surgical and medical treatment, and outcome. Follow-up assessment included review of outpatient physician records, physical examination of the patients, and review of follow-up radiographs. Follow-up monitoring was achieved in all patients for a mean duration of 14 months (range 6 to 29 months).

The series included 14 males and 13 females (mean age 51.2 years; range 16 to 79 years). All patients presented with signs and symptoms of spinal-cord or brain-stem dysfunction (mean duration of symptoms 8 months). Pathology included rheumatoid arthritis with irreducible cranial settling in 11 cases, congenital osseous malformations of the cranovertebral junction in 11, and other causes in five (Table 1).

Radiographic Studies

In every case preoperative and postoperative lateral craniovertebral radiographic studies were compared in flexion and extension. Routine radiographs were obtained preoperatively, within 7 to 10 days after transoral surgery, and subsequently at 3- to 6-month intervals. Tomography, myelography, computerized tomography, and magnetic resonance studies were also reviewed.

Radiographic instability, defined as clear evidence of mobile subluxation (≥ 5.0 mm of movement) among the occiput, C-1, or C-2, was measured by multiple radiographic criteria. This is based upon the data of Fielding, et al.,14 which demonstrate that the transverse ligament tears when the distance between the anterior arch of C-1 and the dens exceeds 3 to 5 mm. Disruption of 5 mm or greater is generally considered evidence of transverse ligament disruption and C1–2 instability. The atlantoaxial interval, dens-basion distance, Chamberlain’s line, Wackenheim’s clival line, the Dublin method, Power’s ratio, and spinolaminar alignment were used to assess craniovertebral junction alignment.1,6,8,10,12,20,21,28,31,32,34 The radiographic site of instability was verified by direct observation at the time of the surgical procedure for internal fixation.

**TABLE 1**

Pathology in 27 patients treated with transoral odontoid resection

<table>
<thead>
<tr>
<th>Pathology</th>
<th>No. of Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>rheumatoid arthritis</td>
<td>11</td>
</tr>
<tr>
<td>congenital osseous malformations</td>
<td>11</td>
</tr>
<tr>
<td>Klippel-Feil syndrome</td>
<td>2</td>
</tr>
<tr>
<td>Chiari malformation</td>
<td>4</td>
</tr>
<tr>
<td>Down’s syndrome</td>
<td>2</td>
</tr>
<tr>
<td>occipitalization of C-1/C-2 dysgenesis</td>
<td>3</td>
</tr>
<tr>
<td>trauma</td>
<td>3</td>
</tr>
<tr>
<td>odontoid fracture/malunion</td>
<td>2</td>
</tr>
<tr>
<td>gunshot wound to C-1</td>
<td>1</td>
</tr>
<tr>
<td>plasmacytoma</td>
<td>1</td>
</tr>
<tr>
<td>osteomyelitis/epidural abscess</td>
<td>1</td>
</tr>
</tbody>
</table>

Surgical Procedures

The transoral surgical procedures in the 27 patients were similar in most respects. Surgical resection was limited to the anterior arch of C-1 and the dens in five cases; the other 22 cases required more extensive resection, including a portion of the inferior clivus and the body of C-2. In all cases, the ligamentous and soft-tissue components of compression were resected, including the apical, alar, and cruciate ligaments and the tectorial membrane. The dorsal surface was routinely visualized to ensure adequate surgical decompression. Internal fixation was performed via posterior approaches in 19 patients; nine underwent upper cervical fusion and 10 had occipitocervical fusion (Fig. 1). No transoral or anterior fusion was performed. Three patients with rheumatoid arthritis developed pseudarthrosis and required repeat surgery. All other patients developed a stable fusion.

Results

Clinical Outcome

Following transoral surgery, neurological deficits improved in 22 patients and were stabilized in five. Nine patients recovered normal neurological function. No neurological complications or worsening of function occurred after transoral procedures. Four patients with a Chiari malformation underwent subsequent posterior

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suboccipital decompression, laminectomies, and duroplasties for persistent compressive symptoms (Fig. 2). These posterior decompressive procedures were performed between 1 and 6 months after transoral surgery.

**Spinal Instability**

Relationships between the type of pathology, transoral surgery, and craniovertebral junction instability are summarized in Table 2. Eight patients (30%) remained stable following transoral surgery without signs or symptoms of spinal instability on follow-up monitoring. Five of these eight had ventral bone resection limited to the dens and the anterior arch of C-1, and three had bone resection that also included the clivus and the C-2 vertebral body.

Nineteen patients (70%) demonstrated craniovertebral junction instability and required internal fixation. In all 19, spinal instability was accompanied by severe neck pain, often with radicular pain in the suboccipital region. All subluxations occurred at the C1–2 level; no patient suffered occipitocervical subluxation. Eight (42%) of these 19 patients had exhibited mobile subluxations preoperatively due to their pre-existing pathology (Table 2 and Fig. 3). The remaining 11 were previously stable and developed mobile subluxations after transoral surgery. Seven cases occurred immediately and were detected by routine postoperative flexion/extension radiographs; in these instances instability appeared to be directly precipitated by the transoral resection. Four cases of delayed instability occurred in which stability was maintained for at least 1 month after transoral surgery. In three cases, instability developed only after subsequent posterior decompression for a Chiari malformation; the fourth patient was a 37-year-old woman with rheumatoid arthritis who developed a symptomatic atlantoaxial subluxation 9 months after transoral surgery. In the four delayed cases, transoral surgery was implicated in contributing to the eventual development of instability.

**Pathological Influences**

Of the 11 patients with rheumatoid arthritis who underwent transoral surgery, 91% required fusion and 45% presented with pre-existing instability. In comparison, patients with congenital osseous malformations were more likely to maintain spinal stability after transoral surgery (Fig. 4); five (45%) of the 11 patients in this group eventually required fusion, and only two
patients had early instability. One patient with Down’s syndrome had pre-existing atlantoaxial instability, and another patient with occipitization of the atlas developed instability immediately after transoral surgery. Three patients with a Chiari malformation became unstable only after subsequent posterior decompressive procedures. Six patients with congenital malformations have remained stable, including one patient with a Chiari malformation who required anterior and posterior decompressive surgery.

The patients with C-2 osteomyelitis (one case), a C-2 tumor (one), or odontoid fracture/malunion (two) required internal fixation. These cases were associated with extensive bone and ligament destruction. In comparison, the patient who had a bullet fragment removed transorally maintained spinal stability.

Discussion

Biomechanical and Anatomical Considerations

The configuration of the osseous and ligamentous structures at the craniovertebral junction provides for simultaneous stable articulations and functional flexibility. This transition zone between the immobile skull base and the spine is susceptible to injury. 6-8,15,16,27,30,36

The normal rotation at C-1–2 ranges from 47° to 65° and accounts for one-half of all cervical rotations. 8,11,13,30 The principal rotational surfaces occur at the atlantoaxial interfaces, and less than 10° of rotation occurs at the occipitoatlantal articulations. 13,30 The skull and atlas rotate together as a unit about the dens of C-2. The occiput–C-1 region is stabilized on the dens ventrally by the anterior arch of the atlas and posteriorly by the thick transverse atlantal ligament. 5,8,11,13,14,22,33,36

The alar ligaments connect the occipital condyles to the dens and entrap C-1 between the occiput and C-2 similar to a “washer.” 35,11,13,36 The alar ligaments prevent excessive rotation of the occiput–C-1 on C-2. 11,13,36,37

Between 8° and 13° of flexion, extension, and lateral bending occur at the occipitoatlantal and atlantoaxial levels. No isolated anterior, posterior, or lateral horizontal translations normally occur. 6,8,11,28,30,37 The motions of the segments at the craniovertebral junction are strongly coupled. 13,28,36,37

Pathophysiology of Craniovertebral Junction Instability

In traumatic ligamentous injuries to the craniovertebral junction (transverse ligament rupture or atlantooccipital dislocation), the primary craniovertebral junction ligaments (transverse and alar ligaments) and the secondary ligaments (such as the apical and capsular ligaments and tectorial membrane) are all severely stretched or disrupted. 6,8,12,14,27,30 These diffuse ligamentous injuries display prolonged marked instability and require internal fixation. 8,14,27,30 In comparison, bone injuries such as fracture of the dens, even when combined with fracture of the atlas, typically heal with only external immobilization. 7,15,16 However, fractures of the dens or atlas associated with concurrent extensive ligamentous injuries are prone to nonunion and may require internal fixation. 8,12,14,16,27,28,30,36,37 The status of both the bone and the ligaments plays an important role.

Transoral surgery involves resection of the dens, C-1 arch, anterior longitudinal ligament, apical ligament, alar ligaments, transverse ligament, and tectorial membrane. In contrast to traumatic instability, the C-1–2 articulations and structure of the remaining ligaments can potentially be preserved after transoral surgery. Therefore, our observations suggest that one possible explanation for why some patients (particularly those with congenital osseous malformations) remain stable following transoral surgery is that postoperative stability is determined by the architecture and quality of the remaining bone and ligaments.

Clinical Applications

Several conclusions can be suggested on the basis of our clinical data. First, if the amount of bone and ligament removal affects craniovertebral junction stability, transoral surgical procedures should be directed toward relieving pathological compression while preserving as much normal osseous architecture as possible. Although bone removal must be adequate to ensure decompression, excessive removal of normal bone should be avoided. If irreducible craniovertebral junction compression occurs with pre-existing spinal instability, the transoral decompressive procedure should be performed first, with subsequent internal fixation. Passing a sublaminar wire or instrumenting a stenotic neural canal can cause neurological injury. If extensive spinal instability exists, surgery can be facilitated with patients externally immobilized in a halo brace. 6,8,17,29,35

Second, as reported previously, 2,4,10,22,23,29,35 our series...
Transoral surgery and craniocervical stability demonstrates that patients with rheumatoid arthritis are highly susceptible to craniocervical junction instability. This is due to a combination of bone softening, ligamentous destruction, and inflammatory pannus formation. Our results suggest that transoral surgery will usually destabilize even previously "stable" patients with rheumatoid disease; thus, most patients with rheumatoid arthritis will require spinal fusion.

Third, as we have shown, individuals with congenital osseous malformations (normal bone and ligament structure but abnormal configurations) tend to maintain spinal stability after transoral surgery. Instability can develop, however, following extensive anterior decompression or subsequent posterior craniocervical junction decompression.

Finally, in patients with simultaneous ventral and dorsal craniocervical junction compression, it may be necessary for each site of compression to be treated with a separate operative approach. Posterior decompression of only the Chiari malformation in these cases can result in progressive neurological deterioration due to accelerated basilar invagination and ventral compression. In these cases, we recommend that the transoral decompression of ventral pathology be performed first. This allows the initial decompression of neural structures to be performed in a neutral supine position. If postoperative instability is detected, posterior decompression of the Chiari malformation and internal fixation can be achieved by a single posterior operative approach.

A high index of suspicion is necessary to detect craniocervical junction instability. Routine pre- and postoperative lateral cranioangiographic radiographs in flexion and extension are indicated in all cases. Surgical resection of the anterior C-1 arch and the dens can obscure the normal landmarks used to assess craniocervical junction relationships and can make postoperative studies difficult to interpret. If plain radiographic studies are indeterminate and instability is suspected, pluridirectional lateral tomography with flexion and extension views can be helpful. Meticulous postoperative clinical and radiographic follow-up monitoring is needed to detect new instability. Severe neck pain, suboccipital radicular pain, or new neurological symptoms should raise the suspicion of craniocervical junction instability.

Several alternative methods of fusion and stabilization are available following transoral surgery. Ideally, bone grafts placed transorally would maintain the most nearly normal anatomy; however, this technique does not provide immediate internal fixation and the bone graft is at risk of becoming infected. Furthermore, our observations and those of others indicate that instability following transoral surgery occurs at the C1-2 junction. Since the majority of the C-1 structure available for fusion is removed in the transoral procedure, it is unlikely that a stable fusion can occur even over time. These observations suggest that anterior fusion following transoral surgery is probably inadequate. Alternatives for posterior fusion and instrumentation include C1-2 fusion and instrumentation, C1-3 fusion and instrumentation, and occipitocervical fusion and instrumentation. Since instability following transoral surgery typically occurs at the C1-2 junction, limiting the fusion to these levels is the ideal goal. Individuals using Halifax clamps for posterior instrumentation have found C1-3 fusion and instrumentation less likely to dislodge than C1-2 constructs. Moreover, if the fusion technique used employs sublaminar wires around large blocks of iliac crest bone graft, then one can argue that fusing and wiring two segments below the unstable C1-2 junction will provide more resistance to anterior flexion deformity than C1-2 fusion alone. When the fusion can be limited to the cervical spine alone, the specific technique chosen is one of personal preference, and excellent results have been achieved with several different techniques. Cervical fusion alone may not be possible, however, when the ring of C-1 is fractured, when C-1 is incorporated into the occiput, or in patients with rheumatoid arthritis. In these situations, occipitocervical fusion is the preferred method of internal stabilization; however, this technique should be limited to those cases not suitable for C1-2 fusion, since it further restricts motion and is associated with a higher rate of pseudarthrosis.

Conclusions

The data of this report indicate that instability following transoral surgery occurs at the C1-2 junction and that 70% of patients undergoing this surgery will require internal stabilization. Ninety percent of patients with rheumatoid arthritis will either present with instability or be rendered unstable by the transoral procedure. However, patients with congenital osseous malformations require internal stabilization only 45% of the time. Thus, pre-existing patient disease is an important factor in determining if instability will occur following transoral surgery. The surgical procedure alone does not fully destabilize the spine, but may potentiate incipient pathological instability.

References


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C. A. Dickman, J. Locantro, and R. G. Fessler

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Address for Dr. Dickman: Department of Neurological Surgery, Barrow Neurological Institute, Phoenix, Arizona.
Address reprint requests to: Richard G. Fessler, M.D., Ph.D., Department of Neurological Surgery, University of Florida College of Medicine, P.O. Box 100265, Gainesville, Florida 32610.