Occipitocervical fusion after resection of craniovertebral junction tumors

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Object. Surgical access to tumors at the craniovertebral junction (CVJ) requires extensive bone removal. Guidelines for the use of occipitocervical fusion (OCF) after resection of CVJ tumors have been based on anecdotal evidence. The authors performed a retrospective study of factors associated with the use of OCF in 46 patients with CVJ tumors. The findings were used to develop recommendations for use of OCF in such patients.

Methods. The authors retrospectively reviewed the cases of 51 patients with CVJ tumors treated by their group between March 1991 and February 2004. Forty-six patients were available for follow up. Charts were reviewed to obtain data on demographic characteristics, presenting symptoms, and perioperative complications. Preoperative computerized tomography scans and magnetic resonance imaging studies were obtained in all patients. Occipitocervical fusion was performed in patients who had undergone a unilateral condyle resection in which 70% or more of the condyle was removed, a bilateral condyle resection with 50% removal, or C1–2 vertebral body destruction. Of the 46 patients, 16 had foramen magnum meningiomas, 17 had chordomas, one had a chondrosarcoma, two had Schwann cell tumors, two had glomus tumors, and eight had other types of tumors. Twenty-three (50%) of the 46 patients underwent OCF, including 15 of the 17 patients with chordomas (88%). None of the patients with meningiomas required fusion. Seventeen (71%) of the 24 patients presenting with neck pain preoperatively underwent OCF.

Conclusions. Patients presenting with neck pain had a 71% chance of undergoing OCF. Patients with chordomas and metastatic tumors were most likely to require OCF. One patient with a 50% unilateral condylar resection returned with OC instability for which OCF was required. Based on their clinical experience and published biomechanical studies, the authors recommend that OCF be performed when 50% or more of one condyle is resected.

Key Words • craniovertebral junction tumor • extreme-lateral transcondylar approach • fusion • occipital condyle

Surgical access for the resection of tumors at the anterior aspect of the CVJ frequently requires extensive bone removal. Tumors arising at this location include chordomas, meningiomas, schwannomas, chondrosarcomas, osteoblastomas, giant cell tumors, metastatic tumors, and plasmacytomas. Some of these tumors, including chordomas and chondrosarcomas, can be locally aggressive, leading to extensive bone destruction. Patients with these tumors can present with neck pain, torticollis, and radiological evidence of rotatory subluxation, suggesting the need for OC stabilization and fusion from the outset. Nonetheless, predicting the need for OCF is not always easy and at times can be challenging. In addition, many patients with these tumors present with extensive previous bone resection with or without radiation therapy, dictating the need for a high degree of adaptability in the choice of stabilization hardware and fusion technique.

We present our experience with OC stabilization and OCF after resection of intra- and extradural tumors at the anterior aspect of the CVJ in adult and pediatric populations. We address issues regarding the indications for OCF and discuss the choice of techniques, as well as the long-term outcomes in the patients we treated. We provide recommendations for stabilization of the CVJ after extreme-lateral transcondylar approaches to tumor removal.

Clinical Material and Methods

We retrospectively reviewed the cases of all patients with tumors located in the lower clivus, anterior or anterolateral foramen magnum, and the CVJ who were treated surgically by our group between March 1991 and February 2004. In all cases, a possible challenge to the stability of the CVJ was caused either by the surgical approach for resection or by the destructive nature of the tumor itself. Medical charts were reviewed for data on demographic characteristics, presenting symptoms, perioperative complications, and deaths. Perioperative death was defined as death within 30 days of surgery. Preoperative CT scans and magnetic resonance imaging studies were obtained in all patients to evaluate and characterize the tumor, extent of bone destruction, and bone removal from prior surgeries. Additional findings such as rotatory subluxation in patients with tor-
Surgical Approach

Occipitocervical fusion was performed either on the day of tumor resection or more commonly within a 24-hour period, except in one case in which OCF was performed 3 days after tumor resection. All patients in whom OCF was deferred until the following day were placed in a firm cervical collar and remained intubated and sedated in the intensive care unit.

At our institution, we utilized the following criteria for performing OCF. 1) A decision to perform OCF could be made at presentation, before surgery for tumor resection, in the cases of patients with severe symptoms such as severe mechanical neck pain and torticollis, patients in whom CT scans reveal rotatory subluxation and/or evidence of a greater than 70% condylar resection, and patients presenting with extensive destruction of the C-1 and C-2 vertebral bodies and posterior elements (including the facets). 2) A decision to perform OCF could be made after tumor surgery in the cases of patients in whom 70% or more of one condyle had been resected for access to the tumor, as reported by the tumor surgeon and in some cases as shown on the CT scan obtained immediately after surgery; patients in whom 50% or more of both condyles was removed; and patients who had undergone C-1 and/or C-2 vertebrectomy and/or extensive removal of the posterior elements of C-1 and C-2, including the facets. The extreme-lateral transcondylar approach was used for the resection of the majority of these tumors (Table 1). The amount of the occipital condyle that was resected depended on the tumor and the local OC anatomy. The occipital condyle is located just anterolateral to the VA where it enters the dura mater. Thus, the extent of condylar resection is determined by the amount of room needed in front of the VA for visualization and resection of the tumor. Resection of the condyle up to the hypoglossal foramen was considered to be a 70% condyle resection, and resection beyond the hypoglossal foramen was considered to be a 70% to 100% resection.

Anesthesia. Preoperatively, all patients presenting for tumor resection in which CVJ instability was present were placed in a firm collar. Endotracheal intubation was performed using either a fiberoptic technique or direct laryngoscopy with in-line stabilization. Total intravenous anesthesia was induced using propofol, and a short- or intermediate-acting narcotic agent was used for anesthetic maintenance. To facilitate physiological monitoring, patients did not receive a nondepolarizing muscle relaxant.

Positioning. The Mayfield three-pin headholder was fixed to the patient’s head, and the patient was placed prone in a firm cervical collar with the head and neck maintained in a neutral position. The head was then fixed in a neutral position relative to the neck, and lateral x-ray films were obtained for confirmation. Careful attention was given to maintaining a neutral head position to prevent postoperative swallowing difficulties. The shoulders were pulled down with wide tape fixed to the foot of the table.

Technique. The occiput, the back of the neck, and the posterior aspect of the iliac bone were prepared. A midline incision was made from the inion to about the third spinous process, depending on the number of levels in the spine to be fused. The extreme-lateral transcondylar incision for tumor resection was too lateral and therefore was not suitable for OC stabilization and fusion. Once the CVJ was ex-
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posed, care was exercised in identifying the VA, because it might have been freed from the foramen transversarium during tumor resection and could be floating freely in the surgical field, allowing for injury to the artery during the exposure (Fig. 1). Because many patients previously had suboccipital craniectomies, care was exercised during exposure to prevent injury to the cerebellum. The amount of bone remaining in the suboccipital region after tumor resection and the remaining posterior elements of C-1, C-2, and C-3 dictated to a great extent the type and extent of the instrumentation that could be used.

During the early years of our series, we mostly used a contoured rod with cables in the skull and sublaminar cables in the spine. When a contoured rod and cables were used for OC stabilization, two bur holes were made on either side of the contoured rod on both sides of the suboccipital bone to enable cables to be passed (Fig. 1). The ability to place bur holes with a solid bridge of bone between the holes to facilitate cable fixation was dictated by the amount of bone remaining in the suboccipital area. Because of these limitations, some patients had room for only a single bur hole at the edge of the craniectomy defect; in these patients, the cable was threaded between the edge of the craniectomy defect, the bur hole, and the rod. In the later years of our series, where feasible, bicortical screws were placed in the suboccipital bone. Sublaminar titanium cables were passed under the posterior elements of C-2 and C-3 or C-3 and C-4, depending on the circumstance. In most cases, the posterior arch of C-1 was not included in the stabilization, given its frequent resection in the surgical approach.

A 5-mm Cotrel–Dubousset rod was cut to the appropriate length and contoured using the BendMeister rod-bending device. A rod with an irregular surface was preferred to a smooth rod to prevent telescoping of the cables on the rod and to avoid settling of the head into the spine. The cables were sequentially tightened at all four corners using temporary tensioners. When fixation was noted to be adequate, the cables were tensioned to the appropriate inch-pounds of tension, the head of the cable crimped, and the excess wire cut. More recently, with the use of plate/rod systems, the occipital fixation may be achieved with the contoured portion of the plate/rod secured with bur holes and cables or with bicortical screws into the suboccipital bone. When plate systems were used, the plate was fixed to the occiput with bicortical screws and to the pedicles of C-2 as well as the lateral masses of C-3 and, if necessary, C-4. Polyaxial screws were used for fixation at C-2, C-3, and C-4.

Onlay bone fusion with bone obtained from the iliac crest was performed from the occiput to the upper cervical spine after decortication. Strips of harvested corticocancellous bone were laid from the decorticated occiput between the contoured rod in the midline to the posterior arch of C-1 and the lamina and spinous process of C-2. Bone was also laid along the lateral masses of C-3 and C-2 to the occiput, lateral to the contoured rod. When the posterior elements of C-1 and C-2 had been removed, bone was predominantly laid laterally along the lateral masses of C-3 and C-2 and the area of the occiput lateral to the contoured rod on either side.

Postoperative Management. All patients were placed postoperatively in a firm cervical collar (Philadelphia or Miami J collar). Patients continued to wear the collar for 3 months. In one patient with a deficient anterior column due to removal of the C-2 body, the OC construct extended to the C-7 posterior elements. This patient was placed in a halo device for 3 months and in a firm collar for an additional 2 months. Before discharge a CT scan of the area was obtained in all patients to evaluate the status of the instrumentation.

Monthly x-ray films were obtained to evaluate the status of the instrumentation and bone fusion. At 3 months CT scans with sagittal, coronal, and three-dimensional reconstructions were obtained in all patients to assess the status of fusion. When adequate bone bridging was noted, patients were allowed to taper the use of the collar over the next 2 to 3 weeks. At this time isometric neck exercises were started to strengthen the neck muscles.

Overall, 23 patients received radiation treatment. In 11 patients the radiotherapy had been given before the patient was transferred to our department, and in 12 patients the radiation treatments were given after tumor resection. In the latter group, radiation treatment was started 3 months after OCF. This delay allowed time for the fusion to progress before radiation treatment was instituted. In one patient who had a recurrent clival chordoma, proton beam treatment was delayed for 6 months due to wound dehiscence.

Ten of the 17 patients with chordomas underwent postoperative radiation therapy. Nine received proton beam treatment, and one received stereotactic three-dimensional conformal radiation therapy. In seven cases, proton beam radiation therapy was given before the patient was transferred to our department. The treatment was generally delivered in 42 fractions using a combination of photon and proton irradiation. The dose in this patient population ranged from 79.4 to 83 cobalt gray equivalents. Radiation treatment was also received by three patients with metastatic tumors, one with synovial carcinoma, one with recurrent ACTH-secreting carcinoma, one with chondrosarcoma,
one with mucoepidermoid carcinoma, and one with non-Hodgkin lymphoma. Seven patients (one each with chordoma, non-Hodgkin lymphoma, metastatic hypernephroma, metastatic adenocystic carcinoma, synovial carcinoma, and mucoepidermoid carcinoma) also received postoperative chemotherapy.

**Results**

Between March 1991 and February 2004, 51 patients with tumors around the CVJ were treated by our group. Of the 51 patients, 46 (16 male and 30 female patients) were available for follow up. Their ages ranged from 8 to 76 years (mean 41.1 years). The mean follow-up duration was 66.1 months (range 9–122 months). Tumors included foramen magnum meningiomas in 16 patients; chordomas in 17 patients; chondrosarcoma, schwannoma, and neurofibroma in one patient each; glomus tumors in two; metastatic tumors (carcinoma of the thyroid, adenocystic cancer of the parotid, and hypernephroma) in three; and other tumors (hemangioblastoma, synovial carcinoma, non-Hodgkin lymphoma, recurrent ACTH-secreting carcinoma, and mucoepidermoid carcinoma) in five patients. The chordoma group included eight patients with pure lower clival chordomas, four with lower clival chordomas plus C-1 involvement, four with lower clival chordomas plus C-1 and C-2 involvement, and one with a lower clival chordoma plus C-1, C-2, and C-3 involvement. The schwannoma and...
neurofibroma were hypoglossal nerve sheath tumors that extended down to the CVJ, as did the two glomus tumors included in this study. In 42 of the 46 patients, an extreme-lateral transcondylar approach was used. In three patients posterior cervical surgery was used for tumor resection, and in one patient an anterolateral cervical approach was used for C1–3 vertebrectomy.

Twenty-four (52%) of the 46 patients presented with neck pain; two of the patients with neck pain had associated torticollis. The group with neck pain included four patients with foramen magnum meningiomas, 10 with chordomas, one with neurofibroma, two with glomus tumors, three with metastatic tumors (carcinoma of the thyroid, adenocystic carcinoma of the parotid, and hypernephroma), and four patients with other tumors (hemangioblastoma, synovial carcinoma, non-Hodgkin lymphoma, and mucoepidermoid carcinoma). The remaining 22 patients (48%) did not complain of neck pain before tumor surgery at our institution.

**Condyle Resection.** In 15 patients more than 70% of one occipital condyle was resected (Fig. 2). In four patients at least one half of both occipital condyles was removed. These 19 patients underwent OCF on the basis of the extent of condylar resection. In 18 patients no condyle resection was performed, less than one third of one occipital condyle was resected in eight patients, and 50% of one condyle was resected in one patient; none of these patients underwent OCF. Four patients with varying degrees of cervical vertebral body and posterior element destruction due to tumor also had OCF (Table 1).

**Instrumentation and Fusion.** Twenty-three (50%) of the 46 patients treated for tumors at the CVJ underwent OCF. Fifteen (88%) of the 17 patients with chordomas underwent OCF (Fig. 2); OCF was also performed in one patient with glomus tumor, three with metastatic tumors (carcinoma of the thyroid, adenocystic carcinoma of the parotid, and hypernephroma), and four patients with other tumors (hemangioblastoma, synovial carcinoma, non-Hodgkin lymphoma, recurrent ACTH-secreting carcinoma, and mucoepidermoid carcinoma). None of the 16 patients with foramen magnum meningiomas required fusion. Among the 23 patients who did not undergo OCF, no condylar resection was required in 14 patients, less than 30% of one condyle was resected in eight patients, and 50% of one condyle was resected in one patient (Table 1). All patients who underwent OCF had onlay bone fusion using autograft bone harvested from the iliac crest.

In 18 patients OCF was performed using a 5-mm contoured Cotrel–Dubousset rod with subcancellous cables and sublaminar cables at C2–3 or at C2–4 (Fig. 1). In two patients a contoured rod/plate system was used, with cables at the skull, screws into the C-2 pedicle, and lateral mass screws at C-3 and C-4 (Fig. 3 left). In two other patients, instrumentation included a 3.5-mm contoured rod with connectors that allowed the placement of screws into the central keel of the subcancellous bone and lateral mass screws in the spine (Fig. 3 right). In one patient, a plate was affixed to the skull with screws in the midline, two rods were secured to the plate, and lateral mass screws were placed in the spine (Fig. 3 center). Instrumentation and fusion was performed in all patients in whom the OCF was deemed unstable after tumor resection. None of the patients in this series had bone graft fusion alone without instrumentation.

At long-term follow up (mean 66.1 months), plain x-ray films and CT scans demonstrated solid bone fusion in 22 (95.6%) of the 23 patients. In one patient who had surgery for a clival C-1 chordoma, the instrumentation was removed at the time of reexploration for recurrent tumor at 5 months. At that time partial fusion was noted, and more autograft onlay bone was added without replacement of the instrumentation. This patient continued to complain of chronic neck pain, although flexion–extension x-ray films and CT scans revealed no instability. Of the 24 patients who presented preoperatively with neck pain, 17 (71%) required fusion. Of the 22 patients who presented without neck pain as an initial complaint, only six (27%) required fusion.

In eight patients in whom less than one third of one condyle was removed, stabilization and fusion were not needed. Seven of these patients had meningiomas, and one had a chordoma. At long-term follow up, 22 of the 23 patients who did not undergo fusion had not experienced neck pain, occipital pain, or torticollis. One patient with a glomus tumor in whom 50% of one condyle had been resected experienced torticollis and severe mechanical neck pain 4 years later, with fracture of the remaining condyle; OC stabilization was required in this patient (Fig. 4).

Although there were complications associated with the removal of these complex tumors, no major complications were associated with the OCF procedure itself. A superficial infection of the occipital wound with partial dehiscence developed in one patient, which was successfully treated with antibiotic agents and local dressing changes. Two patients had ongoing occipital pain after OCF. One patient developed telescoping of the instrumentation. This complication was found on a follow-up x-ray film obtained 20 months after OCF; the patient did not report any symptoms. No deaths occurred in the perioperative period. At the time of completion of this study, 10 of the 46 patients available for follow up had died due to disease progression. Although long-term functional status was not analyzed, at the
time of final follow up for this paper, all living patients had a Karnofsky Performance Scale score greater than 70.

Discussion

Tumors at the CVJ are relatively uncommon. Their location combined with the close anatomical relationship to important vascular and neural structures can make total removal difficult and sometimes impossible. Several different approaches have been described, depending on the origin of the tumor, its location presentation, and whether the tumor is benign or malignant.9,16,18 The procedures and approaches described for the resection of these complex tumors have demonstrated varying degrees of success.1,4,22,24

The extent of condyle resection consistently depends on the surgical exposure required for tumor resection. Quantitative computer analysis of dry cadaveric skulls and CT images has shown a 3-mm (13%) increase in the osseous opening between the lateral mass of C-1 and the condyle with a 25% resection of the condyle and a 7-mm (28%) increase with a 50% resection.21 Nevertheless, there are few reports regarding resection of the occipital condyle and the necessity for stabilization in this group of patients. In recommendations published to date, it is advised that the OCJ should be stabilized when more than 70% of the occipital condyle is removed.5

Stability of the occipitoatlantal joint is provided by the cup-shaped configuration of the occipitoatlantal joint and the thick articular capsule, along with the anterior and posterior atlantooccipital membranes.2,18 The fibrous capsule of the occipitoatlantal joint is usually thickest laterally and posteriorly and thinner, if not deficient, medially. The tectorial membrane, which is a continuation of the posterior longitudinal ligament, attaches to the ventral foramen magnum and laterally to the medial aspects of the occipitoatlantal joints, playing an important role in the stability of the CVJ.11 The alar ligaments are paired and arise on either side of the dens and have two components, the atlantoalar and the occipitoalar ligaments, which connect the dens to the lateral mass of C-1 and to the medial aspect of the ipsilateral occipital condyle, respectively.22 These ligaments, together with the cruciform and apical ligaments, span from the axis vertebra to the occiput (Fig. 5), and all provide some degree of stability to the occipitoatlantal joint.14 The extreme-lateral transcondylar approach19 used in the majority of the patients in this series is likely to promote instability at the occipitoatlantal joint because the thickest component of the fibrous capsule laterally and posteriorly is preferentially removed. In this approach, all or a major part of the occipital condyle is removed, resulting in the loss of the insertion site for the alar ligament. In addition, the insertion site for the transverse ligament is lost with resection of the lateral mass of the atlas. The combination of these losses contributes to instability at the OCJ.

In a biomechanical study of stability at the CVJ after staged unilateral occipital condyle resection, Vishteh and colleagues20 preformed condylectomy in six human cadaver specimens. In each specimen, the condylectomy was performed in four stages, with removal of 25% increments of one condyle from the medial to the lateral side until complete condylectomy was achieved. After 25% resection of one condyle, the range of motion at occiput–C1 demonstrated in flexion–extension tests was significantly greater than at baseline. After 50% resection, there was significant hypermobility for all motions, and after 75% resection of one condyle, there were major changes in the biomechanics of the occiput–C1 and C1–2 motion segments. Statistically significant hypermobility occurred at the occiput–C1
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Joint after 50% resection of one condyle, and frank instability was noted after 75% resection. On the basis of their findings, the authors have recommended that OCF be considered if 50% or more of one condyle is resected. A limitation of their study was that the condylar resection proceeded from the medial to the lateral side, whereas in the extreme-lateral transcondylar approach, the condyle is resected from the posterolateral to the anteromedial side (Fig. 5). In medial resection the alar and tectorial membrane attachments are eliminated early in the procedure; however, the capsule of the occipitocervical joint is thicker laterally and posteriorly and is thin and or deficient medially. Therefore, in resection during the extreme-lateral approach in vivo, the thick membrane of the joint capsule posteriorly and laterally is removed early in the procedure, which may render the OCI unstable even when a smaller proportion of the condyle is resected.

Unlike instability in the subaxial cervical spine, instability at the CVJ is difficult to define. In patients with extensive condylar resection, instability of the OCF may not occur immediately but if left untreated may progress slowly to become frank instability, causing increasing neck pain and torticollis. Therefore, the definition of instability at the CVJ cannot be likened to the definitions for instability in the rest of the spine. In 1995 Benzel introduced a new definition for instability in the spine in which instability was divided into the two fundamental categories of “acute” and “chronic.” Acute instability was divided into “overt” and “limited” instability. Chronic instability was divided into “glacial” instability and the instability associated with “dysfunctional segmental motion.” We have found this classification to be appropriate for defining instability at the CVJ. Acute instability of the overt type at the CVJ could be defined as the inability of the spine to support the weight of the head during normal activity, a situation more frequently seen in the trauma care setting. Limited instability is generally defined as the loss of either ventral or dorsal spinal integrity with the presence of severe neck pain and torticollis. Based on biomechanical studies limited instability of the CVJ would be the most probable situation after a condylar resection of greater than 75%.

Chronic instability at the CVJ can be categorized as glacial instability, which is defined as instability that is not overt or limited and does not pose a significant risk for the rapid development or progression to translational deformities. As with the motion of a glacier, however, the deformity progresses gradually, and the OCF eventually becomes unstable. This concept of glacial instability is applicable to patients with tumors at the CVJ who have undergone prior surgery or who demonstrate local bone destruction caused by the tumor. In this sense, patients in whom condyle resections of greater than 50% have been performed may present with significant mechanical neck pain months after the partial condylectomy, with the CVJ, becoming overtly unstable with time. Although we did not use this classification to determine instability in our series of patients, we believe that this classification system is appropriate for definition of instability at the CVJ.

In this retrospective review of the cases of 46 patients with tumors of the CVJ, the selection criteria for OC stabilization and fusion after tumor removal were based on the pre- and postoperative symptoms and signs, preoperative CT scans, and the extent of condylar resection reported by the tumor surgeon. In our series, 15 of the 17 patients with chordomas, one of two patients with glomus tumors, all three patients with metastatic tumors, and one patient each with non-Hodgkin lymphoma, recurrent ACTH-secreting carcinoma, and mucoepidermoid carcinoma underwent OCF. None of the patients with meningiomas, schwannomas, or neurofibromas underwent fusion. These results are comparable to results reported in the literature. It is interesting to note that of the 24 patients who presented with significant neck pain preoperatively, 17 patients (almost 71%) required OC stabilization and fusion. Although this result could be due to a relatively higher percentage of patients with chordomas (37%) in our series, the presence of neck pain at presentation should raise suspicion of subclinical instability, regardless of other findings.

In most of the patients in our series, the OCF was stabilized with a contoured rod and cables. This system was more adaptable in this group of patients, in whom large areas of the occipital bone and posterior elements of C-1 and C-2 were deficient. More recently, however, we have been using plate/rod systems with screws in the occipital bone, C-2 pedicles, and lateral masses of the cervical spine (Fig. 3). These constructs have exhibited the highest levels of construct stiffness. In children we have used a contoured 3.5-mm rod with connectors, allowing screws to be placed into the midline keel of the occipital bone, together with C-2 pedicle screws and lateral mass screws in the spine (Fig. 3 right). The use of unilateral constructs for stabilization in OC instability has been investigated using finite element techniques. These studies indicated that unilateral instrumentation provided stability that borders on the minimum threshold for requisite motion reduction, although the degree of motion reduction required in vivo to promote fusion has not been established. We performed bilateral instrumentation in all of the patients in this series, because the same studies showed greater stability and motion reduction with bilateral stabilization, which increases the likelihood of promoting fusion.

To our knowledge, the only scientific evidence for the assessment of instability at the CVJ comes from the biomechanical study of Visshteh, et al. On the basis of the data from our clinical series, the findings of previous biomechanical studies, and the new concepts of instability applied to the CVJ, we recommend that OC stabilization and fusion be performed when 50% or more of one condyle is resected or noted to have been destroyed by the tumor. A strong argument supporting this guideline can be made when the extreme-lateral transcondylar approach is used for the resection of these tumors, because in this approach the thickest parts of the capsule of the occipitocervical joint are removed earlier and therefore the joint is susceptible to glacial instability. Thus, in patients who do not undergo stabilization and fusion after 50% or more (but < 70%) of one condyle has been resected for surgical access or has been destroyed by the tumor, glacial instability of the OCF may develop and eventually progress to overt instability, with severe neck pain and torticollis.

Conclusions

Guidelines for OC stabilization after resection of tumors at the CVJ have been based on anecdotal evidence, and the literature includes very few reports of clinical experience in
this area. On the basis of our findings in the clinical series and on the results of published biomechanical studies, we recommend that OC stabilization and fusion be performed in cases in which 50% or more of one condyle is resected or noted to have been destroyed by the tumor. Selection of the construct depends largely on the bone available locally and the age of the patient. Patients with chordomas and metastatic tumors at the CVJ were more likely to require OCF, compared with patients with meningiomas, schwannomas, and neurofibromas.

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