UBAXIAL cervical tumors are relatively uncommon compared with those involving thoracic and lumbar regions and represent less than 10% of spinal metastases. Operations may be undertaken to improve or maintain neurological function, create mechanical stability, and achieve local control for metastatic disease and cure for primary tumors. The surgical treatment of these tumors is often complicated by functional nerve root and brachial plexus involvement, VA encasement, and the need for multilevel reconstruction after anterior–posterior decompression. Although many spine surgeons have a wealth of experience treating cervical spondylosis, the presence of large anterior paraspinal tumors and prior neck irradiation may complicate the standard anterior approach to the cervical spine with regard to the CA, esophagus, and RLN and SLN. We previously reported on the treatment of tumors involving the atlantoaxial cervical spine. In this study we present the decision-making and surgical management processes undertaken in 41 patients who underwent surgery for metastatic and primary malignant tumors of the subaxial cervical spine.

Clinical Material and Methods

Object. The authors describe the preoperative assessment, intraoperative strategies, and long-term outcomes in 41 consecutive patients who underwent spinal reconstruction after resection of subaxial cervical neoplasms.

Methods. Thirty-three tumors were metastatic and eight were primary. Preoperative studies included direct laryngoscopy and vertebral artery (VA) balloon occlusion tests in selected patients. Based on the tumor location, approaches included 12 anterior, 13 posterior, and 16 combined. All patients underwent aggressive intralaminar resection and spinal reconstruction. In 12 patients, the VA was dissected from the periphery of the tumor, two cases of which required ligation. Fibula allograft and an anterior rigid plate fixation were most commonly used for anterior reconstruction. Posterior reconstruction was initially performed using lateral mass plates (LMPs) in 13 patients and screw/rod systems in the remaining patients.

At follow up, pain level improved to mild or was absent in 39 patients (95%) who had presented with moderate or severe pain. The American Spinal Injury Association (ASIA) Scale scores were stable in 25 patients who presented with ASIA Score E and improved in 14 patients (88%) who presented with ASIA Score B, C, or D. Functional radiculopathy significantly improved in 16 (94%) of 17 patients.

Complications occurred in 10 patients (24%) and included three fixation failures requiring revision. Two fixation failures involved cervical LMP screw pullout. The overall mean survival duration was 8.6 months for patients with metastatic tumors and 33.4 months for primary tumors.

Conclusions. Surgery for the treatment of subaxial spine neoplasms is effective for relieving pain, encouraging functional nerve root recovery, and preserving spinal cord function with acceptable complication rates.

Abbreviations used in this paper: ASIA = American Spinal Injury Association; CA = carotid artery; CSF = cerebrospinal fluid; IMRT = intensity-modulated radiation therapy; MR = magnetic resonance; MRC = Medical Research Council; PLL = posterior longitudinal ligament; PMMA = polymethylmethacrylate; PNST = peripheral nerve sheath tumor; RCC = renal cell carcinoma; RLN = recurrent laryngeal nerve; SLN = superior laryngeal nerve; VA = vertebral artery; VAS = visual analog scale; VB = vertebral body.
Operative management of malignant cervical spine tumors

**TABLE 1**

<table>
<thead>
<tr>
<th>Tumors</th>
<th>No. of Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>metastatic</td>
<td></td>
</tr>
<tr>
<td>RCC</td>
<td>6</td>
</tr>
<tr>
<td>breast carcinoma</td>
<td>5</td>
</tr>
<tr>
<td>non-small cell lung carcinoma</td>
<td>3</td>
</tr>
<tr>
<td>colon carcinoma</td>
<td>2</td>
</tr>
<tr>
<td>malignant PNST</td>
<td>2</td>
</tr>
<tr>
<td>lymphoma</td>
<td>2</td>
</tr>
<tr>
<td>prostate carcinoma</td>
<td>2</td>
</tr>
<tr>
<td>squamous cell carcinoma</td>
<td>2</td>
</tr>
<tr>
<td>papillary thyroid carcinoma</td>
<td>2</td>
</tr>
<tr>
<td>other*</td>
<td>6</td>
</tr>
<tr>
<td>total</td>
<td>33</td>
</tr>
<tr>
<td>primary</td>
<td></td>
</tr>
<tr>
<td>chordoma</td>
<td>2</td>
</tr>
<tr>
<td>sarcoma</td>
<td>6</td>
</tr>
<tr>
<td>malignant PNST</td>
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</tr>
<tr>
<td>epitheloid sarcoma</td>
<td>1</td>
</tr>
<tr>
<td>myxoid chordrosarcoma</td>
<td>1</td>
</tr>
<tr>
<td>osteogenic sarcoma</td>
<td>1</td>
</tr>
<tr>
<td>chondrosarcoma</td>
<td>1</td>
</tr>
<tr>
<td>spindle cell sarcoma</td>
<td>1</td>
</tr>
<tr>
<td>total</td>
<td>8</td>
</tr>
</tbody>
</table>

* Other tumors included one case each of the following: esophageal, esthesioneuroblastoma, liposarcoma, mucoepidermoid carcinoma, multiple myeloma, and primitive neuroectodermal tumor.

mon metastatic tumors were RCC and breast carcinoma in six patients each. The primary tumors included six sarcomas of various histopathological compositions and two chordomas. The cervical spine was the first site of metastatic cancer in seven patients. The median interval between the diagnosis of the primary tumor and detection of the cervical spine metastases was 37 months (range 6–144 months). Twenty-five patients harbored other visceral and/or bone metastases at presentation.

All patients presented with neck pain. Pain levels were evaluated using a VAS (Scores 0–10); these scores were converted into descriptive categories: mild pain (VAS Scores 0–4), moderate pain (Scores 5–6), and severe pain (Scores 7–10) based on the method described by Serlin, et al. Pain was rated as severe in 36 patients and moderate in 26 cases the tumor involved multiple VBs or posterior elements (two–five levels). The most common levels of involvement were C-5 and C-6.

Epidural spinal cord compression was assessed on the axial T1-weighted MR images; we noted the degree of spinal cord compression or impingement on the subarachnoid space and spinal cord (Table 4). Most patients suffered spinal cord compression with complete (nine patients) or partial (26 patients) obliteration of the subarachnoid space. In the remaining six patients epidural spinal cord compression was minimal, but either a compression fracture resulting in instability or neural foraminal disease was present.

Magnetic resonance imaging in 17 patients (six with primary and 11 with metastatic disease) revealed tumor encasing the VA (bilateral in six) (Fig. 1). Preoperative angiography and balloon occlusion tests were conducted if tumor dissection or occlusion of a single VA was contemplated. Embolization was performed in all cases involving hypervascular tumors including RCCs and follicular thyroid carcinomas.

Recurrent and superior laryngeal nerve functions were assessed preoperatively. In patients with nerve dysfunction symptoms such as hoarseness may not be apparent on preoperative examination, or patients may not cite a history of vocal cord medialization. Preoperative laryngoscopy was used to ensure bilateral vocal cord function. The side of the approach was chosen ipsilateral to the paralyzed vocal cord if present. Swallowing evaluations were conducted preoperatively in selected patients with high cervical lesions to assess the SLN function.

Indications for surgery were classified into the following three categories: neurological, oncological, and mechanical instability. Neurological indications included radiculopathy causing a functional deficit, myelopathy, and/or imaging studies that demonstrated high-grade spinal cord compression. Indications of mechanical instability were axial or incidental neck pain and sagittal- or coronal-plane deformities. Oncological considerations included best-known treatment for the tumor compared with radiotherapy and chemotherapy, resectable or residual disease after adjuvant therapy, and/or the presence of biologically based pain (nocturnal pain responsive to steroid agents).

Of the 33 patients with metastatic tumors, 23 underwent surgery for neurological indications, nine for mechanical instability, and one for oncological concerns. Of the eight patients with primary tumors, four underwent surgery for patients the tumor extended into the brachial plexus. Single-level tumor involvement was demonstrated in 16 patients, but in 26 cases the tumor involved multiple VBs or posterior elements (two–five levels). The most common levels of involvement were C-5 and C-6.

Radiological and Neuroimaging Studies. Imaging studies at initial presentation included plain radiography, MR imaging, and CT scanning. Vertebral body involvement was present in 16 patients, the posterior elements were involved in nine, and both were involved in 17. Of the 33 patients with VB tumor, 17 burst fractures with resultant kyphotic deformities were demonstrated. Significant paraspinous masses were present in 20 patients, and in 17 cases the lesions were predominantly anterior. In five pa-

**TABLE 2**

<table>
<thead>
<tr>
<th>Grade</th>
<th>Muscle Strength</th>
</tr>
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<tbody>
<tr>
<td>0</td>
<td>no contraction</td>
</tr>
<tr>
<td>1</td>
<td>flicker or trace contraction</td>
</tr>
<tr>
<td>2</td>
<td>movement w/ gravity eliminated</td>
</tr>
<tr>
<td>3</td>
<td>movement against gravity</td>
</tr>
<tr>
<td>4</td>
<td>movement against resistance</td>
</tr>
<tr>
<td>5</td>
<td>normal strength</td>
</tr>
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Tumor Resection and Reconstruction

Approach to the Tumor. The approach for tumor resection was determined by the location of bone, epidural, and paraspinal tumor. An anterior approach alone was performed in 12 patients, posterior alone in 13, and combined anterior–posterior in 16. The anterior approach for C3–6 tumors was a standard ventral cervical approach involving a transverse neck incision. Anterior cervical vertebrae were performed with a head and neck surgeon (D.K.) in cases involving a large anterior paraspinal mass to isolate and mobilize the CA, esophagus, and nerves including the superior and recurrent laryngeal, hypoglossal, and vagus nerves, when indicated. A trap-door approach21 was used when tumors were located at C-7 or extended into thoracic vertebrae or chest. Three patients underwent a posterolateral transpedicular approach for resection of anterior VB tumors. In two cases involving the C-6 level, the pharynx could not be mobilized from the spine because of prior irradiation and operations for thyroid malignancies. The third case involved a patient with a C6–7 tumor who could not tolerate a hemi–clam shell thoracotomy because of poor pulmonary function. Although an en bloc resection was not performed in any patient, all gross tumor was resected, except in patients at risk for functional nerve root deficit or VA injury.

Twenty-eight patients underwent VB resection: 15 underwent single-level resection, 11 two-level, and one patient each underwent a three- or four-level resection. From a technical standpoint, anterior paraspinal masses were initially intralesionally resected in the midline to the level of the anterior longitudinal ligament, and the longus colli muscles were dissected from the VBs including the levels of adjacent VBs to be used for cervical plate fixation. Levels were identified using fluoroscopy. The discs adjacent to the involved VBs are exenterated to the level of the PLL. In our experience, the disc space is never involved with tumor; its anatomy is normal, allowing the tumor to be resected. The VBs are then intralesionally resected to the level of the PLL. The PLL is opened using a No. 11 blade and resected with a 2-mm Kerrison punch. Having finished the VB resection, the remainder of the paraspinal mass can be resected, typically with tenotomy scissors, including stripping of the tumor from the VA.

A score of injury description including stripping of the tumor from the VA.

TABLE 3
Summary of the ASIA impairment scale

<table>
<thead>
<tr>
<th>Score</th>
<th>Degree of Injury</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>A</td>
<td>complete</td>
<td>no S4–5 motor or sensory function preserved</td>
</tr>
<tr>
<td>B</td>
<td>incomplete</td>
<td>sensory but not motor function preserved below neurological level &amp; extends through S4–5</td>
</tr>
<tr>
<td>C</td>
<td>incomplete</td>
<td>motor function preserved below neurological level, &amp; most key muscles below the neurological level are &lt;3/5</td>
</tr>
<tr>
<td>D</td>
<td>incomplete</td>
<td>motor function preserved below neurological level, &amp; most key muscles below neurological level are ≥3/5</td>
</tr>
<tr>
<td>E</td>
<td>normal</td>
<td>motor &amp; sensory function normal</td>
</tr>
</tbody>
</table>

Multiple strategies were used for anterior reconstruction. Early in this series, PMMA and Steinmann pins were used for anterior reconstruction in seven patients with metastatic tumors; this group included a patient who underwent posterolateral decompression for a C6–7 VB tumor. Because of the difficulty of correcting kyphotic deformities with PMMA and Steinmann pin fixation, anterior approach–based strategies were changed to include the placement of bone grafts or cages. Fibula allograft and an anterior rigid cervical plate fixation was performed in 12 and two patients with metastatic and primary tumors, respectively. Four patients harboring primary tumors underwent reconstruction procedures in which an autologous iliac crest graft and an anterior cervical plate were placed. Recently, two patients with multilevel involvement (two and four levels, respectively) underwent reconstruction involving placement of a Harms cage (Johnson and Johnson, Depuy Spine, Raynham, MA) packed with iliac crest graft after resection of primary tumors. This cage can be cut with flanges that extend over the adjacent VBs and secured with cancellous screws. In this anterior construct nonconstrained screws are used, and it was augmented with posterior fixation in both cases.

Twenty-nine patients underwent posterior decompression and placement of instrumentation: posterior decompression alone in 13, combined anterior–posterior approach in 13, and posterolateral transpedicular resections of the VB in three. The posterior decompression included laminectomy in all patients and a complete or partial facetectomy in 17 patients. All patients undergoing uni- or bilateral facetectomy underwent instrumentation–augmented fixation in which at least four points of fixation superior and inferior to the resected level were used, except in one patient in whom fusion had occurred after placement of a fibula strut 25 years prior to this for recurrence (Fig. 1). The median number of levels instrumented was six (range three–11). In all patients local bone graft was packed into the facet joints after decortication. In 15 patients posterior instrumentation was confined to the cervical spine, but in 14 instrumentation was needed to cover the cervicothoracic junction. Early in the series, we used Axis lateral mass plates (Medtronic Sofamor Danek, Memphis, TN; 13 patients) or sublaminar hook rod constructs (Johnson and Johnson, Depuy Spine; three patients). More recently, screw/rod constructs were used (Summit SI; Johnson and Johnson, Depuy Spine) in 13 patients (Fig. 2). Postoperatively, patients wore a soft collar for 2 to 4 weeks and a hard collar for automobile transportation for 6 to 12 weeks. No patient required hal vest immobilization.
Adjuvant Therapy

The majority of patients underwent adjuvant radiotherapy. Six patients with primary tumors underwent postoperative irradiation involving standard external-beam radiation (3000 cGy in 10 fractions; two patients) high-dose conformal proton-beam irradiation (one patient), and IMRT (three patients). The high-dose conformal radiation doses varied from 5800 to 7080 cGy given in 29 to 39 fractions.

In patients with metastatic tumors, disease had progressed in 10 patients following prior external-beam radiation (median dose to the tumor 4000 cGy in 20 fractions) and spinal cord tolerance had been reached in four patients who had undergone prior radiotherapy for neck tumors. Eight patients underwent postoperative radiotherapy.

Patient Outcomes

The conversion from ordinal to descriptive pain scores was performed using the method described by Serlin and colleagues in which 0 to 4 represents mild pain, 5 to 6 moderate, and 7 to 10 severe. Improvement occurred in 38 patients who presented with severe or moderate pain; status in one who presented with mild pain remained unchanged at 1 month. Pain in two patients improved initially, but then recurred. These failures resulted from an early recurrence of chemotherapy-refractory lymphoma and an instrumentation failure.

Neurological assessments were based on ASIA score–determined spinal cord function and MRC grade–based nerve root function. Twenty-five patients were neurologically normal (ASIA Score E) pre- and postoperatively. In
nine patients who presented with ASIA Score D impairment improved to Score E function, and two remained with neurological deficits (ASIA Score D). Four patients who presented with Score C impairment and one with Score B impairment improved to Score D function (Fig. 3).

Although few patients presented with myelopathy, radiculopathy causing a functional motor deficit was evident in 19 cases (Fig. 4). A single nerve root was involved in 13 cases and multiple roots were involved in six. The most common single nerve root involved was that of C-7 (seven patients) followed by C-6 (three patients). Two-level nerve root impingement involved C5–6, C6–7, and C8–T1 in one patient each. Three-level involvement of C5–7 was observed in four patients. The degree of functional nerve root dysfunction and recovery was assessed using the MRC Scale.27 No patient suffered permanent worsening of nerve root function. Of the five patients who presented with Grade 4/5 strength, function recovered to normal in four. In seven patients presenting with Grade 3/5 strength improvement to Grade 4/5 (four patients) or Grade 5/5 strength (three patients) was demonstrated postoperatively. All five patients presenting with Grade 2/5 strength experienced improvement (≥ 4/5 strength). Status in three patients without motor function due to prior brachial plexus tumor resections did not improve. In the perioperative period, two patients presented with a C-6 neuritis resulting in a painless complete loss of biceps and brachioradialis muscle function, and full recovery occurred within 2 months in both.

Surgery-Related Complications

Surgery-related complications occurred in 10 patients. No patient died. One patient with non–small cell lung carcinoma developed bilateral vocal cord paralysis after undergoing a right-sided trap-door approach to expose the C6–7 vertebrae. He eventually required a tracheostomy and gastrostomy. The contralateral paresis probably resulted from left apical chest disease and had been present, although asymptomatic, prior to operation. In a second patient a unilateral recurrent laryngeal nerve palsy developed after thyroplasty. No other patient experienced an RLN or SLN palsy in the postoperative period.

One CSF leak occurred in a patient in whom a postirradiation malignant peripheral nerve sheath tumor was resected from the brachial plexus and who subsequently experienced a marginal spine recurrence. The tumor extended intradurally and required a Duraguard dural patch graft closure (Biovascular Corp., Minneapolis, MN) in a watertight fashion. The CSF leaked 6 days postoperatively and was successfully managed by a 3-day course of lumbar CSF drainage and increased steroid medication to decrease the elevated CSF pressure related to chemical meningitis. Four patients had medical complications—deep venous thrombosis in two and pneumonia in two.

Three patients suffered hardware-related complications requiring revision surgery. In two patients with Axis posterior cervical plates extending over the cervicothoracic junction, cervical screw pull-out occurred. In one case revision involved cervical sublaminar wire fixation and in the other it involved three-level anterior interbody graft fixation to correct the resultant kyphotic deformity followed by posterior hardware revision. In a third patient, who had undergone a resection of the C-6 VB for treatment of RCC and reconstruction involving the placement of an autologous iliac crest graft and an anterior cervical plate, the graft failed at 1 month. Revision surgery required additional resection of the C-5 VB and anterior reconstruction involving placement of fibula allograft, an anterior cervical plate, and Axis posterior cervical plates. No failures have been demonstrated in patients in whom reconstruction involved lateral mass screw/rod systems including six with instrumentation extending over the cervicothoracic junction.

Preoperative irradiation was performed in 14 patients but did not have a significant impact on wound dehiscence or infection; however, the tissue planes were obscured in two patients who had previously undergone radiotherapy.
Operative management of malignant cervical spine tumors

**Fig. 5.** Graph showing survival in patients with metastatic and primary tumors.

for primary head and neck cancers and the pharynx could not be mobilized from the spine. The anterior approach could not be accomplished, and both tumors were excised via a posterolateral approach.

**Patient Survival**

As evaluated by the Kaplan–Meier method, overall survival was 8.6 months for the 33 patients presenting with metastatic tumor. For those with primary tumors, the median survival was 33.4 months (Fig. 5). Aggressive repeated operations were performed for palliation to prevent quadriplegia in four patients with metastatic tumors and limited systemic disease. In three patients local intradural and/or intramedullary metastases recurred following one to four operations. Two of these cases have been reported on previously. Both were malignant peripheral nerve sheath tumors secondary to irradiation for Hodgkin lymphoma. A third intramedullary recurrence was seen 31 months after a laminectomy for epidural colon carcinoma in a patient who did not undergo a repeated operation because of widespread systemic disease. All three patients were quadriplegic.

**Discussion**

Surgery for metastatic and primary malignant tumors of the subaxial cervical spine pose a number of difficult management issues including the approach, tumor resection, and spinal reconstruction. Although radiotherapy remains the treatment of choice in many patients with metastatic disease, surgery is undertaken to prevent significant functional disability that may result from functional radiculopathy and high-level cervical myelopathy resulting in quadriplegic or -plegia and ventilator dependency. In our series, the primary indications for metastatic tumor surgery were progressive neurological dysfunction in cases of radioresistant tumors, neuroimaging-documented high-grade epidural spinal cord compression, and/or mechanical instability. The primary malignant tumors in this series included chordoma and chondrosarcoma. These tumors were often surgically treated for oncological considerations. These tumors are highly resistant to chemo- and radiotherapy, and thus surgery is the best known treatment for these tumors to achieve long-term local disease control and potential cure. High-grade spinal cord compression was also present in six patients with primary tumors. In agreement with other recent series, most patients presented with severe pain, but significant myelopathy was rare. The low incidence of myelopathy at presentation is in large part due to early-stage imaging.

All patients with primary and metastatic tumors underwent resection via an intralesional approach in which gross-total resection was achieved in most patients without causing neurological deficits. There is growing evidence that en bloc resection of primary spinal tumors improves local disease control and a higher probability of cure. To achieve a marginal or wide excision, en bloc resection is technically more demanding than intralesional resection and should be reserved for primary tumors localized to the VB or posterior elements with or without the presence of a unilateral paraspinal mass. Often this will necessitate sacrifice of a functional nerve root and VA. Although technically feasible, it remains to be seen whether this significantly improves survival rates. Analysis of short-term follow-up data for low grade chondrosarcomas indicates a survival advantage associated with en bloc resection compared with intralesional resection. In our series, six of eight patients with primary tumors had high-grade epidural disease and were not considered candidates for en bloc resection.

**Operative Approach and Techniques**

The operative approach was chosen based on the pattern of VB involvement and epidural compression noted on preoperative radiological/neuroimaging studies. The anterior operative approach to the spine is often more complicated than that involved in the standard anterior cervical discectomy. Frequently, there is a large paraspinal mass requiring dissection from critical neurovascular structures and the esophagus or the patients have undergone prior irradiation that obscures tissue planes. For these reasons, a head and neck surgeon often performs an anterior cervical approach to reach the tumor.

The RLN and SLN are at increased risk during anterior approaches to spinal tumors. The risk of temporary RLN palsy in patients with tumors has been reported to be 8%, compared with 1.5 to 7% in individuals without disc lesions. Recurrent laryngeal nerve injuries are usually caused by approaches to the lower cervical and/or upper thoracic (C6–T1) spine. Unilateral RLN injury causes unilateral vocal cord palsy with mild dysphagia and dysphonia. If permanent, it may be treated by vocal cord medialization (medialization thyroplasty). Bilateral RLN injury causes bilateral vocal cord paralysis, as was seen in one patient in our series. Bilateral RLN injury requires a permanent gastrostomy and tracheostomy. The higher risk
Neurological outcomes were excellent in the majority of patients. Despite high-grade spinal cord compression in 85% of patients, myelopathy at presentation was rare. Patients who were neurologically normal (ASIA Score E) at presentation remained so and those with mild deficits (ASIA Score D) improved. In this series, all patients with severe deficits also experienced significant improvement. Long-term outcomes were good, but local recurrences resulted in dysfunction in three patients progressing to quadriplegia (median time to progression 12 months). Overall survival at 8.6 months indicated good local disease control after combination surgery and irradiation in most metastatic patients.

Functional nerve roots were affected in 46% of patients. Aggressive resection of tumor from nerve roots resulted in improvement of function, except in one patient in whom the MRC grade remained 4/5. Significant improvement was seen even in patients with severe nerve root impairment, preoperatively assessed at Grade 2 to 3/5. Three patients who had undergone prior brachial plexus resection that resulted in plegic extremities, as expected, did not recover function.

Reconstruction Techniques

As previously described,25 the anterior column can be reconstructed by using PMMA and Steinmann pins after removal of metastatic tumors. In our series, this technique yielded no failures during the long term, but it is difficult to reduce kyphotic deformities. Fibula allograft and anterior cervical plate fixation was performed in most of our patients with metastases. These patients were not routinely assessed for graft incorporation, but there were no long-term failures. Autologous iliac crest graft was placed after resection of primary tumors, with one fixation failure due to adjacent-segment disease. In a recent series reported by Heidecke, et al.,16 62 patients with metastatic spinal tumors underwent iliac crest bone graft–augmented reconstruction with fusion occurring in 97%. Donor site morbidity and the possibility of tumor in the iliac crest28 precluded our routinely using it in our patients with metastatic tumor.

More recently we have also used a Harms cage cut with flanges through which screws are placed into the VB and filled with iliac crest bone graft. Because of its inability to constrain the screws to the cage, this construct was uniformly augmented with posterior instrumentation but did not require an anterior plate.

Hee, et al.,12 reported on 21 patients undergoing multilevel corpectomy and anterior cage and plate construct–augmented fixation. In five patients complications developed related to the graft or plate, including cage subsidence, proximal screw pullout, or plate and cage construct failure. Their recommendation was to undertake posterior augmentation in patients at high risk, such as those with neuromuscular disorders and osteoporosis. In our series all patients undergoing multilevel corpectomy underwent placement of posterior augmentation, which may explain a low failure rate. Additional posterior fixation may also stabilize the spine in cases involving anterior tumor progression even after single-level VB resection.

Posterior instrumentation was applied in all patients in whom laminectomy was performed for bone involvement of the lamina(e) and/or facet joints to decompress high-grade epidural compression or to augment the multilevel anterior corpectomy. Seventeen (58%) of 29 patients undergoing a posterior approach required uni- or bilateral facetectomy to facilitate tumor resection. A minimum of four fixation points were placed superior and inferior to the level of facet joint resection. Posterior stabilization
Operative management of malignant cervical spine tumors

involved various instrumentation schemes. Initially, lateral mass plate/screw systems were used, which although successful rate in the cervical spine, had a pullout rate of 50% at the cervicothoracic junction. Sublaminar hooks were applied across the cervicothoracic junction in two cases, but have an inherently higher risk of spinal cord injury than lateral mass or pedicle screws. More recently, we have used a rod/screw system (Summit SI). Using these systems, we have seen no instrumentation failures in four cervical and six cervicothoracic junction cases.

Kreshak, et al., recently performed a biomechanical study in cadavers to evaluate posterior instrumentation placed across the cervicothoracic junction; they indicated that lateral mass plate/screw and rod/screw systems provided significantly better stiffness or the same compared with the intact spine for all six degrees of motion (flexion, extension, left and right lateral bending, and axial rotation) in cases of two-column injuries. Reconstruction of three-column injuries, however, resulted in a loss of stiffness, requiring supplemental anterior fixation.

In our study, the 50% failure rate of lateral mass plate/screw systems occurred in patients in whom anterior fixation was not conducted. All failures resulted from cervical screw pullout in a system that did not constrain the screws to the plate. Clinically, we have not seen cervicothoracic junction failures when using the rod/screw systems with or without anterior fixation. This finding has been confirmed in a large study reported by Deen, et al., who primarily treated cervical spondylisis in 21 patients. Similarly, they found no evidence of screw pullout or hardware failure.

Adjuvant Therapy

Radiation therapy was routinely performed postoperatively in all patients with metastatic tumors. Standard fraction external-beam radiation is not typically effective for radioresistant metastases and many primary tumors such as chordoma and chondrosarcoma. Higher-dose radiation can be administered using proton-beam therapy or high-dose conformal photon therapy with delivery systems, such as IMRT. In this series, two patients with primary tumors underwent proton-beam therapy. Postoperative IMRT was conducted in three patients with recurrent radioresistant metastatic tumors and one with primary tumor (chondrosarcoma); pain relief was excellent and Grade 2/5 nerve root function improved to normal motor strength in two patients.5

Conclusions

Subaxial cervical spine neoplasms present difficult management challenges with respect to anterior approaches, VA dissection, and salvage of functional nerve roots and the brachial plexus. Preoperative evaluations, including direct laryngoscopy to assess the SLN and RLN and balloon occlusion, helps limit the potential morbidity associated with these procedures. In our series, aggressive resection of subaxial spinal tumors results in excellent pain relief and functional outcomes with regard to spinal cord and nerve roots. The technical evolution of cervical implants has improved our ability to achieve long-term rigid fixation, particularly over the cervicothoracic junction.

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