Surgical treatment of tumors involving the cervicothoracic junction

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Object. Tumors involving the cervicothoracic junction can have a high propensity for causing instability, with kyphosis and spinal cord compression resulting. Treatment with decompression only can lead to further instability and worsening neurological status. In this article, the authors review their surgical experience in the treatment of 19 patients with tumors involving the cervicothoracic junction. The various approaches and instrumentation techniques involved in decompression and stabilization of the cervicothoracic junction are also reviewed.

Methods. Aggressive instrumentation-augmented fusion after decompression of the cervicothoracic region can provide for immediate stabilization and early rehabilitation. Recent development of new hardware such as dual-diameter transition rods, polyaxial screws, and interlocking devices have enhanced the ability to fashion a strong construct for stabilization of the cervicothoracic junction.

Conclusions. Familiarity with complex instrumentation techniques and various surgical approaches to the cervicothoracic junction will be required for effective treatment of tumors causing instability of this region.

Abbreviation used in this paper: MR = magnetic resonance.

Surgical treatment of cervicothoracic junction diseases can be a challenging issue, as evidenced by diverse reports in the literature from practitioners of many different surgical specialties, including neurological; orthopedic; ear, nose, and throat; and cervicothoracic surgeons. Access to this region is complicated by the presence of major vascular elements as well as important visceral and soft-tissue structures. The cervicothoracic junction can be defined as an area extending from vertebral segments C-7 to T-4, and includes the lower brachial plexus, thoracic outlet, and superior mediastinum. This area is unique in that it is a transition area from a mobile, lordotic cervical spine to a rigid, kyphotic thoracic spine. Furthermore, the cervicothoracic junction, much like the thoracolumbar junction, represents an area under stress as the transfer of weight occurs between levels of the spinal column. In addition, the vertebral index decreases from the C-6 to the T-1 vertebrae, causing added stress to be applied to the more narrow and slender upper thoracic vertebrae.

Pathological processes such as trauma, degenerative processes, infection, and neoplastic involvement, combined with the abrupt change in the biomechanical function of this area, can predispose the cervicothoracic segment to instability. Previous surgeries at the cervicothoracic junction have been well known to destabilize the region. Several authors have reported increasing spinal deformity caused by a previous cervicothoracic junction laminectomy. Furthermore, spinal fusions ending at the cervicothoracic junction can also be a factor contributing to iatrogenic cervical instability. Progressive instability of this area ultimately leads to kyphosis and spinal cord compression.

Neoplastic involvement of the upper thoracic vertebrae accounts for 15% of patients with tumors of the spine. Furthermore, 10% of spinal metastases arise from the T1–4 region. Neurological involvement is a common sequela to cervicothoracic lesions causing instability, and can be as high as 80%. This predisposition to neurological injury may be related to the combination of a smaller spinal canal size at the cervicothoracic junction and a tenuous blood supply. Thus, treatment for lesions involving the cervicothoracic junction is often surgical, with goals encompassing neural decompression, immediate stabilization, restoration of anatomical spinal alignment, and early rehabilitation.

In this article we review our surgically treated cases of tumors involving the cervicothoracic region and review various options for surgical approaches and instrumentation-augmented fusion.
CLINICAL MATERIAL AND METHODS

Patient Population

Between 1998 and 2003 at the Stanford University Medical Center, we performed surgery in 46 consecutive patients with diseases involving the cervicothoracic region (19 tumors, 15 traumas, 10 degenerations, and two infections). Of the 19 patients with tumors, 10 were men and nine were women. The age range was from 36 to 73 years (mean 58 years). Thirteen patients (68%) in the tumor group had metastatic lesions, whereas the other six had primary tumor types (Table 1). Fourteen patients had solitary lesions at the cervicothoracic junction, whereas five had multilevel involvement. For the solitary lesions, T-3 was the most common site (Table 2).

All patients with tumors underwent surgery for signs of myelopathy. Fifteen patients were treated with a posterior approach only for decompression and fusion. One patient whose initial diagnosis was C7-T1 osteomyelitis underwent C7–T1 corpectomy with anterior reconstruction only; instrument failure was noted at 2 months postoperatively, with increasing kyphosis. This patient subsequently underwent posterior fixation and C4–T3 fusion. One year later the same patient was treated with further revision surgery for metastatic colon cancer to T-3. Another patient underwent multiple surgeries because of recurrence of his chordoma. In this patient, a C4–6 corpectomy with placement of a Harms cage and plates extending from C-3 to C-7 was initially performed. This patient experienced increasing kyphosis and instability despite use of a halo brace, and subsequently underwent corrective surgery with occipital–T3 fixation. One patient with metastatic breast cancer to T-2 was treated only with anterior decompression and instrumentation from T1–3 and was doing well on the last follow-up visit. In only one case (a 36-year-old patient with metastatic cervical cancer) was a combined anterior and posterior procedure performed. In the remaining patient who had a schwannoma from C-5 to T-1, a laminectomy was performed for resection without fusion.

Overall, in 14 patients tumor decompression was achieved via a posterior or posterolateral approach, with three patients in this group receiving additional anterior column support with titanium cages. Of three patients who underwent only anterior decompression and fusion initially, progressive instability requiring additional posterior fixation developed in two. One patient underwent a combined anterior and posterior procedure for decompression and stabilization (Table 3).

Postoperative follow-up periods ranged from 1 to 58 months, with a mean of 18.5 months. Retrospective chart reviews were performed to identify the patients’ presenting symptoms, results of physical examination, surgical findings, complications, neurological outcomes, and follow-up status. Their neurological function was graded preoperatively and at the last follow-up visit by using the Frankel classification.

RESULTS

All patients with incomplete spinal cord injury except one remained the same or improved neurologically by at least one Frankel grade postoperatively. One patient classified as Frankel Grade B showed no improvement at the last follow-up visit. Two thirds of the patients were Frankel Grade C or D preoperatively, and all exhibited neurological improvement at the last follow-up visit. One patient who had improved initially suffered a neurological decline 3 months postsurgery and was eventually placed into hospice care. Another patient with extensive recurrent chordoma died of recurrence 2 years postsurgery. The last available follow-up x-ray films in all patients showed maintenance of spinal alignment and integrity of spinal hardware. Two cases that required additional fixation occurred only when stand-alone anterior fusion was attempted. Although 17 of our patients had received perioperative

### TABLE 1

<table>
<thead>
<tr>
<th>Tumor Type</th>
<th>No. of Patients</th>
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<tr>
<td>primary</td>
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<tr>
<td>angiosarcoma</td>
<td>1</td>
</tr>
<tr>
<td>chordoma</td>
<td>1</td>
</tr>
<tr>
<td>lymphoma</td>
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</tr>
<tr>
<td>plasmacytoma</td>
<td>1</td>
</tr>
<tr>
<td>schwannoma</td>
<td>1</td>
</tr>
<tr>
<td>metastatic</td>
<td></td>
</tr>
<tr>
<td>breast</td>
<td>1</td>
</tr>
<tr>
<td>cervical</td>
<td>1</td>
</tr>
<tr>
<td>lung</td>
<td>5</td>
</tr>
<tr>
<td>melanoma</td>
<td>1</td>
</tr>
<tr>
<td>prostate</td>
<td>2</td>
</tr>
<tr>
<td>renal</td>
<td>1</td>
</tr>
<tr>
<td>ovarian</td>
<td>1</td>
</tr>
<tr>
<td>colon</td>
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</table>

### TABLE 2

Vertebral level of tumor involvement in 19 patients with cervicothoracic lesions

<table>
<thead>
<tr>
<th>Level Affected</th>
<th>No. of Patients</th>
</tr>
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<tbody>
<tr>
<td>C-7</td>
<td>0</td>
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<tr>
<td>T-1</td>
<td>1</td>
</tr>
<tr>
<td>T-2</td>
<td>4</td>
</tr>
<tr>
<td>T-3</td>
<td>6</td>
</tr>
<tr>
<td>T-4</td>
<td>2</td>
</tr>
<tr>
<td>multiple</td>
<td>5</td>
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### TABLE 3

Distribution of surgical approaches in 19 patients with cervicothoracic lesions

<table>
<thead>
<tr>
<th>Approach</th>
<th>No. of Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>anterior only</td>
<td>3</td>
</tr>
<tr>
<td>revision w/ posterior fixation</td>
<td>2</td>
</tr>
<tr>
<td>anterior &amp; posterior</td>
<td>1</td>
</tr>
<tr>
<td>posterior only</td>
<td></td>
</tr>
<tr>
<td>transpedicular</td>
<td>6</td>
</tr>
<tr>
<td>costotransversectomy</td>
<td>7</td>
</tr>
<tr>
<td>lat extracavitary</td>
<td>1</td>
</tr>
<tr>
<td>laminectomy</td>
<td>1</td>
</tr>
</tbody>
</table>
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adjuvant therapy in the form of radiation or chemothera-
py, we encountered only one wound dehiscence, which
was effectively treated with antibiotics and local wound
care. In all patients who underwent posterior fixation after
decompression, no instrument-augmented revision was
necessary. Furthermore, 89% of our patients noted signif-
icant improvement of their preoperative neck or upper
thoracic pain at the last follow-up visit. Two patients expe-
rienced transient improvement (< 3 months), followed by
gradual recurrence of their preoperative pain level, but
demonstrated no evidence of hardware failure.

DISCUSSION

Surgical Approaches

Several surgical approaches to the cervicothoracic junc-
tion have been described in the literature; these include
posterior, posterolateral, anterior, or anterolateral ap-
proaches (Table 4). Posterior approaches, such as laminec-
tomy and pediculectomy, are common approaches that
provide poor exposure of the anterior spinal elements and
have limited use in the management of complex spinal
diseases states. When performed for disease centered in
the vertebral body, laminectomy may be less effective and
may have a higher complication rate than anterior or lat-
eral approaches.27,28 Furthermore, with tumors involving
purely anterior and middle portions of the spinal column,
posterior approaches may further destabilize the spine.

The limitations imposed by a purely posterior exposure
have resulted in the development of various anterior and
posterolateral approaches. The first description of a pos-
terolateral approach to the cervicothoracic junction was of
a costotransversectomy, described in 1894 by Ménard22
for Pott disease. In 1954, Capener8 described the lateral
rhacotomy technique; this procedure provided a more ex-
tensive posterolateral exposure afforded by the resection
of a longer rib segment. In 1976, Larson and colleagues20
modified the lateral rhacotomy technique into the lateral
extracavitary approach, which improved the exposure and
reduced morbidity. The lateral parascapular extrapleural
approach is a further modification to the lateral extracavi-
tary approach that provides improved exposure of the up-
ner thoracic region.11

A purely anterior approach to the cervicothoracic junc-
tion was initially described in 1923 and was mainly a su-
pracavicular approach, as mentioned in the article by
Kim, et al.16 Because the clavicle was left intact, the expo-
sure of the upper thoracic area was limited. Further limi-
tations with this approach can be encountered in patients
with short necks or large shoulders. In 1957, Cauchoix
and Binet9 enhanced the exposure by combining the su-
pracavicular approach with a median sternotomy. In
1960, Hodgson and coworkers14 reported a surgical mor-
tality rate of 40% with the sternum-splitting approach and
recommended and described the anterolateral thoracoto-
ymy approach to the cervicothoracic junction, accom-
plished by resection of the third rib. The anterolateral tho-
racotomy approach, however, provides limited access to
the lower cervical spine because of obstruction by the
scapula and upper ribs. Since the 1980s, various modifi-
cations to the sternum-splitting approach have been made
to reduce perioperative mortality and morbidity while
maintaining exposure. This included the transmanubi-
ul–transclavicular approach, as popularized by Sundaresan
and associates29 and modified by others.4,19,21

For tumors with significant intrathoracic extension, a trap-
door technique has been described to achieve gross-total
resection.24 This technique combines a supraclavicular
approach with a sternotomy and an anterolateral approach.

Overall, surgical approaches to the cervicothoracic junc-
tion will be guided by the tumor’s location, extent of
involvement, and histological features, as well as the sur-
geon’s familiarity with the approach. In our own series of
malignant tumors involving the cervicothoracic junction,
we have favored a posterolateral approach for simultane-
ous decompression and stabilization. In three of our pa-
tients, after decompression we were able to reconstruct the
anterior column with an expandable cage via a posterolat-
eral approach. In younger patients with more benign le-
sions, an anterior or anterolateral approach would be con-
sidered if necessary for complete resection. Furthermore,
newer instrumentation materials and techniques have
facilitated the surgeon’s ability to stabilize the cervicotho-
racic junction.

Reconstruction and Stabilization

A growing number of options now exist for cervicotho-
racic reconstruction and stabilization. If anterior recon-
struction is required after tumor resection, several options
are available. In patients with malignant tumors, solid
bone fusion may not be necessary if a shorter life ex-
pectancy is predicted and the effects of radiation therapy
and chemotherapy in inhibiting bone growth are recog-
nized. Anterior column reconstruction with a methyl
methacrylate cast held in place with vertically embedded
Steinmann pins can provide immediate stability and can be
used as an alternative to bone fusion. If an anterior
approach allows adequate exposure of the cervicothoracic
junction, use of fibular allograft, iliac crest autograft, or a
mesh cage packed with autograft are all suitable options
for anterior column reconstruction when supplemented

| Table 4 |

| Options for surgical approaches to the cervicothoracic junction |
|-------------------|-------------------|-------------------|-------------------|
| Anterior (transcervical) | Anterolateral (transclavicular–transmanubrial) | Posterior (laminectomy) | Posterolateral (costotransversectomy, lat extracavitary, lat parascapular extrapleural, transpedicular) |
| supraclavicular | thoracotomy | costotransversectomy | |
| transclavicular–transmanubrial | transcervical–transthoracic | lat extracavitary | |
| transsternal | | lat parascapular extrapleural | |
| | | transpedicular | |

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with anterior plating. Recent availability of expandable cages and metal spacers can further facilitate anterior column reconstruction and deformity correction. Table 5 outlines the options available for anterior reconstruction and posterior stabilization.

The use of posterior cervical fixation has been well documented. Numerous techniques have been used, such as posterior wiring, Harrington/Luque rods with sublaminar wires, lateral mass plating, and cervical pedicle screws. All biomechanical tests on cadaveric spines have shown superior rigidity for posterior screw fixation techniques compared with anterior techniques.30 Bueff and coworkers7 compared three different fixation devices at the cervicothoracic junction: an anterior plate, a posterior plate, and a posterior hook/rod system. They found that the hook/rod system provided up to six times the stiffness of the intact spine, whereas the anterior plate provided stiffness similar to the intact spine. Under laboratory conditions, none of the wiring techniques achieved the stability of the intact segment and all performed poorly with forces other than flexion.30,32 In extension and torsion, lateral mass screws and plating devices have shown increased stability compared with posterior wiring alone.31 Analysis of posterior screw pullout revealed a correlation with the length of the screw’s passage through bone.13 Biomechanically, transpedicular screw fixation of the unstable lower cervical spine has provided the most stability.17 Nevertheless, a high rate of pedicle violation was noted, even when a partial laminectomy was used for screw placement.23

Because the cervicothoracic junction represents a transition zone, significant anatomical variations are common. It represents a change in spinal alignment from a mobile, cervical lordosis to a rigid, thoracic kyphosis. Anatomical understanding of this area is important for stabilization. The lower cervical laminae are thinner and weaker compared with upper thoracic vertebrae. Together with a narrow spinal canal, this often limits use of the hook/rod system for stabilization at the cervicothoracic junction.

Use of lateral mass screws should take into consideration the location of the vertebral artery and the spinal nerves.1 Compared with T-1, the C-7 vertebra has a closer anatomical relationship with the vertebral artery. This vessel will be at risk of injury if a lateral mass screw is too long or is directed less than 14° laterally from the midpoint of the lateral mass of C-7. These neurovascular relationships may change with significant kyphotic/scoliotic deformity of the spine, and these changes can subject them to greater risk of injury with posterior screw fixation.

Aiming too caudal with the lateral mass screws may lead to spinal nerve injury. Furthermore, the C-6 and C-7 lateral masses are the thinnest in the cervical spine because they are in transition to becoming transverse processes. A gentle touch will be needed to obtain adequate screw purchase in the lateral masses at C-6 and C-7. As a rough guideline and similar to the technique described by An, et al.,1 we have found a trajectory of 30° lateral and 30°

<table>
<thead>
<tr>
<th>Structural Graft</th>
<th>Instrumentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior</td>
<td>Posterior</td>
</tr>
<tr>
<td>iliac crest autograft rib</td>
<td>iliac crest autograft local autograft from laminectomy bone</td>
</tr>
</tbody>
</table>

![Fig. 1. Upper Left: Sagittal T2-weighted MR image revealing a metastatic lung carcinoma involving C7–T4. The patient presented with myelopathy and had already received a full course of radiation therapy. Upper Right: Intraoperative photograph showing decompressive C7–T4 laminectomy. Stabilization was achieved with cervical sublaminar wires secured to cross-links and the use of thoracic hooks below the decompression site. Lower: Postoperative x-ray films showing that the upper thoracic hook as a transverse device, whereas the two lower thoracic ones were pedicle/facet hooks.](image)
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Use of pedicle screws in this area requires familiarity with the anatomy. The mean pedicle width increases from 5.2 mm at C-5 to 7.8 mm at T-1, and then decreases to 4.4 mm at T-5. Thus, the pedicles at T-1 and T-2 are large enough for screw fixation and should be incorporated into the fusion construct if possible. The narrow size of the pedicles can limit the use of pedicle screws in the T-3 to T-5 vertebrae. The pedicle angle also decreases from 50° medially at the C-5 to 11° medially at the T-5 vertebra. The pedicle length increases gradually between the C-5 and T-5 vertebrae, however, with no significant differences between adjacent vertebral levels. The mean distance of the spinal nerve from the superior and inferior pedicles ranged between 0.8 and 2.3 mm, with greater separation between the nerve and the superior pedicle. Thus, pedicle screw violation of the superior cortex may place the nerve at higher risk of injury than in the inferior cortex.

In our series, we have incorporated a variety of techniques for posterior cervicothoracic stabilization to include combinations of sublaminar wiring, the hook/rod system, lateral mass screws, and cervicothoracic pedicle screws. Early in our series, we initially used primarily hooks and rods in combination with sublaminar wiring for stabilization (Fig. 1). As lateral mass screws became increasingly popular and biomechanically superior to sublaminar wiring, we incorporated this into our fusion construct (Fig. 2). With the advent of polyaxial screws, dual-diameter rods, and interlocking connections, we have shifted our stabilization technique to placement of lateral

Fig. 2.  Left: Sagittal T₂-weighted MR image demonstrating metastatic disease causing destruction to T1–2, with resulting kyphosis and spinal cord compression.  Center: Intraoperative photograph showing polyaxial lateral mass screws with thoracic hooks.  Right: Intraoperative photograph. Note the use of a dual-diameter rod to interlink the lateral mass screws with thoracic hooks.

Fig. 3.  Left: Sagittal T₂-weighted MR image demonstrating fracture at T-3 with instability and spinal cord compression.  Right: This patient underwent a costotransversectomy for decompression followed by stabilization. Note the dual-diameter rod with interlinking connectors. At least two cross-links were used for quadrilateral stability. Songer cables were secured to the upper cross-link to minimize upper screw pullout.
mass polyaxial screws in the cervical area, pedicle screws or hooks in the thoracic area, and use of at least two cross-links (one above and one below) to create quadrilateral stability (Figs. 1–5). Because of concerns and reports of upper cervical screw pullout, we have reinforced our cervical construct with a sublaminar wire secured to one of the upper cross-links (Figs. 1 and 5). Another potential option would be to extend the cervical construct rostrally to incorporate a C-2 pedicle screw fixation. For the mid-cervical spine, we prefer placing lateral mass screws over cervical pedicle screw placement, because the inherent risks of neurovascular injury are higher with the latter procedure. If the lesion is below T-2, placement of T-1 and T-2 pedicle screws will enhance the construct’s stability (Figs. 1, 3, and 5). In certain cases, use of mid- or lower-thoracic pedicle screws instead of hooks may be necessary and can further enhance the biomechanical strength of the construct (Fig. 4). Furthermore, because the cervicothoracic area represents an area of inherent instability, the demands on the fixation construct can be high. In this regard, we have routinely chosen to create a long construct, at least three or four levels above and below the diseased area.

CONCLUSIONS

As oncological treatments continue to expand and improve, the population of patients with tumors involving the spine will grow. Treatment goals may shift from palliative procedures to more aggressive curative surgical attempts. In lesions involving the cervicothoracic junction, a thorough understanding of the anatomy and biomechanical properties of this region is necessary to create a sound instrumentation-augmented fusion construct. As patients continue to live longer, the integrity of the construct will be greatly tested.

In this report of 19 surgically treated patients with tumors involving the cervicothoracic junction whose mean follow-up duration was 18.5 months, only one death has been noted. In the remaining patients, the only instrument failures that we have noted were with stand-alone anterior constructs at the cervicothoracic junction. Other authors have also noted this clinically; their stand-alone anterior cervicothoracic junction stabilization failure rate was 36%. This affirms the biomechanical advantage of a posterior screw/rod/wire construct over anterior plating systems. None of our patients who received posterior instrumentation encountered hardware failure. Furthermore, we have found that a posterolateral approach is sufficient for resection of soft tumors and can allow simultaneous, adequate anterior column reconstruction. Clinically, in this report and in others, prolonged patient survival and lasting neurological improvement are possible after aggressive resection of spinal tumors, followed by spinal reconstruction and stabilization.

As instrumentation technology and biological innovations continue to advance and challenge us to improve our practice, stringent biomechanical testing and clinical studies are necessary to affirm the effectiveness of the new processes. Althought dual-diameter rods, polyaxial screws, and interlocking devices enhance our ability to stabilize the cervicothoracic region, only through the test of time and with rigorous biomechanical trials can we learn their true effectiveness.

References

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