Total En Bloc Spondylectomy for Primary and Metastatic Spine Tumors

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Abstract

This study reports the surgical and clinical outcomes of spinal tumors managed with total en bloc spondylectomy. The authors searched their prospectively maintained database for patients undergoing total en bloc spondylectomy between 2001 and 2013. Ten patients (9 men, 1 woman; average age, 50.7 years; range, 42-68 years) were identified. The authors obtained demographic information, surgical outcomes (estimated blood loss, complications), and clinical outcomes (recurrence, survival). All patients had pain and were classified as American Spinal Injury Association grade E. The lesions were located in the thoracic (8 patients) and lumbar (2 patients) spine. Anterior column reconstruction was performed with strut allograft (7 patients), mesh cage (2 patients), and polymethyl methacrylate (1 patient). An average of 2.3 (range, 2-4) of 6 portions of the vertebrae were involved, according to the Kostuik classification. Mean estimated blood loss, operative time, and hospital stay were 3.5 L, 500 minutes, and 7.8 days, respectively. Perioperative complications included pleural tear (2 patients) and aortic tear, vena cava tear, retained sponge, pulmonary embolism, urinary tract infection, pneumothorax, anterior column support failure, and prominent instrumentation requiring removal (1 patient each). Postoperatively, all patients remained classified as American Spinal Injury Association grade E. Two patients had recurrence at distant spinal segments, and 1 had a new lesion in the thigh. Five patients had died (mean, 34.5 months after surgery), and 5 were alive a mean of 19.6 months after surgery (range, 6-48 months). Total en bloc spondylectomy is challenging, but in appropriately selected patients, it can be used to treat primary and metastatic spinal lesions. [Orthopedics. 2015; 38(11):e995-e1000.]

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Surgical management of primary and metastatic spinal tumors is challenging. The spine is the most common site of metastases to the skeletal system. Up to 70% of patients with cancer have spinal metastases, and this occurrence is attributed to spread via the segmental artery system or the valveless Batson’s venous plexus. The goals of surgery for aggressive spinal lesions include decompressing the neural elements and providing pain relief, achieving mechanical stability, increasing life expectancy (in cases of metastatic disease), and improving the quality of life. For benign lesions, intralesionel resection is often the preferred approach, whereas for aggressive lesions, a wide margin is preferred. With cervical and thoracic spine tumors, there is a risk of spinal cord injury as a result of vertebral destruction and tumor extension into the epidural space. In the lumbar spine, epidural compression can present as radiculopathy and cauda equina syndrome in patients with severe stenosis.

Total en bloc spondylectomy is an all-posterior method for achieving spinal tumor resection. The thread wire saw technique was first reported in Japan by Tomita et al in 1994. The technique relies on en bloc laminectomy and en bloc resection of the vertebral body via a thread wire saw, followed by reconstruction of the anterior column. Oncologically, the goal of this technique is to avoid rupturing the tumor capsule and potentially obtaining a wide margin. However, more commonly, a marginal margin or an intralesionel margin, if there are epidural metastases, is usually obtained. This article reports the surgical and clinical outcomes of primary and metastatic spinal tumors managed with total en bloc spondylectomy at Johns Hopkins Hospital.

Materials and Methods

Institutional review board approval was obtained from Johns Hopkins Hospital for this retrospective study of consecutive patients with spinal tumor. The study design was a retrospective evaluation of prospectively collected data. Inclusion criteria were the presence of aggressive spinal lesions, malignant primary tumors, or metastatic spinal tumors and treatment with total en bloc spondyllectomy. All surgery was performed by the senior author (K.M.K.) at a single institution between 2001 and 2013. For all 10 patients who met the criteria, the authors collected the following data: patient characteristics (demographics, lesion location, American Spinal Injury Association score, Kostuik classification, patient diagnosis); surgical outcomes (estimated blood loss, operative time, length of hospitalization, perioperative complications); and clinical outcomes (recurrence and survival).

The 9 men and 1 woman had a mean age of 50.7 years (range, 37.2-68 years) at the time of surgery (Table 1). Patient diagnoses were metastatic renal cell carcinoma (3 patients), primary chondrosarcoma (1 patient), metastatic chondrosarcoma (1 patient), epithelioid hemangioendothelioma (1 patient), fibrous dysplasia (1 patient), Ewing sarcoma (1 patient), pleomorphic liposarcoma (1 patient), and fibrosarcoma (1 patient). Eight lesions were in the thoracic spine (T3-T12), and 2 lesions were in the lumbar spine (L2). Two patients had multilevel involvement at T4-T6. Because of its uncommon presentation and the patient’s symptoms, and to avoid recurrence, total en bloc spondylectomy was elected for the 1 case of fibrous dysplasia.

On presentation, all patients were symptomatic with pain. All patients were classified as American Spinal Injury Association grade E on the basis of the American Spinal Injury Association impairment scale. The Kostuik classification was used to classify the degree of tumor involvement of the spinal column (average score, 2.3 columns; range, 1-4 columns).

The 3 patients with metastatic renal cell carcinoma had undergone previous radiation therapy and preoperative embolization. Three patients (1 each with metastatic chondrosarcoma, fibrosarcoma, and Ewing sarcoma) had preoperative chemotherapy. The patient with epithelioid hemangioendothelioma had a biopsy and video-assisted thoracic resection of the lesion at another institution before the pathologic results were known, and this resulted in tumor seeding of the thoracic cavity. The patient with fibrosarcoma was initially believed to have a compression fracture and was managed via vertebroplasty at another hospital. When the pathologic findings showed fibrosarcoma, the patient was referred to the authors’ institution for management.

All patients underwent total en bloc spondylectomy as described previously and in further detail later. After total en bloc spondylectomy, anterior column reconstruction was performed with structural allograft (n=7; humeral allograft, 4; femoral allograft, 3), Harms cage (n=2), and/or polymethyl methacrylate block (n=2). Patients underwent posterior instrumentation and fusion of an average of 6.2 levels (range, 5-9 levels).

The surgical technique is as follows and can be seen online. If the tumor is metastatic and known to be vascular, such as renal cell, thyroid, or hepatocellular cancer, the authors routinely perform preoperative embolization of the affected level within 48 hours of surgery. Intraoperative neuromonitoring, consisting of somatosensory evoked potentials and transcranial motor evoked potentials, is used. After standard exposure of the posterior spine, a marker is used to identify the level of the planned resection. Pedicle screws are placed via the freehand technique 2 to 4 levels above and 2 to 4 levels below the planned resection level. The authors resect a minimum of 4 ribs (2 per side) from the planned resection level. A minimum of 5 cm rib is removed and carefully dissected from the plane under the rib to avoid violating the pleura. A Ponte-type osteotomy is performed at...
the segment above the planned resection (ie, for T10 resection, T9-T10 Ponte osteotomies) is performed, but the superior articular facet is not preserved. A curved osteotome is used to perform bilateral pediculectomies. The authors find this easier than using the thread wire saw, as in Tomita’s technique. Once the bilateral pediculectomies are completed, the lamina and the posterior elements are removed en bloc. The authors next identify the nerve roots of the resection level and place 2-0 silk sutures on the nerve roots proximal to the dorsal root ganglion. A No. 15 blade knife is used to sacrifice the nerve root. The ties are left on the nerve roots to help to gently mobilize the dura and spinal cord. Ties are also placed around the intercostal vessels, and they are ligated. The authors use finger dissection to carefully create a plane between the anterior vertebral body and the great vessels. Next, 2 malleable retractors are placed anterior to the vertebral body. The authors ensure that the dura is completely free anteriorly with a combination of fine Metzenbaum scissors and bipolar electrocautery. Then 18-gauge needles are placed to mark the location of the disk above and below the resection level. A sublaminar wire is used to help to pass the thread wire saw anterior to the vertebral body and to place a rod on 1 side. The authors place thread wire saw handles on both ends of the thread wire saw and start to move the saw in a gentle back-and-forth manner. This procedure is repeated on the inferior disk space. An osteotome is used to make the last cuts on the posterior cortex of the vertebral body. After ensuring that the vertebral body is completely free, the rod is distracted. Next, a Cobb elevator is used to help to lever the vertebral body out. After the specimen is removed (Figure 1), the authors use different options for anterior column reconstruction, including humeral strut graft allograft contoured to the appropriate length, mesh cages, and polymethyl methacrylate. When using an allograft or a mesh cage, the authors place a combination of allograft and autograft (not containing tumor) inside. To safely place the strut allograft, the authors distract the rod on the contralateral side while being careful not to overdistract on the spinal cord. The authors alert the neuromonitoring staff that they are distracting so that they can release the distraction if any changes in motor evoked potentials or somatosensory evoked potentials occur. Once the anterior column reconstruction is performed, the authors compress on the rod. The second rod is placed, and a crosslink over the open dura is performed. The authors then place a deep drain and perform meticulous closure of the fascial and superficial layers.

**RESULTS**

**Surgical Outcomes**

Estimated blood loss averaged 3.5 L (range, 1.5-8.9 L), and surgical time averaged 500 minutes (range, 420-718 minutes). Average hospital stay was 7.8 days (range, 5-10 days). There were 5 intraoperative complications in 4 patients (Table 2); the patient with the retained sponge returned to the operating room for

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**Table 1**

Patient Demographics

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Diagnosis</th>
<th>Age at Surgery, y</th>
<th>Lesion Location</th>
<th>Management</th>
<th>Recurrence</th>
<th>Survival, mo</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Epithelioid hemangioendothelioma</td>
<td>39.5</td>
<td>T4, T5, T6</td>
<td>TES T4-T6, PSF T1-T10, humeral allograft</td>
<td>No</td>
<td>9 (deceased)</td>
</tr>
<tr>
<td>2</td>
<td>Metastatic renal cell cancer</td>
<td>59.5</td>
<td>T9</td>
<td>TES T9, PSF T6-T11, PMMA</td>
<td>Yes</td>
<td>51 (deceased)</td>
</tr>
<tr>
<td>3</td>
<td>Metastatic renal cell cancer</td>
<td>37.2</td>
<td>T3</td>
<td>TES T3, PSF T1-T6, humeral allograft</td>
<td>Yes</td>
<td>71 (deceased)</td>
</tr>
<tr>
<td>4</td>
<td>Metastatic renal cell cancer</td>
<td>39.5</td>
<td>T5</td>
<td>TES T5, PSF T3-T8, Harms cage filled with PMMA</td>
<td>No</td>
<td>22 (deceased)</td>
</tr>
<tr>
<td>5</td>
<td>Metastatic chondrosarcoma</td>
<td>57</td>
<td>T4, T5, T6</td>
<td>TES T4, PSF T1-T8, Harms cage and autograft</td>
<td>No</td>
<td>24 (deceased)</td>
</tr>
<tr>
<td>6</td>
<td>Fibrous dysplasia</td>
<td>37.5</td>
<td>T7</td>
<td>TES T7, PSF T3-T11, humeral allograft</td>
<td>No</td>
<td>48 (alive)</td>
</tr>
<tr>
<td>7</td>
<td>Chondrosarcoma (primary)</td>
<td>67.3</td>
<td>T11</td>
<td>TES T11, PSF T9-L2, femoral allograft</td>
<td>No</td>
<td>24 (alive)</td>
</tr>
<tr>
<td>8</td>
<td>Fibrosarcoma</td>
<td>68</td>
<td>T12</td>
<td>TES T12, PSF T10-L3, humeral allograft and PMMA</td>
<td>No</td>
<td>6 (alive)</td>
</tr>
<tr>
<td>9</td>
<td>Ewing sarcoma</td>
<td>49</td>
<td>L2</td>
<td>TES L2, PSF T10-pelvis, femoral allograft</td>
<td>No</td>
<td>7 (alive)</td>
</tr>
<tr>
<td>10</td>
<td>Pleomorphic liposarcoma</td>
<td>42</td>
<td>L2</td>
<td>TES L2, PSF T12-L4, femoral allograft</td>
<td>No</td>
<td>13 (alive)</td>
</tr>
</tbody>
</table>

Abbreviations: PMMA, polymethyl methacrylate; PSF, posterior spinal fusion; TES, total en bloc spondylectomy.
its removal. There was no intraoperative neurologic injury despite spinal cord mobilization to achieve en bloc resection of the vertebrae. There were 8 perioperative complications in 7 patients (Table 2).

Clinical Outcomes

No patient had permanent neurologic deficits, and all patients remained classified as American Spinal Injury Association grade E at the latest follow-up. One patient had postoperative left lower-extremity weakness that resolved. Pathologic examination showed that marginal resection was obtained in 8 patients and wide resection was obtained in 2 patients. At the latest follow-up, all patients had significant improvement in pain compared with preoperative levels.

There were no local recurrences, although 2 patients with metastatic renal cell carcinoma had recurrence at other levels of the spine an average of 24 months postoperatively (range, 6-41 months) (Table 1).

At the latest follow-up, 5 patients had died (average, 35.4 months; range, 9-71 months) and 5 patients were alive (Figure 2) (average, 19.6 months after surgery; range, 6-48 months).

Discussion

Resection of tumors of the spine in accordance with Enneking’s8 principles of musculoskeletal tumor resection can be challenging.9 Traditional resection of spinal tumors relied on intralesional resection.10 En bloc resection of spinal tumors, when used, predominantly relied on combined anterior-posterior approaches.9,11 Stener,12 Lapresle et al,13 Magerl and Coscia,10 and Boriani et al11 reported their experiences with posterior-based en bloc spondylectomy. Tomita et al4 introduced the technique of an all-posterior total en bloc spondylectomy in 1994 with the assistance of a thread wire saw, and Tomita and Kawahara14 described the thread wire saw in further detail. The initial report included a series of 20 patients with metastases to the spine.4 In that series, at 17-month follow-up, no local recurrences were reported and 9 of 20 patients were still alive. The technique was further expanded for primary malignant vertebral tumors in 1997.15 Marginal margins were reported in these patients, with no local recurrences.15 Recent reports also described the technique for metastatic lung and thyroid cancers.16,17

In the current study, the authors reported their experience with total en bloc spondylectomy using a technique similar to that reported by Tomita et al14,15 and Tomita and Kawahara.14 The authors started using this technique to manage spinal tumors in 2001. To date, the authors have performed this technique in 9 patients with malignant spinal lesions and 1 patient with a benign aggressive lesion. Because all 10 patients were classified as American Spinal Injury Association grade E, the indication for surgery was pain relief rather than neurologic deficits. However, if untreated, spinal tumors can lead to vertebral collapse, metastatic epidural spinal cord compression, and neurologic deficits.

The reported complications attest to the technical challenge of this technique. Two pleural tears occurred during posterior dissection, and an aortic tear and vena cava tear occurred during anterior dissection. The aortic and vena cava tear occurred in a patient with epithelioid hemangioendothelioma who had undergone previous unsuccessful thoracoscopically

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Diagnosis</th>
<th>Intraoperative Complications</th>
<th>Perioperative Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Epithelioid hemangioendothelioma</td>
<td>Aortic tear, vena cava tear</td>
<td>Pulmonary embolism, urinary tract infection</td>
</tr>
<tr>
<td>2</td>
<td>Metastatic renal cell cancer</td>
<td>Retained sponge requiring return to operating room</td>
<td>Failure of anterior column support requiring revision</td>
</tr>
<tr>
<td>3</td>
<td>Metastatic renal cell cancer</td>
<td>Pleural tear</td>
<td>Pneumothorax</td>
</tr>
<tr>
<td>4</td>
<td>Metastatic renal cell cancer</td>
<td>None</td>
<td>Clostridium difficile</td>
</tr>
<tr>
<td>5</td>
<td>Metastatic chondrosarcoma</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>6</td>
<td>Fibrous dysplasia</td>
<td>Pleural tear</td>
<td>None</td>
</tr>
<tr>
<td>7</td>
<td>Chondrosarcoma (primary)</td>
<td>None</td>
<td>Urinary retention</td>
</tr>
<tr>
<td>8</td>
<td>Fibrosarcoma</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>9</td>
<td>Ewing sarcoma</td>
<td>None</td>
<td>Left lower-extremity weakness (resolved)</td>
</tr>
<tr>
<td>10</td>
<td>Pleomorphic liposarcoma</td>
<td>None</td>
<td>Hypertension</td>
</tr>
</tbody>
</table>

Figure 1: Total en bloc spondylectomy specimen.

Figure 2:

Table 2

Intraoperative and Perioperative Complications Associated With Total En Bloc Spondylectomy

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guided biopsy and tumor resection. While creating a plane between the great vessels and the anterior vertebral body, the authors found substantial scarring that led to the aortic and vena cava tears. These tears were managed with the assistance of vascular surgeons. Of the 2 pleural tears, 1 resulted in pneumothorax that required chest tube placement. Both pleural tears were managed with primary suture repair.

The authors also found a high estimated blood loss (average, 3.5 L), a lengthy hospital stay (average 7.8 days), and a long operative time (average, 500 minutes). There is a learning curve associated with total en bloc spondylectomy. The authors’ intraoperative surgical time decreased from 605 minutes for the first case in 2001 to 480 minutes for the last case in 2013. The rate of intraoperative complications also decreased over the study period. Intraoperative complications occurred in the first 4 cases, but not in the last 2. For this technique to be performed safely, a core team of anesthesiology, operating room, and surgical staff is needed. Over the past decade, the authors developed such a team.

Recently, Matsumoto et al noted instrumentation failure in 6 of 15 malignant spinal tumors managed via total en bloc spondylectomy. In the current study, an anterior column support failure (polymethyl methacrylate) occurred and was revised with a titanium mesh cage. Medical complications (pulmonary embolism, urinary tract infection, urinary retention, and Clostridium difficile infection) were most common in the perioperative period.

For 8 of the 10 cases, the authors obtained a marginal resection. Two patients had wide margins. Five patients died an average of 35.4 months after surgery, and 5 were alive an average of 19.6 months after surgery. Three distant recurrences (2 in 1 patient) occurred in patients with metastatic renal cell cancer. In a series of 33 patients with metastatic renal cells of the spine, King et al reported a 49% recurrence rate at 5 months after piecemeal resection and reconstruction. In the current study, both patients with recurrences had marginal resections and died more than 4 years (51 months and 71 months, respectively) after the index procedure.

Total en bloc spondylectomy is a challenging surgical technique. If wide margins are obtained in patients with isolated malignant lesions of the spine, then with a combination of radiation and systemic therapy, the surgery may be curative. In the current study, the 2 patients with wide margins had isolated chondrosarcoma and Ewing sarcoma. They responded well to systemic therapy and were alive at the latest follow-up. However, if marginal margins are obtained in such cases, then the increased morbidity associated with total en bloc spondylectomy must be weighed against the benefits.

Innovations to the total en bloc spondylectomy technique, as described by Tomita et al and Tomita and Kawahara, continue. Recently, Gasbarrini et al reported a spinal cord protection device called Promid (Novatek, Bologna, Italy) that can be attached to the stabilization rod and used to guide the thread wire saw during the back-and-forth motion of cutting the vertebral body. Traditionally, a spatula is used to protect the dura during the back-and-forth motion with the Tomita saw. The current authors’ technique left a small portion of the posterior cortex and use a curved osteotome to perform the final cuts. The Promid device holds promise for making total en bloc spondylectomy even safer and potentially increasing its use.

Stereotactic radiosurgery is another modality that is being increasingly used for spine tumors. One of the largest series was reported by Gerszten et al, in which stereotactic radiosurgery (range, 12.5-25 Gy) was used to treat 500 patients with...
spinal metastases; the authors noted that 86% had pain improvement. Exclusion criteria were myelopathy associated with the tumor, neurologic deficits, and spinal instability. Complications associated with stereotactic radiosurgery include vertebral body fractures, and a fracture rate of 13% to 20% has been reported. Risk factors for vertebral body fractures include lytic tumors, more than 20 Gy in a single fraction, age greater than 55 years, and baseline pain. Longer follow-up is needed, and prospective studies comparing life expectancy and outcomes in patients managed with total en bloc spondylectomy vs stereotactic radiosurgery would be useful.

Limitations
This study had some limitations. The sample size was small, and data on functional outcomes were limited. The authors initiated the collection of health-related quality of life questionnaires halfway through the study period. The small sample size was a reflection of the authors’ strict criteria for the use of this technique. Additional limitations included the heterogeneous case mix; it would have been ideal to have a series of 1 type of tumor. The authors are currently collecting such data from multiple centers. To the authors’ knowledge, there have been few reports in the literature on total en bloc spondylectomy other than from centers that pioneered this technique, perhaps because of the challenge associated with the technique and the limited number of eligible patients. To the authors’ knowledge, this is the first North American series to report this technique. Future studies should involve multicenter collaborations to further define the indications, outcomes, cancer-free survival rates, and recurrence rates associated with this procedure.

CONCLUSION
An all-posterior total en bloc spondylectomy procedure in 10 patients with aggressive spinal tumors resulted in local control and patient-reported pain relief. At the latest follow-up, 5 patients had died (average, 35.4 months) and 5 patients were alive (average, 19.6 months) after surgery. Total en bloc spondylectomy is a challenging surgical technique that is best performed at centers that specialize in the treatment of spinal tumors.

REFERENCES