Surgical management of metastatic spinal neoplasms

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Object. In this study the authors retrospectively review outcomes in patients treated for metastases to the spine. Surgery for metastatic tumors to the spine remains an important part of the treatment armamentarium. Maximum tumor resection with a minimum number of complications is one of the goals of surgery. Current surgical procedures include tumor resection and spinal stabilization for optimal results.

Methods. The records of 96 patients who underwent surgery for a metastatic spine tumor at the authors’ institution were reviewed. Spinal instrumentation was used in the majority of patients. Ambulatory status was maintained in 91% and pain improved in 94% of patients. Complications included infection (5.2%), cerebrospinal fluid leak (2%), and delayed hardware failure (3.1%). The mortality rate was 4.1%; the main cause was due to tumor progression.

Conclusions. Surgery is indicated in a select group of patients with metastatic tumors to the spine. A multidisciplinary approach is recommended for patient selection and complication avoidance. Surgical options, including approach, type of reconstruction and extent of resection (including en bloc spondylectomy) need to be addressed for optimal outcomes.

KEY WORDS • metastasis • spine tumor • spinal instability • spinal stabilization

Abbreviations used in this paper: CSF = cerebrospinal fluid; MMA = methylmethacrylate; MR = magnetic resonance; VB = vertebral body.
CLINICAL MATERIAL AND METHODS

Patient Population

Between September 1, 2000, and September 1, 2003, 96 patients with metastatic spine tumors underwent a total of 108 operations at H. Lee Moffitt Cancer Center, and are the focus of this study. There were 56 male and 40 female patients with a mean age of 53 years (range 10–76 years). Patients with chordomas, primary bone tumors, and non-metastatic lesions were excluded. The patients’ hospital records were retrospectively reviewed.

Evaluation and Indications for Surgery

Preoperative evaluation included a neurological examination, MR imaging, and plain x-ray films. In selected cases, computerized tomography scanning was performed. All patients except three had an estimated life expectancy of more than 3 months according to their oncologists. Indications for surgery included evidence of spinal instability (kyphosis, subluxation, or retropulsed bone fragment); evidence of tumor progression (radiographically, clinically, or both) despite previous radiotherapy; neurological deterioration during radiotherapy; medically intractable pain; rapid development of neurological compromise or myelopathy; lack of tissue diagnosis; or radiation-resistant tumor (melanoma, sarcoma, or renal carcinoma).

RESULTS

The tumor origin was as follows: lung cancer (28.1%), sarcoma (18.7%), renal carcinoma (12.5%), breast carcinoma (9.3%), hematological malignancy (7.3%), gastrointestinal malignancy (6.2%), prostate cancer (5.2%), melanoma (4.1%), gynecological origin (3.1%), unknown origin (2%) and miscellaneous (3%). Sixty-six patients (68.7%) had undergone previous external-beam radiotherapy. All patients presented with pain, and 40% exhibited symptoms or signs of myelopathy. Spinal stabilization was performed in 71 patients (74%). All but two patients with myelopathy improved neurologically.

There were no neurological deficits attributable to the surgery itself. Pain improved in all but five patients (95%). Pain that did not improve was caused by new metastatic lesions involving other parts of the spine or skeletal system. Although their pain improved, most patients continued to use some form of narcotic analgesic medication. Ambulatory status was maintained for at least 3 months postsurgery in 88 (91.6%) of 96 patients. At a mean follow-up time of 12 months, 46 (48%) of 96 patients were alive. Complications included five infections (5.2%), four deep and one superficial; only one of the infections required further surgery. All patients with infections had previously undergone radiation therapy, and two had undergone previous embolizations. All infections occurred after operations performed via a posterior (laminctomy) approach. Two patients had a CSF leak. Three patients (3.1%) had evidence of delayed hardware failure; two of the three required additional revision surgery. One patient died of a pulmonary embolism in the immediate postsurgical period. Three more patients died within 4 weeks after surgery (total 4.1% mortality rate) because of tumor progression. Those patients had insisted on surgery, despite the fact that the expected survival time was less than 3 months.

ILLUSTRATIVE CASES

Cases 1 to 6

Simultaneous, Circumferential, Short-Segment Tumor Resection and Instrumentation in the Thoracic Spine.

This technique involves an initial laminectomy with the patient prone, with definition of the thecal sac and ligation of the exiting nerve root. Subsequently, the operating bed is “airplained” to a 45° angle position and a retropleural thoracotomy is performed22 (Fig. 1). An anterior vertebrectomy with resection of the entire tumor is then followed by an anterior stabilization with a cage and VB screws. The patient is then moved again to an almost prone position, and a short-segment posterior instrumentation is performed through the same J-type incision one level above and below the lesion, by using screws, hooks, or both.

A total of six patients underwent this procedure, four of them female and two of them male. The tumor origin was as follows: lung in three of six, esophagus in one of six, sarcoma in one of six, and breast carcinoma in one of six. All patients presented with pain, and three of six had spinal cord compression. Four patients had received prior radiation therapy to the spine. In all cases, the tumor involved both the anterior and posterior elements. All patients tolerated the surgery well, and there were no immediate complications. All patients experienced an improvement in pain, and in their neurological condition (if it had been impaired preoperatively). One patient suffered junctional kyphosis 4 months postsurgery and required revision and additional stabilization. Two of six patients were alive at 18-month follow-up review. All patients with lung carcinoma died within 6 months of surgery.

This approach allows complete tumor resection through the same incision, and simultaneous anterior and posterior thoracic spine when a complete resection with a short-segment fixation is the goal. A trapezius flap can be used at the same time to reduce the chance of infection, especially in patients who have previously received radiation therapy.

Case 7

Double Rod Sacroiliac Fixation for a Sacral Tumor.

This 56-year-old woman had a 5-year history of locally invasive rectal carcinoma to the sacrum. She had undergone two previous abdominal resections, radioactive seed implantation, additional radiation therapy, and chemotherapy. She presented to us with bilateral S-1 radiculopathy and incontinence, and she had been unable to bear weight for 4 weeks. The patient was bedridden, and she weighed 230 lbs. She underwent posterior L-5 and S-1 laminectomies with bilateral facetectomies and resection of all the dorsal epidural tumor and full decompression of the thecal sac. In addition, a subtotal resection of the sacral tumor was performed.
Instrumentation procedures included placement of multiaxial screws in the pedicles of L-2, L-3, and L-4 (Fig. 2). Iliac 8-cm screws were placed bilaterally in the iliac wings in a typical Galveston rod position. In addition, iliac screws were placed on both sides; they were placed lateral to the sacroiliac joints in the iliac crests from a superior-to-inferior direction. All iliac screws were reinforced with MMA. Four 6.25 mm titanium rods were connected with the iliac screws, creating a dual-rod construct. This construct combined the iliolumbar fixation of the Galveston technique with a second rod that was connected with the screws in the iliac crest. The operation lasted 6 hours, and the blood loss was 2400 ml. The patient was able to ambulate 72 hours after the surgery with a walker, and independently after that. She died of tumor progression 9 months after surgery.

This case shows that for patients with metastatic tumors to the sacrum and limited life expectancy, rigid stabilization and early mobilization is desired. This requires the maximum possible fixation, especially when there is complete instability because of destruction of both sacroiliac joints. In this technique we used a dual-rod system that involves a combination of the Galveston and iliac crest screw fixation, which prevents both the “open book” and “windshield wiper” effects associated with previous fixations. The patient does not have to lie in bed for 6 weeks to maximize their chance for fusion; this technique allows immediate stability.

**DISCUSSION**

**En Bloc Resection**

The role of en bloc resection in patients with metastatic spine tumors is unclear. Most studies point to a reduction in the recurrence rate but do not show a clear survival advantage in metastatic tumors. Local malignancies such as chordomas, selected sarcomas and chondrosarcomas, Pancoast tumors, giant cell tumors, and osteoblastomas are currently the types of tumors for which an en bloc resection should be considered. En bloc resection is technically more demanding, is associated with a higher risk of neurological complications, and requires that the tumor be confined within a limited number of VBs, as well as requiring absence of epidural disease and an intact contralateral pedicle. In addition, the extent of dissection increases, and with it the need for subsequent anterior and posterior spinal reconstruction. In most circumstances (except for certain sacral chordomas), a marginal en bloc resection is all that can be achieved. If the pathological examination confirms tumor-free margins, radiation therapy...
can be avoided. In some cases, such as sarcomas, en bloc resection may require the removal of tumor-adherent dura. In those cases, a watertight duraplasty with autologous fascia is recommended, with appropriate muscle flap coverage if there has been previous radiotherapy. This is done because CSF fistulas in previously irradiated fields are hard to correct and can be associated with a high risk of wound infection and meningitis.

Although en bloc resection provides the best chance for disease-free long-term survival in selected patients, its use is limited by prior surgery or radiation therapy. Certain neoplasms, such as chordomas and sarcomas, may have “skip areas” or “micrometastases” not detected on MR imaging at the time of the surgery, which will eventually compromise the clinical result. Because of the magnitude of the surgery and the risks involved, appropriate preoperative psychological counseling is recommended.

**Spinal Instability**

The definition of spinal instability is not always clear. As defined by Panjabi, et al., spinal stability is the degree of motion that prevents pain, neurological deficit, and abnormal angulation. Instability caused by tumors appears to be different from that associated with traumatic injuries. Current classification proposals have divided each vertebral body into two, three, or six columns, but have failed to predict accurately future neuroimaging and/or clinical confirmation of progression consistent with instability. This could be due to the fact that in normal individuals there is considerable variability in bone density, ligamentous integrity, and concomitant degenerative changes, which, together with the subjective nature of pain, confounds the issue of stability and restricts the use of uniform criteria. In addition, ligamentous structures are more frequently involved in trauma than in tumors, and pathological fractures rarely follow the anatomical patterns typical of traumatic ones. A more practical and pragmatic way of categorizing spinal instability is to classify it as acute or chronic.

**Acute Instability.** This form of instability includes the presence of a kyphotic deformity and/or subluxation, with spinal cord compression accompanied by pain and/or myelopathy. This form of instability is the most obvious and almost always involves the need for surgical stabilization (Fig. 3).

**Chronic Instability.** In contrast, chronic instability is a more subtle form that includes compression fractures of various degrees, which are not associated with spinal cord compression or severe pain (Fig. 4). This form of instability can be managed conservatively, at least initially, with
observation, bracing, vertebroplasty, or kyphoplasty, as well as with chemotherapy, radiation, or hormone therapy, depending on the biology of the tumor. Chronic instability has the potential to progress to acute instability, resulting in the need for surgical fixation; however, given the uncertainty of the progression, we do not recommend prophylactic spinal stabilization in these cases (Fig. 5).

Other Factors in Spinal Instability. Other factors that contribute to instability and should be taken into account in the decision-making process include the presence of circumferential disease, contiguous multilevel disease, junctional (cervicothoracic or thoracolumbar) tumor location, and the presence of earlier laminectomy (Fig. 6). Not every resection of metastatic tumor requires spinal stabilization. Unilateral transpedicular/costotransversectomy/ far-lateral approaches, especially in the thoracic spine, can be used for tumor resection without a need necessarily for concomitant spinal instrumentation (Fig. 6).

To Fuse or Not to Fuse

Pseudarthrosis is defined as the failure of an attempted fusion by 1 year postsurgery. In patients with cancer, many do not live long enough to be assessed for fusion or they undergo spinal reconstruction with MMA. Therefore, pseudarthrosis is more of an issue with primary spine tumors or long-term cancer survivors. Although in surgery for degenerative spine disease, a solid bone fusion is the ultimate goal because it provides lasting spinal stability, in patients with cancer, fusion may not be achievable. In cases of tumor, fusion is difficult or impossible to accomplish because of the effects of perioperative radiotherapy, chemotherapy, steroid drugs, malnutrition, anemia, frequent use of allograft, and smoking. Therefore, in such cases one may need to rely on rigid spinal instrumentation to provide long-term stability. Rigid systems include pedicle screws, and by definition do not rely on adjacent ligaments or articulations of the spine for load sharing. This is in contrast with semirigid systems such as hooks or sublaminar wires that rely on those structures for support.

There are few data regarding the presence of pseudarthrosis in metastatic spine tumors, as the goal of treatment shifts to recurrence-free, long-term survival and not necessarily to fusion. In one retrospective study of 25 patients with spine tumors who were treated with anterior or vertebrectomy, autologous grafting, and perioperative radiation therapy, a 16% radiographic pseudarthrosis rate was found at 1 year of follow up. There was a trend toward pseudarthrosis for lumbar lesions, primary tumors, or patients who received dosages of more than 4000 rads. Clinically, pseudarthrosis is indicated by the presence of pain, progressive deformity or instrumentation failure af-
Fig. 6. A–C: Neuroimages obtained in a 50-year-old man with a history of lung carcinoma. He had undergone previous radiation therapy for a tumor in the cervicothoracic junction, and presented with spinal cord compression and instability. A: Sagittal T1-weighted MR image with contrast, demonstrating a tumor involving C-7 and T-1 with epidural invasion and spinal cord compression. B: Lateral x-ray film demonstrating the finished construct after a C-7 and T-1 vertebrectomy, anterior plating followed by posterior instrumentation, and fusion from C3–T6. C: Postoperative x-ray film, AP view, of the finished construct. A long construct was selected because of the junctional location and multilevel disease at T-3 and T-4. D: Sagittal MR image obtained in another patient, demonstrating the “bowstring” effect on the spinal cord and kyphotic deformity caused by multilevel metastatic disease secondary to breast carcinoma. E: Axial T1-weighted MR image with contrast obtained in a 64-year-old man with a history of sarcoma involving the left T-7 and T-8 region. The patient underwent gross-total resection of the tumor via a left lateral costotransversectomy approach with no need for reconstruction.

ter a pain-free interval. Radiographic signs include lucency around cages and/or screws or grafts, resorption of bone graft, increased motion on dynamic films, discontinuity in fusion mass, or a positive bone scan. Pseudarthrosis implies a persistent motion in a segment that was intended to fuse. It may be completely asymptomatic, but it can also lead to graft collapse or fracture, metal fatigue with rod or screw breakage, and subsequent spinal deformity. In the latter cases, one needs to rule out the possibility of tumor recurrence, radiation necrosis, or infection, which, similar to pseudarthrosis, can lead to delayed structural failure.

In our series, three delayed cases (3.1%) of structural failure were seen in two of the three patients who required instrumentation revision. Salvage strategies in those cases included the use of more rigid fixation (screws instead of hooks, larger-diameter screws, longer construct, claws, and MMA reinforcement of the screws). In addition, a different approach (ventral if a dorsal approach was performed previously and vice versa) is recommended. A combined anterior–posterior approach is recommended for significant kyphotic deformities with spinal cord compression.18 The use of bone morphogenetic protein–2, autografts, and electromagnetic stimulation could also be considered in cases requiring revision.

Surgical Approach

Three main approaches have been used in the treatment of metastatic spine tumors: 1) laminectomy; 2) costotransversectomy; and 3) thoracotomy.27,28 The laminectomy approach is the one most familiar to neurosurgeons and, in combination with a uni- or bilateral transpedicular approach allows access to dorsally and ventrally located lesions.21 Its disadvantages include incomplete tumor resection in ventral lesions and a higher risk of infection.

A costotransversectomy is a 45° approach to the spine along the angle of the rib head as it attaches to the transverse process. It is versatile and can be combined with anterior and/or posterior instrumentation. It is best for eccentrically located neoplasms that involve the lamina, pedicle, and VB on only one side.

For lesions involving the VB exclusively, the thoracotomy approach is the most advantageous.16 It is best for correcting kyphosis and safest for removal of retropulsed bone fragment after pathological fractures. It is associated with a higher risk of pulmonary complications, especially in patients of advanced age and those with a history of chronic obstructive pulmonary disease. The thoracotomy can be performed on the side that allows maximum tumor access, or otherwise from the right side for the mid-thoracic region and from the left side for access to the thoracolumbar junction. Usually the thoracotomy is made through the rib bed that corresponds to two levels above the involved VB. If the thoracotomy is closer to the spine (that is, far-lateral approach) and not centered along the midaxillary line, however, a single level above or the same level can be used for optimal exposure. For the upper thoracic region (Pancoast tumors) the traditional dorsolateral thoracotomy may not provide adequate exposure. In those cases, one may use a trapdoor or median sternotomy approach, depending on how anterior the tumor is and whether major blood vessels are involved. For sacral tumors, a dorsal approach can be used below S-3 and a combined ventral–dorsal approach above it to avoid vascular complications.2,14,15,17

Types of Reconstruction

Anterior Reconstruction. A variety of grafts are available (autologous or allografts) depending on the size of the defect (fibula, tibia, femoral ring) and goal of fusion. Vascularized fibula, vascularized rib grafts, or a combination of allograft and autograft can also be used. Traditionally, spondylectomy defects in patients with cancer have been reconstructed with MMA.23 Its low cost, instant stability, and resistance to tumor invasion and radiotherapy have made it the spacer material of choice in the majority of cases, especially in patients with an anticipated life expectancy of less than 6 months. Nevertheless, there is frequently a need to use K-wires or screws to improve MMA anchorage to the adjacent VBs.19 Because MMA may “piston” in the setting of weak bone, the pins may

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migrate to penetrate vital structures (spinal cord, aorta). The chest tube technique and our own modifications (endplate preparation, then distraction, then placement of MMA against endplates, then compression with ventral or dorsal instrumentation) avoid the use of anchoring pins and their associated risks (Fig. 7). Nevertheless, MMA never fuses and its utility in long-term survivors is questionable. Although long-term stability can be seen after MMA reconstruction, this is usually due to the accompanying instrumentation.

For patients with a life expectancy of more than 6 months, reconstruction with an allograft or cage is recommended. We use cages to try to imitate a bone graft. In a bone graft the cancellous bone fuses, although it is not load-bearing. The load is supported by the cortical bone, which is imitated by the cage. Cages can be cut to various sizes and can imitate the normal contour of the spine. Stackable carbon fiber or titanium cages are commonly used; expandable cages that allow distraction are also available. In our series, we have not observed deformation of the cages, even in recurrent tumors or delayed instrumentation failure. In contrast to fixation with MMA, cages do not need to be removed in the event of an infection (infection associated with MMA requires either its removal or lifelong antibiotic suppression therapy).

Appropriate sizing of the cage to the vertebrectomy defect is of paramount importance to avoid subsidence. Cages can be inserted from a posterior or (preferably) an anterior approach with certain geometric constraints depending on surgical exposure, ability to resect the thecal sac, and ability to sacrifice nerve roots (C1–3 and T2–10). Regardless of the graft of choice, the anterior spacer needs to be loaded and maintained in compression by rigid spinal instrumentation. A lateral (or anterior) approach allows placement of simultaneous anterior instrumentation, except in the lumbosacral and craniocevic juncions. Anterior instrumentation is very useful, especially in the correction of kyphotic deformities, and may allow a shorter construct compared with posterior approaches.

A simultaneous anterior–posterior, short-segment instrumentation in the thoracic spine was used in six patients in this study, with good results. Nevertheless, in one patient delayed junctional kyphosis developed that required revision. In that patient, a large area of chest wall resection and junctional and multilevel involvement led to progressive kyphosis that could have been prevented by the use of a longer construct. A similar anterior–posterior approach was previously described in 26 patients, with good results.

**Posterior Reconstruction.** With posterior reconstruction, screws (through the pedicles or lateral masses) are preferable to hooks. Hooks are useful in patients with osteoporosis and at the midthoracic region where the pedicles are small. Posterior constructs are under high stress at the proximal and the distal aspects, especially if they are used to address an existing kyphotic deformity. In those cases a solely posterior approach can be used, with reduction of the deformity by using the cross-rod bending technique. The construct should be well balanced in its proximal and distal ends and should be supported by an anterior spacer. One should avoid passing wires or hooks through the extreme kyphotic or lordotic portion of a deformity.

Posterior constructs can be placed in compression (to reduce kyphosis) or distraction (to produce kyphosis). They should not finish in segments in which there is tumor involvement, junctions (T-1 or L-1), spondylolisthesis, spinal stenosis, or otherwise significant degenerative changes. Excessive compression, poor bone quality, or excessive laminotomy may fracture the lamina, transverse processes, or pedicles. On the other hand, hooks, if not adequately placed in compression, may pull out, especially with flexion.

**Avoidance of Complication**

Surgery in patients with metastatic spine tumors is high risk and is associated with a significant number of complications. The most frequent complication is wound infection, which ranges from 0 to 45%. and is more prevalent in patients who have received prior radiotherapy and have undergone operation via a posterior approach. In those patients, the operation starts by planning the closure. Prophylactic vascularized flap coverage (trapezius, latissimus, superior gluteal, or paraspinal muscle flaps) should

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**Fig. 7.** Neuroimages obtained in a 68-year-old man with a history of hepatocellular carcinoma who presented with an L-1 pathological fracture after radiation therapy. Because of the limited (< 6-month) life expectancy for this patient, we elected to resect the tumor via a posterior approach (transpedicular vertebrectomy), followed by an anterior reconstruction with MMA. After the vertebrectomy, the discs adjacent to the defect were removed. Pedicle screws were placed above and below the vertebrectomy and distraction was applied. The vertebrectomy defect was then filled with MMA which was finally placed in compression by the posterior instrumentation. A and B: Preoperative MR images demonstrating tumor at L-1. C: Plain lateral x-ray film obtained after tumor resection and spine reconstruction.
be considered in radiation-treated wounds, especially if a CSF leak is present.\textsuperscript{8,9} Tension-free wound closure, coverage of hardware with vascularized muscle tissue, and adequate postoperative nutrition (with administration of total parenteral nutrition if needed) will minimize wound-related complications. Preoperative embolization, especially of renal carcinomas and sarcomas should be considered.\textsuperscript{18} Intraoperative monitoring of motor evoked potentials and somatosensory evoked potentials has the advantage of assessing both ventral and dorsal spinal cord function. Monitoring is recommended but not required in patients with significant spinal cord compression.

Intraoperative euvoemia and normotension is of paramount importance because blood loss can be challenging in certain cases. Imaging-based guidance can be helpful in placement of thoracic pedicle screws and for intraoperative navigation in sacral lesions.

**CONCLUSIONS**

Because of the highly individualized nature of spinal neoplasms, a multidisciplinary approach is recommended. A team consisting of a neurosurgeon and/or an orthopedic spine surgeon/radiation and medical oncologist, pain specialist, thoracic, and plastic surgeon is important for patient selection, tumor access, and ultimate avoidance of complications.

**References**


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