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The Diagnosis and Treatment of Metastatic Spinal Tumor

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Key Words. Spine metastases · Radiation therapy · Magnetic resonance imaging · Chemotherapy · Laminectomy · Posterolateral · Transcavitary · Transpedicular

ABSTRACT

Metastases to the spine represent a challenging problem in an oncology practice. Treatment decisions require multidisciplinary review. Radiation therapy remains the primary treatment for metastatic spinal tumor, but advances in radiation therapy, chemotherapy, and surgery have changed the roles of each and lead to improved patient outcomes. Regardless of the treatment, diagnosis and treatment before the development of significant neurologic and functional deficits improve outcomes. Physician awareness and appropriate imaging greatly assist in the early detection of tumor. The Oncologist 1999;4:459-469

INTRODUCTION

Metastases to the spine are a common problem in a large oncology center. Between 5% [1] and 10% [2] of all cancer patients develop spinal metastases during the course of their disease. Therapeutic intervention can alleviate pain, preserve or improve neurologic function, achieve mechanical stability, optimize local tumor control, and improve quality of life. Treatment options available for metastatic spine tumors include radiation therapy (RT), surgery, and chemotherapy. The appropriate treatment for an individual patient requires a multidisciplinary review including input from a medical oncologist, internist, radiologist, radiation oncologist, neurologist, and surgeon. RT is accepted as the first-line choice for most patients with metastatic spinal tumor, but surgical advances over the last 15 years have dramatically improved surgical outcomes for these patients. These advances include anterior transcavitary and posterolateral approaches to the spine and the application of anterior locking plates and posterior segmental spinal fixation. In the absence of prospectively randomized trials comparing radiation therapy with current surgical techniques, treatment decisions continue to be based predominantly on retrospective case series and institutional experience, but the indications and timing for each are becoming more clear.

PRESENTATION

Early diagnosis of metastatic spinal disease is important because functional outcome depends on neurologic condition at the time of presentation. Back pain, the most common presenting symptom in patients with metastatic tumor to the bone or epidural space, often precedes the development of other neurologic symptoms by weeks or months. Back pain may even begin years after the initial cancer diagnosis or may represent a new treatment-related tumor in the spine (e.g., post-radiation sarcoma). Two distinct types of back pain are encountered in patients with spinal tumors: tumor-related and mechanical. Tumor-related pain is predominantly nocturnal or early morning pain and generally improves with activity during the day. This pain may be caused by inflammatory mediators or tumor stretching the periosteum of the vertebral body [3]. Tumor-related pain generally responds to administration of low-dose steroids (e.g., decadron 12 mg daily). Definitive treatment of the underlying tumor with radiation or surgery often relieves this pain. Recurrence of pain following treatment may be a harbinger of locally recurrent tumor.

Mechanical pain results from a structural abnormality of the spine, such as a pathologic compression fracture resulting in instability. This pain is movement-related and may be exacerbated by sitting or standing which increases...
the axial load on the spine. Additionally, patients with tho-
racic or thoracolumbar compression fractures resulting in
ekypnosis may have severe pain in recumbence and often
give a history of sleeping upright in a chair for several
weeks. The presumed mechanism is extension of the unsta-
tble kypnosis. Mechanical pain does not typically respond to
steroids, but may be relieved with narcotics or an external
orthosis, pending definitive therapy. Pathologic thoracic
compression fractures often present with pain for a few
days, which resolves without bracing, unless the tumor
additionally involves the posterior spinal elements.

Neurologic symptoms and signs often begin with
radiculopathy (nerve root symptoms) and are followed by
myelopathy (spinal cord compression). Radiculopathy in
the cervical or lumbar spine causes pain or weakness in the
upper or lower extremity, respectively. In the thoracic
spine, radiculopathy occurs as a band-like pain at a seg-
mental level. Some patients develop a mechanical radicu-
lopathy resulting from instability and neuroforaminal
compression by tumor in the lumbar spine. This pain occurs
when bearing weight and is relieved by lying down. It is
often accompanied by mechanical back pain.

Myelopathy begins as hyperreflexia, a Babinski reflex
and clonus, but progresses to weakness, proprioceptive sen-
sory loss, and loss of pain and temperature below the lever
of the spinal cord compression. Autonomic dysfunction
may result from spinal cord compression or cauda equina
compression. Painless urinary retention suggests a neuro-
logic cause [4]. Isolated loss of bowel and bladder function
in the absence of motor or sensory symptoms most often
results from compression at the conus medullaris (tip of the
spinal cord at approximately L1) or sacral tumor. In other
segments of the spinal cord, loss of autonomic function is
frequently a late finding.

The evaluation of spinal patients should include a pain
assessment, quantitative neurologic score, and a general per-
formance score. Pain assessment can be most readily per-
formed with a visual analog scale which is familiar to many
cancer patients. The score can be converted to reflect mild
(0 to 4), moderate (5 to 6) and severe (7 to 10) pain [5]. The
two most commonly used neurologic scales include the
Frankel grading system [6] and the American Spinal Injury
Association (ASIA) score [7] (Table 1). Both assess motor
function with a score of “E” being normal and “A” being
complete paralysis. Performance status reflects ambulation,
medical comorbidities and extent of disease. A patient may
have normal motor strength, but be unable to ambulate
from loss of proprioception, fracture in the lower extremity,
poor nutritional status, poor pulmonary function and a vari-
ety of other symptoms. We have used the Eastern
Cooperative Oncology Group (ECOG) performance status
[8] as a functional assessment. It is important to include
both neurologic and performance status when reviewing
outcomes in cancer patients. Unfortunately, the majority of
papers reviewing the treatment of spinal metastases report
one or the other.

A correct and complete diagnosis of neurologic symp-
toms is necessary to give appropriate treatment. The presence
of spinal disease does not exclude the possibility of coexist-
ing disease in a similar distribution. For example, extremity
symptoms may result from infiltration or compression of the
brachial plexus, lumbosacral plexus, peripheral nerve, or a
peripheral neuropathy. Additionally, metastatic bone tumor
may mimic nerve root pain. Hip involvement from tumor or
vascular necrosis often presents as groin pain, suggesting an
L2 radiculopathy. Leptomeningeal tumor involving the spine
may result in radiculopathy or myelopathy with a similar pre-
sentation compared to epidural tumor compression. We have
seen two patients over the last year that presented with acute
myelopathy from leptomeningeal tumor without additional
epidural disease.

**IMAGING**

Advances in imaging have improved the sensitivity of
detecting spinal metastases and the specificity of differenti-
ating from other processes that involve the spine. Magnetic
resonance imaging (MRI) has revolutionized assessment
of metastatic spinal tumor, but many imaging modalities

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**Table 1. ASIA impairment scale**

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
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<tbody>
<tr>
<td>A</td>
<td>Complete: No motor or sensory function is preserved in the sacral segments S4-S5.</td>
</tr>
<tr>
<td>B</td>
<td>Incomplete: Sensory but not motor function is preserved below the neurological level and extends through the sacral segments S4-S5.</td>
</tr>
<tr>
<td>C</td>
<td>Incomplete: Motor function is preserved below the neurological level, and the majority of key muscles below the neurological level have a muscle grade less than 3.</td>
</tr>
<tr>
<td>D</td>
<td>Incomplete: Motor function is preserved below the neurological level, and the majority of key muscles below the neurological level have a muscle grade greater than 3.</td>
</tr>
<tr>
<td>E</td>
<td>Normal: Motor and sensory function is normal.</td>
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play a role in evaluating patients with metastatic spinal tumor including plain radiographs, bone scan, computerized tomography (CT) scan, myelogram, and positron emission tomography (PET). The goal of imaging is to be 100% sensitive and specific in identifying tumor, give precise anatomic detail, identify distant metastases, and show recurrent tumor following the placement of instrumentation. No single imaging modality accomplishes all of these goals, but understanding the advantages and disadvantages of different imaging modalities will assist the clinician in patient screening and treatment planning.

Plain radiographs are often ordered as the first test to evaluate a patient with cancer who has new onset of back pain, but are relatively poor screening tests for metastases. Visualization of a radiolucent defect on plain radiographs requires a 50% destruction of the vertebral body. Additionally, metastatic tumor may infiltrate the bone marrow of the vertebral body without destroying the cortical bone. Compression and burst fractures are readily identified. Plain radiographs can identify sagittal (kyphosis) and coronal (scoliosis) plane deformities in a weight-bearing state, whereas spinal deformities imaged in a supine position by MRI or CT scans may be reduced and thus remain undetected. Dynamic flexion and extension films may be used to detect instability, although they are rarely necessary in our experience and may put the patient at risk for progressive spinal cord injury. Following surgery, plain films are the best imaging modality for assessing spinal alignment and structural integrity of the instrumentation.

Bone scan (99mTc-MDP) is more sensitive than plain radiographs for detecting spinal metastases. The advantage of bone scan is the ability to screen the entire skeleton with a single image. Patients with spinal tumor often have other bone involvement that may be causing symptoms or require intervention. For example a patient with L2 vertebral body disease causing nerve root compression may have concomitant, symptomatic tumor in the pelvis, hip, or femur.

Bone scans rely on an osteoblastic reaction or bone deposition to detect spinal metastases [9]. Thus, patients with rapidly progressive, destructive tumors may not be detected [10]. Bone scan is relatively insensitive for multiple myeloma and tumors confined to the bone marrow [10]. It also has a low specificity for tumor. Fractures, degenerative disease, and benign disorders of the spine (Schmorl’s nodes, hemangiomia) all may be positive. Additionally, paraspinal tumors that enter the epidural space through the neuroforamina result in back pain, and progressive neurologic symptoms are often unseen on bone scan. In a review by Avrahami et al. [11], 21 out of 40 patients (52%) with previously diagnosed tumor and symptoms referable to the spine had a negative CT scan and bone scan; however, the MRI detected the presence of tumor. Frank et al. [12] reviewed a series of 95 patients in which 28% had a negative bone scan with MRI scan showing tumor and a discordance rate between the two imaging modalities of 31%.

Until MRI became widely available, myelogram and CT scan were the best diagnostic modalities for assessing acute spinal cord compression. Risks associated with myelography, including acute neurologic decompensation in patients with high grade blocks, have diminished its role [13, 14]. CT scan continues to be useful for assessing the degree of bone destruction and whether bone or tumor is causing the spinal cord compression. For patients who have had spinal reconstruction with placement of metallic instrumentation, including titanium, it is often difficult to obtain accurate images of the spinal canal with MRI [15, 16]. Myelography and postmyelogram CT images continue to be used for imaging these patients. Newer composite alloys such as carbon fiber will improve imaging with MRI, even further diminishing the role of myelogram.

MRI is the most sensitive and specific modality for imaging spinal metastases. Sagittal screening images of the entire spine reveal bone, epidural, and paraspinal tumor. The extent and degree of spinal cord compression can be readily appreciated [17]. Hybrid scans of the brachial or lumbosacral plexus may reveal tumor in patients with extremity weakness that is not entirely related to spinal cord or root involvement. Leptomeningeal metastasis is often well visualized, but requires the use of contrast agents (Gd-DPTA) [18].

Imaging sequences used to evaluate spinal metastases typically are T1- and T2-weighted. Tumor on a T1-weighted image is hypointense relative to the normal marrow signal (Fig. 1A). The ports from prior spinal radiation can be discerned on T1-weighted images as hyperintense signal change and may assist in making acute therapeutic decisions when radiation port films are not available. Tumor is hyperintense relative to marrow on standard T2-weighted imaging and produces a myelogram effect with cerebrospinal fluid appearing hyperintense (Fig. 1B). Unfortunately, using the recently developed, time-saving fast spin echo T2 techniques may decrease tumor conspicuity. This decreased conspicuity can be compensated using short tau inversion recovery (STIR) techniques. STIR images show enhanced contrast between the lipid marrow (hypointense) and tumor (hyperintense) [19-21] (Fig. 1C). STIR images may be the most sensitive screening modality for tumor, but give less anatomic detail than standard T1 or fast spin echo T2 images [22].

While MRI is an excellent screening tool for metastatic tumor to bone, differentiating tumor from osteomyelitis, osteoporotic compression fractures, and previously treated tumor may be difficult. The T1 and T2 signal characteristics are similar in all of these conditions. Osteomyelitis is more likely to cause changes in the end plate and disc space whereas tumor rarely, if ever, involves the disc space.
Based on these imaging characteristics, An et al. [23] differentiated with 97% accuracy osteomyelitis from tumor. Unfortunately, patients with tumor may secondarily become infected rendering the imaging patterns unreliable [24]. We have encountered six patients over the past four years with documented tumor in the lumbar or thoracic spine that were treated with RT for radiosensitive tumors. The patients had progressive pain post-RT and subsequent imaging showed vertebral body destruction, but no specific MRI evidence of infection. All patients underwent surgical procedures for instability and presumed progression of tumor and were subsequently shown to have infection.

Osteoporotic compression fractures are extremely common in a cancer population and have been differentiated from pathologic fractures with 94% accuracy based on T1-weighted imaging characteristics [25]. Osteoporotic fractures are more commonly thoracic, lack signal change or have band-like abnormality, and do not involve the pedicle or have contour abnormality. Pathologic fractures showed homogeneously decreased signal, convex vertebral contour, and involved the pedicles and lumbar location.

Response to RT or chemotherapy is difficult to assess in bone tumors because of the lack of signal change on MRI. Oncologists often rely on imaging changes to determine the efficacy of treatment. On T1-weighted images both treated and viable tumor appear hypointense relative to normal marrow signal. In a study of breast cancer patients, only 3% of patients had a reduction in the volume or number of vertebral bodies involved following treatment [26]. In a palliative situation, clinical response to therapy (resolution of tumor-related pain) may suffice despite the absence of radiographic change. Therapeutic decisions for some metastatic tumors (e.g., Ewing’s sarcoma, neuroblastoma, seminoma) rely on differentiating viable from necrotic tumor. MRI cannot reliably differentiate.

We and other authors [27] have begun to explore the use of 2-[F-18] fluoro-2-deoxy-D-glucose (FDG-PET) for differentiating osteoporotic from pathologic compression fractures, and the viability of previously treated tumor. Osteoporotic compression fractures greater than three days from the onset of symptoms are hypometabolic with a standardized uptake value (SUV) of less than 3. In general tumors have an SUV greater
weeks [36]. Over a two-year follow-up, the proportion of cancer were randomized to receive either 90 mg of pamidronate or placebo intravenously every three to four events, such as pathologic fractures. In a double-blind, mul-
pamidronate has been shown to reduce or delay skeletal is the most commonly used biphosphonate for cancer ment of malignancy-associated hypercalcemia. Pamidronate a subsequent diagnosis of non-Hodgkin’s lymphoma. We recently transferred a 14-year-old male to our institution with excruciating low back complications result from the higher doses [33]. In a case control series from a single institution, total side effects seen in the moderate and high-dose steroids were 8% and 29%, respectively. Complications from steroids include hyperglycemia, gastrointestinal hemorrhage, intestinal perforation, and avascular necro-
sis of the hip. Steroids are not required to prevent acute RT complications as they do for brain RT, and thus do not need to be given in patients undergoing RT for malignant spinal cord compression who are fully ambulatory. In a case series of 20 patients, all maintained ambulation without toxicity [34]. In a patient with an undiagnosed spinal mass, one must resist the temptation to deliver steroids prior to biopsy because of the oncolytic effect for certain tumors, such as lymphoma and thymoma [35]. We recently transferred a 14-year-old male to our institution with excruciating low back pain from a lumbar vertebral body and paraspinal mass who received a single dose of steroids for pain control prior to biopsy. Open biopsy showed necrosis only and treatment was delayed. One month later the patient developed a pathologic fracture dislocation of the dens requiring internal fixation with a subsequent diagnosis of non-Hodgkin’s lymphoma.

Biphosphonates are drugs that inhibit osteoclastic activ-
ity, suppress bone resorption, and are effective in the treat-
ment of malignancy-associated hypercalcemia. Pamidronate is the most commonly used biphosphonate for cancer patients. In combination with systemic antitumor therapy, pamidronate has been shown to reduce or delay skeletal events, such as pathologic fractures. In a double-blind, mult-
icenter, parallel group trial, 372 women with stage IV breast cancer were randomized to receive either 90 mg of pamidronate or placebo intravenously every three to four weeks [36]. Over a two-year follow-up, the proportion of patients who developed pathologic fractures or required RT or surgery was significantly less in the pamidronate-treated group. The median time to first skeletal event in the pamidronate-treated group and the placebo group was 13.9 months and 7 months, respectively. Benefit has also been seen in patients with multiple myeloma and osteolytic metas-
tases [37]. The most significant side effects are febrile reac-
tions, often in combination with myalgias and lymphopenia. Other side effects include transient neutropenia, thrombophlebitis, hypocalcemia, and rarely, ocular complications (uveitis) [38]. The high initial cost analysis of the drug may be justified by the substantial quality-adjusted survival benefit.

Antitumor chemotherapy has an important role in the treatment of chemosensitive tumors, such as neuroblastoma, Ewing’s sarcoma (PNET) [39], osteogenic sarcoma, germ cell tumors, and lymphoma. At our institution chemotherapy may be used as primary treatment for patients with these tumors even with epidural compression. Surgery and RT may be used as adjuncts for residual radiographic tumor.

RT
In the 1960s and 1970s, when numerous comparative studies showed no difference in outcome between patients undergoing external photon beam RT and laminectomy with out posterior segmental fixation, often in combination with RT, RT replaced laminectomy as first-line therapy [13, 40-56]. In these older series, approximately 75% of patients were nonambulatory at the time of presentation [57]. Patients undergoing RT alone showed a 79% rate of maintaining ambulation and a 42% rate of return to ambulation in paraparetic patients. Both ambulatory and nonambulatory patients had an approximate 21% risk of neurologic decompensation during RT. Patients undergoing laminectomy alone or with postoperative RT had a 48% to 67% rate of maintaining ambulation and a 33% rate of recovering ambulatory status in paraparetic patients. A range of 17% to 52% showed neuro-
logic decompensation following surgery with or without the addition of postradiation RT. The post-treatment morbidity was significantly less from RT than from surgery.

One of the sentinel studies shifting the emphasis from surgery to RT was a retrospective review of 235 patients by Gilbert et al. [44] in which analysis was based on the radiation sensitivity of the tumor and preoperative functional status. The overall rate of postoperative ambulation in the laminectomy and RT versus RT alone was 46% and 49%, respectively. Patients with radiosensitive tumors (breast, myeloma lymphoma) had better functional neurologic outcome compared to less radiosensitive tumors (lung, colon, renal cell), regardless of the treatment. Those patients ambulatory at the outset of treatment also had better outcomes compared to those paraparetic (nonambulatory) or paraplegic.
A more recent radiation study again confirms the utility of this modality for the treatment of spinal metastases [58]. Maranzano et al. conducted a prospective trial in which 275 patients were treated with RT for metastatic spinal cord compression over a six-year period with a median follow-up of 49 months. Patients who were endstage or who had strong surgical indications were excluded from analysis. Exclusions included the 25 patients who died during their course of RT because of their medical condition, tumor at a site other than their spine, or sequelae from prior systemic therapy. No patient died from treatment. An additional 20 patients (7%) underwent surgery as initial treatment for an unknown diagnosis, vertebral body collapse with bone impingement in the spinal canal, prior RT, or spinal instability.

All patients were treated to a total dose of 3,000 cGy using two different fractionation schedules. Patients were divided into radiosensitive (e.g., breast, prostate, lymphoproliferative) and radioinsensitive tumors (e.g., lung, renal, colon). The overall rate of maintaining or improving to ambulatory status and of improving sphincter control was 76% and 44%, respectively. Regardless of radiosensitivity of the tumor, patients who were functionally normal or with minor ambulation difficulties had a 94% rate of maintaining post-RT ambulation. In nonambulatory patients, the rate of return to ambulation post-RT was 60% and was heavily dependent on radiosensitivity of the tumor. The improved rates of maintaining ambulation compared to older studies may be reflective of excluding deaths and maintaining stringent surgical criteria for initial therapy.

The standard RT treatment for palliation of spinal metastases is daily 300 cGy fractions to a total dose of 3,000 cGy. Either a single posterior field or opposed fields are used to encompass the involved segment plus one to two levels above and below this involved region. Spinal cord or cauda equina tolerance to RT is the limiting factor in significantly raising the dose to greater levels to achieve higher rates of local control. Higher doses of RT place the patient at an increased risk for pathologic radiation myelopathy and functional spinal cord transection. Schiff et al. [59] reviewed the Mayo Clinic experience in patients with malignant spinal cord compression who either underwent reirradiation for locally recurrent tumor within the port or were treated for separate sites of disease but with overlapping ports. In 54 patients the median initial treatment dose was 3,000 cGy and the median total dose of radiation in the reirradiated segment was 5,425 cGy. All patients were ambulatory following the first course of RT, and 69% of patients remained ambulatory following the second course of RT at a median follow-up of 4.2 months. Pre-RT ambulation was a predictor of good outcome. Five patients became nonambulatory at 6.5 to 35 months. In this group four of the patients had documented spinal cord compression at the time of functional decompensation. The limited life expectancy of these patients may make it possible to reirradiate the spine with limited risk.

Advances in radiation delivery, patient immobilization, and dosing schemes may continue to improve outcomes either alone or in combination with surgery. These advances include intraoperative radiation therapy (IORT), three-dimensional conformal radiation therapy (3D-CRT), and intensity-modulated radiation therapy (IMRT). All three technologies provide a higher tumor dose of radiation with reduced damage to surrounding tissues and potentially smaller fields compared to conventional external beam techniques. IORT involves the delivery of a custom-designed electron beam or high-dose rate brachytherapy photon beam that precisely demarcates the tumor volume. Lead shields [60] and gold foil [61] have been used to shield the spinal cord. In a retrospective review by Seichi et al. [60], 37 patients underwent IORT with electron beams following surgical resection to a total dose of 2,000 cGy, a dose estimated by the authors to be biologically equivalent to 4,500 cGy of conventional fractionated external beam RT. Twenty-two patients also received fractionated external beam RT to a median dose of 3,400 cGy. One patient who was not shielded developed symptomatic radiation myelopathy. Local control was achieved in all patients at a median follow-up of 11 months.

3D-CRT is a method of irradiating a tumor volume with an array of x-ray beams that are individually shaped to conform to a 3D rendering of the target. Treatment planning considers dose inhomogeneities caused by the differing electron densities of various tissues and calculates the resulting dose distribution using sophisticated algorithms. The technology has been successfully employed in prostate cancer in which the dose-limiting factors are the adjacent bowel, rectum, and bladder.

IMRT represents an advanced form of 3D-CRT in which multileaf collimators are used to dynamically change the field shape during treatment, thus permitting the delivery of an inhomogeneous dose that conforms more tightly to the target region. Because of the precise dosimetry of both 3D-CRT and IMRT, accurate delivery of these complex plans requires reproducible patient setup and positioning. We are currently investigating the use of body frames and infrared camera systems to improve the accuracy of treatment delivery. In addition, internal organ motion is being evaluated by CT whose gantry is connected to the linac treatment couch. Such approaches may permit the delivery of a higher dose of radiation to a target tissue while maintaining the dose delivered to the spinal cord within an acceptable tolerance level. This may improve the clinical outcome of inoperable patients and those requiring a boost after surgical resection.
Surgery

The role of surgery in the treatment of spinal metastases is still being defined. Results using laminectomy as initial therapy either alone or with adjuvant radiation yielded relatively poor outcomes. Laminectomy does not provide exposure to resect lateral and anterior epidural or vertebral body tumor. Additionally, resection of the posterior elements without instrumentation often leads to progressive kyphosis and increased neurologic deficits.

Improved surgical outcomes have been seen using techniques that provide exposure for more radical tumor resection than laminectomy. Reconstruction following these aggressive approaches is now possible using rigid posterior segmental fixation and anterior instrumentation. These approaches include anterior, transcavitary [2, 3, 62-75] and posterolateral, transpedicular [63, 68, 70, 71, 76-81]. The decision to use a particular surgical approach is dependent on the location of the bone, epidural, and paraspinal tumor, type of reconstruction required, patient comorbidities, extent of disease, and surgeon’s familiarity.

Anterior transcavitary approaches may be used to address tumors in any spinal segment. The particular approach depends on the level of spine involved. For example, the high thoracic spine (T1 to T3) can be addressed through a median sternotomy or trap door approach [82], midthoracic spine (T4 to T10) through a standard thoracotomy, and the low thoracic spine (T11 to T12) via a thoracoabdominal approach. In terms of tumor resection, anterior transcavitary approaches address anterior paraspinal tumor, vertebral body tumor, and anterior or unilateral epidural tumor on the side of the approach.

Reconstruction is most often achieved using methylmethacrylate and Steinmann pins, autologous bone graft, or cages with the addition of an anterior locking plate, such as a Z-plate (Danek; Memphis, TN). An anterior approach may be followed by a laminectomy or posterolateral approach for maximal tumor resection and circumferential fusion [80].

The posterolateral approach is used mainly to resect tumor in the thoracic and lumbar spine (Figs. 2A, B). The posterior midline incision and lamina resection are identical to a laminectomy. Additional bone including the pedicle and facet joint are then removed to provide a relatively wide exposure to the vertebral body. Epidural and vertebral body tumor can then be piecemeal resected. Reconstruction is most often achieved with long posterior segmental fixation and may be augmented with an anterior strut, generally with methylmethacrylate and Steinmann pins. The posterolateral approach may be indicated in patients with three-column involvement, multilevel vertebral body or epidural tumor, vertebral body tumor with bilateral or circumferential epidural spinal cord compression, or major spinal deformity. Additionally, some cancer patients who require vertebrectomy or circumferential decompression and fusion may be poor candidates for an anterior approach due to poor pulmonary function, concurrent medical illness, previous surgery, previous RT, and/or unresectable, anterior paraspinal tumor or scar.

Results using these techniques have improved surgical outcomes compared to laminectomy alone or in combination with RT. Resection of the tumor and spinal fixation have resulted in dramatic improvements for both tumor-related pain and mechanical back pain. Multiple series reporting pain outcomes have shown a 76% to 100% improvement [2, 3, 62, 68-71, 73-80]. Neurologic outcomes are similar using both anterior and posterolateral approaches. Functional and neurologic improvements have been seen in 50% to 76% of patients. Additionally, patients who were operated on without a deficit (in our system ASIA E, ECOG 0) maintained function in greater than 95% of

Figure 2. A, B) Postoperative plain radiographs showing reconstruction of a posterolateral approach with anterior methylmethacrylate and Steinmann pins and posterior segmental fixation using pedicle screws and sublaminar hooks.
cases. Patients with minor or no neurologic deficits (ASIA D or E) represent up to 81% of patients in some recent series [3]. This percentage of ambulatory patients is substantially greater than the previously reported radiation literature. This may represent a selection bias on candidates for operation or the improved ability to screen patients with MRI.

As with RT, factors that impact on outcome include preoperative neurologic and functional status and favorable tumor histology. Klekamp and Samii [68] reviewed 101 patients who underwent operation for metastatic spinal tumor prior to receiving adjuvant therapy (RT or chemotherapy) for their spinal tumor. The operations included posterolateral (79%), anterior transcavitary (12%), and anterior and posterior approach (9%). Ninety-six percent of patients who were ambulatory preoperatively maintained the ability for at least three months, while only 22% of patients nonambulatory regained ambulation for the same duration. This maintenance or recovery of function is similar to the RT data presented by Maranzano [58]. Additionally, 89% of patients maintained continence for three months, but only 31% regained autonomic function. Patients with favorable tumor histology (e.g., breast, kidney, thyroid, prostate) had significantly better neurologic outcome and survival than those with unfavorable histologies (lung, gastrointestinal tract, and unknown primary). As has been seen in other studies [73], local recurrence rates are significant. In this study 58% recurred after six months, 69% at one year, and 96% after four years. Factors predictive of low recurrence rates included preoperative ambulatory status, favorable tumor histology, cervical level, low number of affected vertebral bodies, complete resection, and elective surgery.

Review of multiple series shows complication rates from surgery ranging from 10% to 52% [2, 3, 62-78]. Complications include medical issues such as deep venous thrombosis, myocardial infarct, and pneumonia. Surgical complications include failed fixation requiring revision and postoperative hematoma. Wound dehiscence and infection are complications seen predominantly with posterolateral approaches in up to 15% of cases. We have found that trapezius or latissimus dorsi rotation flaps provide excellent soft tissue coverage and markedly reduces the morbidity from this complication. Mortality rates are as high as 13%. Frequently these are related to the medical or oncologic condition of the patients.

As with RT, advances in surgical technique may help improve the quality of life for patients with metastatic spinal tumor. Preoperative embolization for vascular tumors (e.g., renal cell, papillary thyroid carcinoma, leiomyosarcoma) dramatically reduces operative blood loss [83, 84]. In our series of 25 patients operated via a posterolateral approach with circumferential instrumentation, there was no significant difference in blood loss between embolized tumors (i.e., renal, thyroid, angiosarcoma) and those not requiring embolization, 1,900 ml and 1,620 ml, respectively.

"En bloc" spondylectomy was recently described by Tomita [85]. This technique is based on sound oncologic principles. The intent of this surgery is en bloc resection of the tumor with negative histologic margins. This surgery is feasible as a one- [85] or two-stage procedure [86-88] but is technically quite demanding. Results with this approach are encouraging, both in terms of functional outcome and local control; however, we reserve this approach for patients in whom the spine surgery is being performed as a curative, rather than palliative procedure. Based on anatomic considerations, the majority of patients with metastatic tumor are not candidates for this type of surgery because of the extensive epidural disease, multilevel vertebral body involvement, and large paraspinal masses.

Thoracoscopic vertebral body resection for tumor has been reported in a small series [89, 90]. This relatively noninvasive approach has proven useful for removing anterior thoracic discs and anterior releases for scoliosis corrections. The potential use for most tumors requiring resection is probably limited. We currently reserve this technique for biopsies in patients who have failed CT-guided biopsies.

At our institution RT is first-line for most patients who present with metastatic spinal tumor. Surgery is reserved for a variety of indications (Table 2). Patients with radioresistant tumors (e.g., sarcoma, renal cell carcinoma), spinal instability, and/or a pathologic fracture with bone in the spinal canal are considered for surgery prior to RT. Additionally, patients with circumferential epidural tumor that is moderately to highly radio-resistant are more likely to worsen during RT when compared to other patterns of

### Table 2. Surgical indications

<table>
<thead>
<tr>
<th>Primary Surgery</th>
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<tbody>
<tr>
<td>▲ Radioresistant tumors (e.g. sarcoma, renal cell carcinoma).</td>
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<tr>
<td>▲ Spinal instability.</td>
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<tr>
<td>▲ Pathologic fracture with bone in the spinal canal.</td>
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<tr>
<td>▲ Circumferential epidural tumor.</td>
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<tr>
<td>Moderate to highly radio-resistant tumors (e.g. colon, lung).</td>
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<td>▲ Occult primary tumor.</td>
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<tr>
<th>Post-treatment (RT/chemotherapy) surgery</th>
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<tbody>
<tr>
<td>▲ Progressive neurologic symptoms.</td>
</tr>
<tr>
<td>▲ Progression of tumor with high grade spinal cord compression.</td>
</tr>
<tr>
<td>▲ Spinal instability.</td>
</tr>
<tr>
<td>▲ Rule out residual tumor post RT/chemotherapy.</td>
</tr>
<tr>
<td>(e.g. Ewing’s sarcoma, osteogenic sarcoma, germ cell tumor).</td>
</tr>
</tbody>
</table>

All patients should be assessed medically and for extent of disease by a medical internist and treating oncologist.
References


69 Kostuik JP. Anterior spinal cord decompression for lesions of the thoracic and lumbar spine, techniques, new methods of internal fixation results. Spine 1983;8:512-531.


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