The modern concept of surgery for spinal metastasis involves radical excision with the primary goal of local cure and secondary goals of alleviating pain, preserving neurological status, and stabilizing the spine. The surgical approach that best accomplishes these goals remains uncertain. Anterior and lateral approaches directed at the site of primary tumor encroachment on neural elements have achieved good results, superseding those of laminectomy alone; however, they may not be ideal in all situations. These procedures require entering either the thorax or the retroperitoneum in which concomitant parenchymal pulmonary or retroperitoneal disease may make surgery more risky and damage to viscera more likely. Such approaches may not achieve complete removal of tumor or adequate stabilization if the posterior elements are disrupted by tumor infiltration, a situation that may necessitate a second, posterior operation. Posterolateral vertebral body resection combined with stabilization avoids some of the pitfalls of anterior and lateral procedures while providing adequate circumferential decompression of the neural elements. The few surgeons who use the posterolateral approach have achieved good success. This technique represents a useful alternative to other commonly used surgical approaches for the treatment of spinal metastases, and it should aid surgeons in selecting the optimum approach for individual patients.

**Key Words** • spinal metastasis • posterolateral approach • vertebrectomy • spinal instrumentation

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**Single-stage posterior vertebrectomy and replacement combined with posterior instrumentation for spinal metastasis**

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The authors present a series of 25 patients who underwent single-stage complete spondylectomy, vertebral body reconstruction, and posterolateral vertebrectomy for malignant metastatic disease involving multiple columns of the thoracolumbar spine. Patients were selected for this approach primarily because they were poor candidates for a transcavitary or lateral extracavitary approach or because the tumor involved both anterior and posterior columns of the spine. The operative approach used combines radical local resection of tumor via a bilateral transpedicular route, methylmethacrylate vertebral body reconstruction, and Luque rectangle stabilization in a single operation. Following surgery, the majority of patients experienced improvement in their neurological status, reduction in pain, or both. Most patients were functionally improved, or at least no worse, and spinal alignment was maintained in all. There was one local recurrence in a long-term survivor. Complications included cerebrospinal fluid fistulas, migrating graft material, and wound healing problems. The authors conclude that this surgical approach is safe and feasible for the radical resection of vertebral metastasis when combined with reconstruction and stabilization. This technique represents a useful alternative to other commonly used surgical approaches for the treatment of spinal metastases, and it should aid surgeons in selecting the optimum approach for individual patients.

**Key Words** • spinal metastasis • posterolateral approach • vertebrectomy • spinal instrumentation

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**Clinical Material and Methods**

**Patient Population**

From 1989 to 1995, 110 patients underwent surgery for spinal metastasis via a variety of posterior approaches at the M. D. Anderson Cancer Center. Treatment consisted of laminectomy alone or in conjunction with posterior instrumentation in 34 cases, laminectomy and partial vertebrectomy via a posterior approach in 11 cases, and subtotal posterior vertebrectomy and posterior instrumentation without vertebral reconstruction in 31 cases. Surgery in
nine cases combined a lateral transcavitary approach with posterior instrumentation. Twenty-five patients were treated with a single-stage operation combining a near-complete (> 90%) single- or multi-level spondylectomy, vertebral body replacement using methylmethacrylate (MMA), and posterior fixation; these 25 patients were selected for further analysis and form the basis for this report. An additional 44 patients underwent anterior (two patients), lateral transcavitary (40 patients), or lateral extracavitary (two patients) approaches to thoracolumbar spinal tumors and were not considered further.

We reviewed the patients’ charts to collect data on their gender and age, type of primary neoplasm, spinal levels involved with tumor, pre- and postoperative pain and neurological status, and administration of adjunctive therapies. Thirteen of the 25 patients were men; the patients’ average age at the time of surgery was 53.8 ± 2.6 years (mean ± standard error of the mean). Although most patients had metasteses at other sites, their disease was believed to be stable at the time of surgery and patients were offered this surgery only if they had a life expectancy that exceeded 3 months.

Because rigid selection criteria are difficult to develop for patients undergoing resection of spinal metastasis, treatment plans for such patients at the M. D. Anderson Cancer Center are highly individualized. These 25 patients were chosen to undergo a posterolateral approach for one or more fundamental reasons. First, the medical condition of many patients precluded placing a large incision on the chest or abdomen and a second posterior incision for spinal instrumentation. It was believed that using such an approach in these patients might result in undue postoperative morbidity and an excessive hospital stay. Patients with preexisting pulmonary, mediastinal, or retroperitoneal disease and the resultant functional compromise of these systems were also considered for a posterolateral approach. Second, when patients had significant tumor posterior to the pedicles, that is, three-column spinal involvement, we considered a posterolateral approach because tumor resection and stabilization could be performed in a single operation. Other situations favoring the use of a posterolateral approach included involvement of two or more spinal levels or involvement at two discontinuous levels. In many patients, multiple factors led to the surgeon’s choice of a posterolateral approach. Because tumor resection and stabilization could be performed in a single operation. Other situations favoring the use of a posterolateral approach included involvement of two or more spinal levels or involvement at two discontinuous levels. In many patients, multiple factors led to the surgeon’s choice of a posterolateral approach.

The patients’ neoplasms had varied origins (Table 1) and affected various vertebral levels. Tumors in all of the patients were malignant. Lung and kidney accounted for the primary tumor in over half of the cases (13 of 25 cases), and three patients had primary sarcomas arising in...
the soft tissues. The spinal levels involved ranged from T1–L3, with a majority of tumors involving the midthoracic region. Eight patients had metastases involving more than one level; in three of these, the tumors involved three contiguous levels (Fig. 1) and in one, the disease involved two noncontiguous levels (T-2 and T-7). In that patient, the tumor at T-7 was treated in the same manner as other tumors in this series and the tumor at T-2 was treated with partial vertebral resection and posterior instrumentation during the same surgical session as the T-7 lesion. In the four other patients the tumors were in two adjacent vertebrae. Twelve patients had received prior radiation therapy without chemotherapy and another eight had received both local radiation therapy and chemotherapy before surgery. Three patients received postoperative radiation therapy after allowing a sufficient time for wound healing.

Preoperative magnetic resonance (MR) imaging or computerized tomography (CT) scanning revealed that all patients had at least two-column spinal involvement (Figs. 1 and 2). Tumor in the middle column affected one (17 patients) or both (eight patients) pedicles and commonly spread into adjacent posterior elements such as the facet joints, laminae, and even spinous processes. In all patients, more than 80% of the vertebral body was involved by tumor, which occasionally extended minimally into the posterior paravertebral space. Extension into major body cavities was limited in this group of patients because such extension precluded the single-stage posterolateral approach.

All patients were examined by several physicians both pre- and postoperatively with respect to the extent and severity of their pain and neurological deficits (Table 2). All patients presented with some back or neck pain, either mechanical or radicular in nature; it was a major part of the overall symptom complex in all but two patients. Seven patients presented with pain only. Eighteen patients experienced pain in conjunction with neurological deficits or signs of spinal cord compression. Neurological compromise ranged from subtle signs of spinal cord or root compression to nearly complete paraplegia. Only one patient was completely paraplegic prior to surgery, which was the result of a rapid decline in strength over the imme-
diately preceding 24 hours. No patient undergoing this procedure had complete paraplegia lasting more than 24 hours.

The patients’ functional status was graded retrospectively on a four-tiered scale: independent (ambulatory without assistance), ambulatory with assistance (braces or walker), confined to a wheelchair, or bedridden. Thirteen patients were ambulatory prior to surgery, seven of whom

<table>
<thead>
<tr>
<th>Site of Origin</th>
<th>No. of Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>lung</td>
<td>8</td>
</tr>
<tr>
<td>kidney</td>
<td>5</td>
</tr>
<tr>
<td>breast</td>
<td>4</td>
</tr>
<tr>
<td>soft tissue (sarcoma)</td>
<td>3</td>
</tr>
<tr>
<td>head &amp; neck</td>
<td>3</td>
</tr>
<tr>
<td>cervix</td>
<td>1</td>
</tr>
<tr>
<td>unknown</td>
<td>1</td>
</tr>
</tbody>
</table>

TABLE 1
Origins of primary neoplasms in 25 patients undergoing posterolateral resection and posterior instrumentation

Fig. 2. Representative radiographs obtained in a 55-year-old man with metastatic renal cell carcinoma in T-10. This patient presented with pain, paraparesis and sensory changes and was ambulating independently. His pain and paraparesis improved postoperatively and he remained functionally independent. A: Plain anteroposterior (AP) x-ray film through the T-10 level demonstrating destruction of the left T-10 pedicle and early partial collapse of the T-10 vertebral body (VB). B: Sagittal T1-weighted magnetic resonance (MR) images of the thoracic spine revealing infiltration of the T-10 VB with extension through the left pedicle into the posterior elements. C: Axial T1-weighted MR image through T-10 confirming the involvement of all three spinal columns at that level. D: Postoperative postmyelogram computerized tomography scan through T-10 clearly showing the thecal sac without extrinsic compression and the extent of VB replacement with methylmethacrylate. E and F: Postoperative plain AP (E) and lateral (F) x-ray films demonstrating spinal reconstruction and stabilization.
### TABLE 2

Clinical and pathological findings in 25 patients undergoing posterolateral resection and spinal reconstruction*

<table>
<thead>
<tr>
<th>Age (yrs), Sex</th>
<th>Pathology</th>
<th>Level</th>
<th>Preop Neurological Status</th>
<th>Preop Functional Status†</th>
<th>Postop Neurological Status</th>
<th>Postop Functional Status</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>62, M</td>
<td>adenocarcinoma</td>
<td>T2–3</td>
<td>pain, paresis, &amp; sensory loss</td>
<td>pain &amp; paresis improved</td>
<td>III—III</td>
<td>large posterior paraspinal component</td>
<td></td>
</tr>
<tr>
<td>43, F</td>
<td>ductal carcinoma</td>
<td>T4–5</td>
<td>pain, paresis, &amp; sensory loss</td>
<td>pain &amp; paresis improved</td>
<td>III—II</td>
<td>CSF leak managed with reinforcement</td>
<td></td>
</tr>
<tr>
<td>69, M</td>
<td>adenocarcinoma</td>
<td>L-2</td>
<td>pain only</td>
<td>pain resolved</td>
<td>III—II</td>
<td>neurologically normal at last exam</td>
<td></td>
</tr>
<tr>
<td>27, F</td>
<td>squamous cell carcinoma</td>
<td>L-1</td>
<td>pain, paresis, &amp; sphincter dysfunctions</td>
<td>pain &amp; paresis improved, residual</td>
<td>I—I</td>
<td>wound infection &amp; dehiscence 14 days after surgery requiring debridement &amp; secondary closure</td>
<td></td>
</tr>
<tr>
<td>40, F</td>
<td>ductal carcinoma</td>
<td>T-11</td>
<td>pain only</td>
<td>pain improved, neurologically intact</td>
<td>IV—II</td>
<td>Steinman pin migrated 19 days after surgery requiring thoracotomy</td>
<td></td>
</tr>
<tr>
<td>57, F</td>
<td>ductal carcinoma</td>
<td>T-7</td>
<td>pain &amp; paresis</td>
<td>pain improved, paresis &amp; myelopathy unchanged</td>
<td>IV—II</td>
<td>severe paresis at last exam</td>
<td></td>
</tr>
<tr>
<td>31, M</td>
<td>neurofibrosarcoma</td>
<td>T-11</td>
<td>pain, paresis, &amp; myelopathy</td>
<td>pain resolved, dense paresis with myelopathy</td>
<td>III—III</td>
<td>TSRH hooks used with bone fusion; prior hemipelvectomy</td>
<td></td>
</tr>
<tr>
<td>63, M</td>
<td>squamous cell carcinoma</td>
<td>L-3</td>
<td>pain, paresis, &amp; myelopathy</td>
<td>pain &amp; paresis improved</td>
<td>IV—IV</td>
<td>sacral &amp; rib metastasis prevented further improvement</td>
<td></td>
</tr>
<tr>
<td>43, F</td>
<td>adenocarcinoma</td>
<td>T-7</td>
<td>pain, paresis, &amp; myelopathy</td>
<td>pain improved, paresis &amp; myelopathy unchanged</td>
<td>III—III</td>
<td>no comment</td>
<td></td>
</tr>
<tr>
<td>69, F</td>
<td>ductal carcinoma</td>
<td>T-12</td>
<td>pain &amp; myelopathy</td>
<td>pain improved, myelopathy unchanged</td>
<td>IV—IV</td>
<td>additional spine metastasis at T-2, T-9, L-1, &amp; sacrum</td>
<td></td>
</tr>
<tr>
<td>62, F</td>
<td>small cell carcinoma</td>
<td>L-2</td>
<td>pain, paresis, &amp; myelopathy</td>
<td>pain resolved, neurologically intact</td>
<td>I—I</td>
<td>cauda equina syndrome from retropulsion of MMA graft 5 wks postop, required posterior revision; neurological deficits resolved</td>
<td></td>
</tr>
<tr>
<td>37, M</td>
<td>teratocarcinoma</td>
<td>T-4</td>
<td>paraplegia</td>
<td>severe paresis</td>
<td>IV—IV</td>
<td>no comment</td>
<td></td>
</tr>
<tr>
<td>67, F</td>
<td>sarcoma</td>
<td>L-1</td>
<td>pain only</td>
<td>pain significantly improved</td>
<td>IV—II</td>
<td>wound required reinforcement for CSF leak</td>
<td></td>
</tr>
<tr>
<td>44, M</td>
<td>sarcoma</td>
<td>C7–T1</td>
<td>pain, paresis, &amp; myelopathy</td>
<td>unchanged</td>
<td>II—II</td>
<td>no comment</td>
<td></td>
</tr>
<tr>
<td>55, M</td>
<td>clear cell carcinoma</td>
<td>T-10</td>
<td>pain, paresis, &amp; myelopathy</td>
<td>pain &amp; paresis improved</td>
<td>I—I</td>
<td>recurrence of paresis at last exam, remains independent</td>
<td></td>
</tr>
<tr>
<td>26, F</td>
<td>adenocarcinoma</td>
<td>T-9</td>
<td>pain &amp; sensory changes</td>
<td>pain improved</td>
<td>I—I</td>
<td>spinal cord compression from retropulsion of MMA graft removed via thoracotomy with resulting residual paresis</td>
<td></td>
</tr>
<tr>
<td>48, F</td>
<td>adenocarcinoma</td>
<td>T2–4</td>
<td>pain, paresis, &amp; myelopathy</td>
<td>pain &amp; paresis improved</td>
<td>IV—IV</td>
<td>CSF leak &amp; poorly healing wound treated with reexploration &amp; repair of dural laceration at T-3 root sleeve</td>
<td></td>
</tr>
<tr>
<td>66, M</td>
<td>adenocarcinoma</td>
<td>T-1</td>
<td>pain &amp; upper-extremity pain &amp; neurological status unchanged</td>
<td>II—II</td>
<td>paresis &amp; myelopathy from slipped MMA graft that was removed, weakness</td>
<td>strat placed via anterior approach; residual paresis &amp; central cord syndrome</td>
<td></td>
</tr>
<tr>
<td>20, F</td>
<td>clear cell carcinoma</td>
<td>T-7‡</td>
<td>myelopathy only</td>
<td>unchanged</td>
<td>I—I</td>
<td>wound dehiscence without infection treated conservatively</td>
<td></td>
</tr>
<tr>
<td>43, M</td>
<td>clear cell carcinoma</td>
<td>T-4</td>
<td>pain only</td>
<td>minimal improvement in pain</td>
<td>I—I</td>
<td>continued improvement in pain</td>
<td></td>
</tr>
<tr>
<td>65, F</td>
<td>adenocarcinoma</td>
<td>T-10</td>
<td>pain, paresis, &amp; myelopathy</td>
<td>pain, paresis, &amp; myelopathy improved</td>
<td>II—II</td>
<td>back pain &amp; paresis 4 mos postop with myelographic block; refused further surgery; pain managed medically</td>
<td></td>
</tr>
<tr>
<td>58, M</td>
<td>clear cell carcinoma</td>
<td>T-5</td>
<td>pain only</td>
<td>pain improved</td>
<td>II—II</td>
<td>no comment</td>
<td></td>
</tr>
</tbody>
</table>

* CSF = cerebrospinal fluid; MMA = methylmethacrylate; TSRH = Texas Scottish Rite Hospital spinal instrumentation system.
† Functional Grades: I = independently ambulatory; II = ambulatory with devices; III = wheelchair bound; IV = bedridden.
‡ ... at T-2 treated with partial vertebrectomy and posterior instrumentation during the same operation as the T-7 lesion.
Posterolateral resection of vertebral metastasis

Operative Technique

All patients underwent identical surgical resection and reconstruction with the goal of completely resecting the tumor and stabilizing the spine. The operation begins with the patient in the prone position supported by standard positioning systems and padding. A posterior midline skin incision centered on the affected level(s) is made long enough to expose at least two levels above and below the tumor. The surgeon uses sharp dissection around posterior tumor masses, taking particular care to keep the dissection outside them, and performs a complete laminectomy of the affected segments. He then removes the superior and inferior facets and costovertebral joints of the affected levels, using a combination of rongeurs and curettes or a high-speed air drill. Schematic representation of the operative approach in the axial perspective is shown in Fig. 3. The posterior and lateral epidural tumor is then removed on itself once the core has been removed. When the pedicles can be safely removed to gain access to the vertebral body. A gentle curetting action is used to remove the tumor-laden pedicle from inside outward, collapsing it on itself when tumor involvement is as extensive as that found in this group of patients. A very thin rim of noninfiltrated bone is left at the circumference of the vertebral body both to provide a mold into which the MMA can later be placed and to prevent damage to mediastinal or retroperitoneal structures. Great care is taken to keep the dissection within the vertebral body and not to extend it into the chest or retroperitoneal cavity.

When multiple levels are involved, the intervening disc material is removed. Disc material adjoining the affected segments is also removed to allow proper mating of graft material to the bone surface. The final portion of the vertebrectomy usually involves applying reverse-angle (Epstein) curettes to the remaining ridge of bone just anterior to the thecal sac at the midline. This bone fragment and the overlying posterior longitudinal ligament often contain occult remnants of tumor and must be resected carefully, yet completely, to prevent local tumor recurrence. Complete circumferential decompression of the thecal sac and thus of the spinal cord is obtained. One can clearly inspect the anterior thecal sac for residual tumor or compression through the cavity that has been created. Hemostasis is obtained by bipolar cauterization of soft tissues and placement of a combination of Gelfoam and Avitene within the resection cavity.

Once the spondylectomy has been completed, preparation is made for reconstruction and fixation. Steinman pins are cut to an appropriate length and inserted at right angles to the endplates into the intact, tumor-free vertebral bodies adjacent to the resection cavity. If space within the cavity allows, a right-angle bend is placed into the free end of the pins prior to insertion, leaving them with a “hockey stick” appearance. The pins are cut so that they span the resection cavity and overlap each other. Experience has shown that the optimum diameter for the pins is 9/64 in. The pins are pushed into the adjoining vertebral body until a 1.5- to 2-cm portion protrudes into the resection cavity. For a one-level vertebrectomy, a pin length of 4 cm is appropriate. For two- or three-level removals, pins 1 to 2 cm longer are chosen because they provide a more stable pin placement across two adjacent vertebrae. Occasionally, a thoracic nerve root on one side may be divided distal to the ganglion to simplify proper pin placement.

were independent. Five patients were confined to a wheelchair and seven patients were bedridden owing to severe pain, neurological deficits, or both.

FIG. 3. Schematic representations showing the operative approach in the axial perspective. A: Anatomical relationships between the tumor and spinal structures prior to resection. The vertebral body is almost completely replaced by tumor that extends through the left pedicle and into the posterior perispinal space. The arrows show the bilateral trajectory used for tumor resection and spinal cord decompression. B: The posterior elements and pedicles have been removed bilaterally, allowing bilateral decompression of the spinal cord. It can be seen that complete circumferential decompression of the spinal cord can be performed using this technique. C: Anatomical relationships following spinal reconstruction. The anteriorly placed methylmethacrylate graft and the posterior instrumentation can be seen in this view. There is ample space for the spinal cord and it remains completely decompressed. Adapted from Shaw, et al.31
In most patients, posterior fixation is performed using Luque rectangles (Zimmer, Warsaw, IN) and sublaminar cables (Songer cables; Danek, Inc., Memphis, TN). The rectangle is chosen to span the distance extending from at least two segments above to at least two segments below the affected levels. The spinous processes within the span of the rectangle are removed. Similarly, at each interlaminar space, a small midline laminotomy is made to expose the epidural space for subsequent passing of the cables. The rectangle is bent with a gentle curve to fit the spine, or it may be left flat to correct minimally the abnormal flexion created by a collapsed vertebral body. At each intact laminar arch spanned by the rectangle, the cables are passed under the laminae as a pair, cut, and brought around each side of the rectangle. The cables are tightened to 18 ft/lb and cut with the instrument supplied. Cables at the upper and lower segments of the attachment should be crossed to prevent slippage around the smooth corners of the rectangle, which would result in a loss of full fixation. In the first patient in this series, Luque rods rather than a rectangle were inserted and in another patient who presented early in the series, stabilization was achieved using Harrington rods. We now prefer the rectangle because it provides greater rotational stability than the rods.10 Two of our early patients underwent posterior spinal fixation using the Texas Scottish Rite Hospital (TSRH) spinal instrumentation system (Zimmer), which provided a claw-hook construction with cross-links at two levels above and two levels below the affected segments. For one of these patients, as well as the patient in whom Harrington rods were placed, posteriorly placed bone grafts were added to the MMA vertebral body reconstruction.

After inspecting the posterior construct for rigidity, the surgeon turns to reconstruction. Fast-curing MMA in semiliquid form is mixed and placed in the resection cavity, starting from the deepest portion and moving to the most superficial in a single motion. It is important that the acrylic should cure in a single block and contain no discontinuities. Otherwise the block may not be held firmly by the pins and slippage of the acrylic may occur, resulting in spinal cord compression. The area is irrigated copiously with cool saline, and Penfield dissectors or tongue blades are used to keep the semisolid acrylic away from the dura until it has completely cured. Once the acrylic plug has hardened completely, it is tested for rigidity and lack of perceptible movement on manipulation. If the plug does not harden in a single mass or if the cured plug moves perceptibly, the acrylic must be drilled away and a new plug placed. Following this, the wound is irrigated and closed with nonabsorbable sutures in the posterior thoracolumbar fascia.

Postoperative care emphasizes early patient mobilization and liberal use of inflatable antiembolism stockings. Most patients require narcotic analgesia at a stable dose for 2 to 3 days, tapering slowly over 7 to 10 days. Spine x-ray films are obtained postoperatively for use as a baseline against which future studies can be compared and to assess alignment of the spine and implanted hardware. Patients are routinely fitted with a thoracolumbosacral orthosis. Those patients with upper thoracic (interscapular) incisions are encouraged to wear a figure-eight sling to prevent excessive stress on the incision and subsequent dehiscence. Patients are allowed to ambulate when their pain has subsided enough to allow movement, generally within the first 4 days postoperatively.

Results

At the time of review, 22 patients (88%) had died. Three patients were alive with extraspinal metastatic disease. The mean length of survival of those who had died was 29.5 ± 8.2 weeks following surgery. For the three patients alive at the time of review, the mean follow-up period was 38.8 ± 24.0 weeks. Nine patients (36%) were alive 6 months after surgery and three (12%) were alive at 1 year. The average postoperative hospital stay for all patients was 15.4 ± 2.8 days, including days spent in the inpatient rehabilitation unit. No patient exhibited progressive kyphotic or scoliotic angulation of the spine. One patient developed a local recurrence of the tumor requiring reoperation.

After surgery, the majority of patients experienced full or partial relief of their pain and improved neurological status (Table 2). All seven patients with pain as their sole symptom experienced improvement postoperatively; six of the seven patients had either complete resolution or significant improvement in pain. Of the 18 patients with a neurological deficit, 10 showed improvement in both pain and neurological status after surgery. One patient suffered a recurrence of back pain months after surgery following an initial period of improvement, but his neurological status remained stable. Another patient developed renewed interscapular pain 18 months after surgery; this led to the discovery of recurrent tumor. Seven of the 18 patients were neurologically unchanged, and one was worse after surgery. However, in five of these eight patients, pain had resolved or improved and, overall, 20 of 25 patients had less pain after surgery.

The functional status of all patients was improved or unchanged after surgery. Six patients improved at least one functional grade postoperatively. Three patients who were bedridden prior to surgery (due to severe pain) were able to ambulate with assistance postoperatively, representing a two-grade improvement. In the largest group (19 patients), however, functional status was unchanged postoperatively. No patients experienced a decline in their functional grade as a result of the surgery.

Nine patients survived more than 6 months and could be evaluated for long-term stability and neurological status. The mean follow-up review for these patients was 14.7 ± 4.5 months. Tumor recurred in one patient approximately 18 months after the initial resection. He required reoperation, repeat resection, and revision of the posterior instrumentation. Three patients showed continued improvement in their pain at last follow-up review with no change in their neurological status, whereas two patients showed worse paresis at last follow-up contact. One patient was unchanged; the status of three is unknown due to incomplete documentation in their charts.

There was no 30-day operative mortality and no deaths related to neurological causes have occurred at any time. Thirteen complications occurred in 12 patients (Table 3). The single most common complication, persistent cerebrospinal fluid leakage from the wound, occurred in four patients, all of whom had previously received radiation.
Posterolateral resection of vertebral metastasis

therapy. The leakage was treated initially with lumbar drainage alone in two patients. The treatment stopped the leak in one patient who required no further specific therapy; the other patient required reexploration and direct repair of a small dural tear at the axilla of the T-3 nerve root. In two patients, reinforcement of the wound without external cerebrospinal fluid diversion was sufficient to stop drainage from the wound.

The most serious complications were related to migration of part or all of the material used for reconstruction. These complications presented at a variety of postoperative times (range 14 days–7 weeks; mean 29.3 ± 8.0 days). Four patients suffered from migrating graft material, either the MMA graft itself (three patients) or a Steinman pin (one patient). All four patients required reoperation for this problem. In one patient with migrating MMA, a thoracotomy was performed to remove the graft and replace it with a fibular strut. In another patient, the graft was removed and revised through the original posterior incision. For the third patient, we used an anterior approach to T-1 to remove and rebuild the MMA graft. In the last patient, we performed a thoracotomy to retrieve the migrated pin and remove the MMA, which was replaced by a fibular allograft.

Other postoperative complications included three nonhealing wounds, two of which were treated with debridement and closure. The third was treated conservatively with frequent dressing changes. Two of these patients had received radiation therapy prior to their wound healing problems. There were no deep wound infections involving the graft or hardware that required reoperation for removal. One patient suffered a painful thoracic radiculopathy, which started 5 weeks after surgery, but imaging studies could not determine an exact cause. She was treated medically with good success. One patient presented to the hospital 4 months postoperatively with an acute paraparesis and myellographic block. That patient refused further surgical therapy, was treated medically, and died less than 1 month later.

Discussion

Choice of Operative Approach and Technique

Transcavitary or lateral extracavitary surgical approaches may not be tolerated by all patients; some may fare better with a posterior or posterolateral approach. A number of authors have described techniques for resecting spinal metastasis that do not require a transcavitary approach. A more limited, unilateral transpedicular technique without reconstruction or stabilization has been advocated for debilitated patients with spinal metastasis. The patients in this study were considered poor candidates for a lateral operation because of their physical condition, the tumor’s location, or both; thus a posterolateral approach for the removal of the metastasis and the associated reconstruction was applied. We have evaluated the ability of this technique to provide complete resection of spinal metastases while palliating pain and preserving neurological function and spinal alignment.

Complete removal of all parts of one or more vertebrae above the sacrum (“spondylectomy”) has been performed both for primary malignant tumors of the spine and for metastatic spine tumors with no undue morbidity. In this report, a select group of patients underwent a single-stage spondylectomy via a posterolateral approach. Although a thin rim of normal bone is usually left anteriorly for previously noted technical reasons, this resection represents a high-grade (> 90%) removal of the vertebral body and all of the posterior elements. This approach has been criticized for producing inadequate decompression of neural structures and incomplete resection of tumor. We were able to achieve not only excellent visibility of the ventral and ventrolateral thecal sac following vertebral body resection, but also complete circumferential decompression. This series demonstrates low recurrence rates and a lack of precipitous or significant neurological decline after surgery using this approach, which would not be expected if inadequate tumor removal and decompression were characteristic. The current report adds to the literature, demonstrating the feasibility and safety of the posterolateral approach for vertebrectomy, and comprises one of the largest published series of patients undergoing complete spondylectomy for spinal metastasis.

Radical excision of spinal tumors using almost any approach produces further spinal instability that must be corrected at the time of resection. The first system widely used in conjunction with posterolateral decompression was the Harrington rod system, a variety of devices, such as the Luque rod and rectangle and the Cotrel–Dubousset and TSRH systems, have been used since then to stabilize the spine. With few exceptions, all patients in this report underwent posterior spinal stabilization using a Luque rectangle secured with sublaminar cables. In experimental tests of several spinal instrumentation constructs, the Luque rectangle and sublaminar wire configuration has been shown to be one of the strongest posterior constructs available and to be particularly resistant to torsional motion, although it suffers from the lack of a distraction force, such as that found in the TSRH system, and has less stability than combined anterior and posterior constructs. Methyl methacrylate has been used extensively to augment posterior instrumentation constructs or to reconstruct the vertebral body. In our patients, the posterior instrumentation was augmented by anterior vertebral body reconstruction using MMA, a procedure we believe protects the integrity of the posterior instrumentation and creates a more stable construct overall. This belief is supported by the finding that no progressive spinal deformity due to posterior instrumentation failure was observed in this series, as has been the case when

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TABLE 3

Complications in a group of 25 patients who underwent posterolateral vertebrectomy and reconstruction

<table>
<thead>
<tr>
<th>Complication</th>
<th>No. of Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>cerebrospinal fluid fistulas</td>
<td>4</td>
</tr>
<tr>
<td>migrating graft or hardware</td>
<td>4</td>
</tr>
<tr>
<td>wound healing problems</td>
<td>3</td>
</tr>
<tr>
<td>persistent radicular pain</td>
<td>1</td>
</tr>
<tr>
<td>acute paraparesis with myelographic block</td>
<td>1</td>
</tr>
</tbody>
</table>
Anterior reconstruction has not been performed. In fact, the need for anterior reconstruction after radical resection of vertebral body tumors has been emphasized by several authors.\(^1\)\(^4\)\(^5\)\(^6\)

Anterior reconstruction is not completely without risk, however, as the graft has the potential for dislodgment. Graft dislodgement is probably related to poor mating of the MMA with the vertebral bone and improper seating of the Steinman pins in adjacent vertebral bodies free of tumor. Indeed, incidence of graft slippage has been reduced in later patients in this series by the absolute requirements of secure placement of the Steinman pins into tumor-free bone and no demonstrable movement of the graft upon final curing. When patients’ grafts did slip, no permanent neurological damage occurred. We therefore believe that the benefits of performing anterior reconstruction to prevent failure of the posterior instrumentation outweigh the potential risks of graft dislodgment.

**Comparison With Other Studies**

Series of patients treated with posterolateral transpedicular resection and posterior stabilization have previously been reported.\(^2\)\(^9\)\(^16\)\(^18\)\(^21\)\(^23\)\(^24\)\(^31\) However, our series of patients differs in a number of important ways (Table 4). All previous studies comprised mixtures of patients who either had a variety of tumor types (such as primary vs. metastatic, tumors of reticuloendothelial origin vs. tumors of solid organs)\(^9\)\(^21\) or who underwent a variety of surgical techniques\(^4\)\(^8\)\(^18\)\(^21\) and spinal fixation methods.\(^2\)\(^9\)\(^21\)\(^31\) Complete and radical resection, and hence vertebrectomy, was not uniformly performed in all patients in these studies and not distinguished from subtotal or partial resections performed through unilateral apertures into the vertebral space. The goal of some authors was neural decompression alone,\(^2\)\(^5\) whereas others attempted complete resection in only a fraction of their patients.\(^2\)\(^9\)\(^16\)\(^18\)\(^21\)\(^23\)\(^24\) Reconstruction of the spine ranged in extent from none at all to bone grafting to complete reconstruction with MMA. Bridwell, \textit{et al.},\(^2\)\(^1\) did not perform vertebral reconstruction in any of their patients. They applied posterior augmentation of the instrumentation with MMA, stating that anterior reconstruction was not necessary to maintain spinal alignment in their patients. A variety of posterior instrumentation methods were also used by the surgeons in these studies, but they were not uniformly applied to all patients.

All patients in our series underwent complete vertebrectomy, vertebral reconstruction, and posterior instrumentation. As such, they are most comparable to the few patients in other studies who underwent the most radical resection of tumor and the most complete reconstruction and stabilization. As can be seen from Table 4, the current series represents the only study in which a uniform operative method (with only minor deviations) was applied to a large number of patients with spinal metastasis. In fact, our series contains the largest number of patients who universally underwent radical resection, vertebral body reconstruction, and instrumentation for spinal metastasis; it therefore adds significantly to the studies of patients described in the literature who have undergone such combined procedures.

Despite differences between operative techniques, the overall outcomes of our study and others are similar. Several authors have demonstrated improvement, predominantly in pain management, but also in neurological function, in a majority of patients and functional improvement in many.\(^2\)\(^9\)\(^16\)\(^23\)\(^31\) We, too, noted improvement in pain and neurological status in many of our patients. Spinal alignment was maintained and local recurrence was minimal. Heller, \textit{et al.},\(^16\) reported two of 33 patients with recurrent tumors following this procedure. Bridwell, \textit{et al.},\(^2\) discussed treating three of their patients with recurrent tumors via an anterior approach; retrospectively they thought that a more radical resection might have been possible at the time of initial posterolateral surgery. We attempted complete and radical resection in all patients in this series, resulting in only one recurrence 18 months after the initial resection. Although no statistical comparisons can accurately be made, approaching these tumors with radical resection in mind may have contributed to the low recurrence rate in our series.

Despite our aggressive surgical approach, morbidity

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**TABLE 4**

Studies involving posterolateral transpedicular decompression and stabilization in a single stage for treatment of spinal metastasis

<table>
<thead>
<tr>
<th>Authors &amp; Year</th>
<th>No. of Patients</th>
<th>Total Graft*</th>
<th>Anterior Instrumentation</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Faccioli, et al., 1985</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>Heller, et al., 1986</td>
<td>33</td>
<td>0</td>
<td>0</td>
<td>33</td>
</tr>
<tr>
<td>Lesoin, et al., 1986</td>
<td>11</td>
<td>UK</td>
<td>0</td>
<td>11</td>
</tr>
<tr>
<td>Lozes, et al., 1987</td>
<td>15</td>
<td>9</td>
<td>15</td>
<td>12</td>
</tr>
<tr>
<td>Bridwell, et al., 1988</td>
<td>25</td>
<td>UK</td>
<td>0</td>
<td>UK</td>
</tr>
<tr>
<td>Magerl &amp; Coscia, 1988</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Johnston, et al., 1989</td>
<td>34</td>
<td>9</td>
<td>8</td>
<td>34</td>
</tr>
<tr>
<td>Shaw, et al., 1989</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>Akeyson &amp; McCutcheon, 1996 (current report)</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
</tr>
</tbody>
</table>

* MMA = methylmethacrylate; UK = unknown.  
† These authors supplemented the posterolateral transpedicular approach with a costotransversectomy.
Posterolateral resection of vertebral metastasis

and mortality in our series were no greater than those specified in reports by others using similar surgical techniques. There was no postoperative (30-day) mortality in this series although a mortality rate of 11% to 16% has been reported with this technique.\textsuperscript{9,18,31} Much of the reported mortality was the result of deep venous thrombosis or pulmonary embolism. The low incidence of these conditions in this series may be the result of aggressive postoperative mobilization and the use of inflatable antiembolism stockings as described in the operative technique section. Our overall complication rate of approximately 50% is in keeping with that of previously published reports.\textsuperscript{2,9,16,18} In addition, the 12% rate for wound healing problems in our series is no higher than previously published statistics of 12% to 24%.\textsuperscript{2,16,18} and none of our patients suffered a deep infection that required revision of posterior hardware, which has also been reported.\textsuperscript{18} We have shown that aggressive surgical removal of spinal metastasis via the posterolateral approach carries an acceptable degree of morbidity and mortality and that even debilitated patients can fare well with a radical posterior operation, a view not shared by all authors.\textsuperscript{50}

Postoperative Surveillance

Although accurate views of the preoperative extent of these tumors are possible with MR imaging, postoperative follow up and surveillance are less easily performed. Plain x-ray films show the position and integrity of both the MMA and the posterior instrumentation construct. On CT scanning, and especially on MR imaging, the ferromagnetic artifact caused by the Luque rectangle and cables often profoundly obscures the details of the anatomical outline and signal intensity on which the diagnosis of residual or recurrent tumor relies. We rely on myelography to confirm extradural compression in patients who develop new neurological pathology, but confirmation of the presence of tumor can sometimes be achieved only by CT scanning. Recently developed instrumentation systems and cables composed of titanium alloy produce a more discrete signal void on MR imaging, and improve the clarity of postoperative imaging. Indeed, these systems have been used in patients with spinal metastasis treated recently at our institution with the expected results. However, they are not included here to retain the uniformity of the operative method.

Conclusions

Surgical techniques for treating spinal metastasis are varied. We have applied one technique, combining radical posterior vertebrectomy, vertebral reconstruction, and posterior instrumentation, for a series of 25 patients who were deemed candidates for this approach. The results and outcomes are comparable to those of previous studies using less radical techniques, and the complications are acceptable given the locally extensive nature of the tumors and the suboptimal medical condition of some patients. Although it is difficult to state whether a more radical surgical approach significantly prolongs the patients’ survival, the functional quality of survival is good and rates of recurrence are low with this particular surgical approach. The merits of this approach for appropriate patients include efficacy and safety, direct and radical removal of tumor involving two or three columns, and complete reconstruction of the spine performed in a single operation through a single incision. This report confirms and supplements the data of others on the technical feasibility and outcome of this approach and suggests that it is an appropriate part of the menu from which optimum surgical approaches for individual patients are selected. Further studies are underway to determine if a similar, but more restricted operation without vertebral body reconstruction produces similar results in patients with less extensive spinal disease.

References


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