Treatment of neoplastic epidural cord compression by vertebral body resection and stabilization

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The results of treatment of neoplastic spinal cord compression by vertebral body resection and immediate stabilization in 101 consecutive patients over a 5-year period have been analyzed. Sites of primary cancer included the lung (25 patients), kidney (15 patients), breast (14 patients), connective tissue (12 patients), and a variety of others (35 patients). Of the 101 patients, 23 received surgery de novo; the remaining 78 patients had undergone previous therapy. Sites of involvement included the cervical region in 13 patients, the thoracic region in 68 patients, and the lumbar region in 20 patients. Prior to surgery, severe pain was noted in 90% of the patients, and 45% were non-ambulatory. Using an anterolateral surgical exposure, the vertebral body was resected along with all epidural tumor. Immediate stabilization was achieved with methyl methacrylate and Steinmann pins. Following surgery, the overall ambulation rate was 78%, and 85% of patients experienced pain relief. Of the 23 patients who had received no prior therapy, 90% continued to be ambulatory at their last follow-up examination or until death. The authors believe that surgery prior to irradiation is indicated in selected patients with neoplastic cord compression. In patients with solitary osseous metastasis to the spine, potentially curative resection can be undertaken if surgery is performed when the tumor is still confined to the vertebral body.

KEY WORDS • vertebral body resection • spine stabilization • metastatic tumor • spinal cord compression • surgery

Compression of the spinal cord by metastases to the axial skeleton represents a major cause of morbidity in cancer patients. Several different mechanisms are implicated in the pathogenesis of neoplastic epidural cord compression; they include hematogenous metastasis to the vertebral body, direct extension from a paravertebral tumor mass, spread along the perineurium of the spinal nerves, or direct extension through the intervertebral foramina by lymphatic permeation.2,4 Virtually all neoplasms may thus involve the spine, but the most frequent primary sites are those from the breast, lung, prostate, and hematopoietic system. These four sources account for up to two-thirds of all cases of spinal metastases in most series.5,10,14,18,34,37,38,40 The propensity for some solid tumors to metastasize selectively to bones is termed "osteotropism." Although the basic mechanisms for osteotropism are not clearly understood, a clearer understanding of this phenomenon may provide the rationale for the design of selective therapy to prevent such metastases.3

Spinal metastases may complicate any stage of the cancer patient's illness, although involvement of the spine with resulting compression of the cord frequently heralds the first sign of malignancy.38,41 Clinically, most patients describe the illness as beginning with progressive neck or back pain. If diagnosed accurately and treated promptly at this stage, symptomatic relief with arrest of further destruction of the spine is possible.21,23,47 Emphasis has therefore shifted to an attempt to diagnose early epidural extension of tumor by myelography when neurological signs are still minimal or absent.19,33 Despite this, the overall results of treatment are still unsatisfactory; only half of patients with spinal metastases are presently diagnosed while still ambulatory, and 10% become severely paraparetic or deteriorate to complete paraplegia either before or following treatment.20,46

The role and timing of surgery in the management of neoplastic cord compression remains controversial, although reports of most surgical series indicate varying degrees of pain relief and improvement of neurological
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function. The classical approach to the treatment of spinal cord compression is decompressive laminectomy, usually with postoperative external radiation therapy (RT). While laminectomy is clearly indicated in compressive lesions located lateral or posterior to the spinal cord, this approach frequently fails to relieve neurological deficits or the block seen myelographically in patients with ventral defects secondary to collapsed vertebrae or tumor. Further instability may result and may aggravate the neurological deficit, especially if the vertebral body is extensively destroyed by tumor. With rare exceptions, most published series fail to show any superiority of combined-modality treatment (surgery plus RT) when compared to RT alone.

Although RT and corticosteroid therapy are indicated for palliation in patients with widespread metastases, many other patients present with localized disease involving the spine, or with radiosensitive tumors that are not significantly benefited by RT alone. Even in cases with relatively radiosensitive solid tumors, between 10% and 30% of patients have associated structural changes in the spine that cannot be effectively treated by RT. Others who deteriorate within a few months after being successfully treated with RT may demonstrate progressive collapse of the vertebral body, indicating segmental instability as a cause of recurring pain and weakness. The restoration and maintenance of stability represent an important goal of therapy in these subgroups, and one that can only be successfully accomplished by surgery.

Bailey and Badgley are credited with the first report in 1960 of successful removal of a tumor involving a cervical vertebra; following tumor resection, stability was ensured with a bone graft. Although autologous bone grafts are useful in selected patients because they provide physiological fusion, immediate stability is more easily restored with the use of a fast-setting acrylic compound such as polymethyl methacrylate. The advantage of methyl methacrylate is that patients can be allowed to walk early and do not require prolonged use of rigid external orthoses. Methyl methacrylate was originally used by Charnley in 1957 for replacement arthroplasty of the hip and, in 1959, Knight used it for stabilization of the cervical spine in benign conditions. In 1967, Scoville, et al., described a technique for vertebral body replacement with methyl methacrylate in a patient with lymphoma involving the cervical spinal cord. Although their patient died of pneumonia in the perioperative period, no adverse effect on the spinal cord was noted at autopsy. Since that time, numerous reports in the literature have been published describing the use of methyl methacrylate for tumors involving the spine and analyzing its physical properties and interaction with bone. Most of these reports describe approaches to the cervical segments, which are easily accessible through a standard Cloward approach. Lesions involving the thoracic or lumbar spine require more extensive exposures for anterior spinal surgery. Although the initial surgical efforts at anterior spinal surgery were focused on Potts’ disease, similar principles apply to cancer patients. We present an analysis of 101 consecutive cases of neoplastic epidural cord compression treated by vertebral body resection and tumor excision, followed by immediate stabilization with methyl methacrylate. This series represents a 5-year experience, a portion of which has been previously reported.

Summary of Cases

Clinical Material

We reviewed the records of all patients who underwent vertebral body resection and stabilization between January, 1979, and February, 1984, at Memorial Sloan-Kettering Cancer Center. Fifty-two patients were male and 49 were female; their ages ranged from 9 to 80 years (median 51 years). The sites of primary cancer are given in Table 1. Indications for vertebral body resection in these patients were as follows: 1) a pathological compression fracture as presenting feature of malignancy; 2) a solitary site of relapse; 3) destruction of the spine secondary to paraspinal tumor; 4) a radioresistant melanoma, sarcoma, or tumor of the kidney; 5) structural abnormalities of the spine (collapsed vertebral subluxation, or localized kyphosis); and 6) segmental instability following RT.

Nine patients had primary osseous tumors of the spine. In the remaining 92 patients, the spine was involved by tumor extension or metastasis from tumors arising elsewhere. In 24 patients, compression of the spinal cord resulted from direct extension of a paravertebral mass; in 68 patients, tumor extended into the epidural space from hematogenously disseminated metastases to the vertebral body. The period from diagnosis of the primary cancer to onset of spinal metastasis was extremely variable. In 43 patients, invasion of the spine was the presenting symptom of malignancy; in the others, spinal cord compression occurred several years after the diagnosis of the primary lesion.
months to 10 years following diagnosis and treatment of the original cancer.

The initial symptom of spine involvement was severe unrelenting pain in the neck or back in 90 (90%) of the 101 patients. Of these, 42 patients had back pain only and 48 had a radicular component in addition to the back pain. The remaining 11 patients did not consider their pain of any significance. The duration of pain prior to the development of neurological deficit varied from 6 weeks to 3 months. In Table 2, the neurological deficits prior to surgery are listed; patients were classified into two major groups, ambulatory (55 patients) and non-ambulatory (46 patients), since this was used as the major endpoint for evaluating treatment. Paraparetic patients were classified into three grades: mild, those who could move their legs in bed against gravity; moderate, those who could move their legs but had no anti-gravity strength; and severe, those who could just contract one or several leg muscles. Neurological evaluations were performed after full-dose corticosteroid therapy since most patients had been under prior treatment for spinal metastases or had been treated prior to neurosurgical evaluation.

Radiological evaluation included plain x-ray films, myelography, and computerized tomography (CT) scans in the majority of cases. Tumor involved a single vertebral body in 56 patients, two adjacent vertebrae in 34 patients, three vertebrae in 10 patients, and four vertebrae in one patient. Sites of involvement included the cervical segments in 13 patients, the thoracic region in 68 patients, and the lumbar region in 20 patients. Destruction or collapse of the vertebral body was apparent on plain radiography or demonstrated by CT scans in the majority of patients; in addition, an anterolateral paravertebral tumor mass was seen in 37 patients, and localized collapse with retropropulsion of a bone fragment was noted in 16. Myelography revealed high-grade (more than 80%) or complete block in 69 patients, and varying degrees of epidural encroachment in 26 patients; myelograms were normal in six cases.

Prior to surgery, 78 patients had received various forms of treatment for their spinal metastasis. Fifty-one patients had received a full course of RT and had relapsed following treatment; in 12 patients both surgical decompression and RT had failed; eight had undergone only surgery; and seven others had had their RT course interrupted by surgery. Of the 20 patients who underwent surgery, 16 had laminectomy and four

<table>
<thead>
<tr>
<th>TABLE 2</th>
<th>Neurological deficit prior to surgery</th>
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<tr>
<td>Neurological Deficit</td>
<td>No. of Cases</td>
</tr>
<tr>
<td>ambulatory patients</td>
<td>55</td>
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<tr>
<td>no deficit</td>
<td>23</td>
</tr>
<tr>
<td>radicular deficit or plexopathy</td>
<td>32</td>
</tr>
<tr>
<td>non-ambulatory patients</td>
<td>46</td>
</tr>
<tr>
<td>radicular deficit</td>
<td>4</td>
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<tr>
<td>cauda equina compression</td>
<td>9</td>
</tr>
<tr>
<td>mild paraparesis</td>
<td>12</td>
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<tr>
<td>moderate paraparesis</td>
<td>12</td>
</tr>
<tr>
<td>severe paraparesis</td>
<td>9</td>
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<tr>
<th>TABLE 3</th>
<th>Classification of anterior surgical approaches</th>
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<tr>
<td>Vertebral Segments</td>
<td>Surgical Approach</td>
</tr>
<tr>
<td>cervical &amp; cervicothoracic (C1-T2)</td>
<td>transmandibular median glossotomy</td>
</tr>
<tr>
<td>Cloward anterior cervical transfenral</td>
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<tr>
<td>thoracic (T3-12)</td>
<td>posterolateral thoracotomy</td>
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<tr>
<td>thoracolumbar (T12-L2)</td>
<td>thoracolumbar with 10-12th rib resection</td>
</tr>
<tr>
<td>lumbar (L2-5)</td>
<td>retroperitoneal flank transabdominal</td>
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</tbody>
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had anterior decompression or limited removal of paravertebral tumor. Excluding the nine patients with primary bone tumors, the extent of systemic disease was evaluated in 92 patients. Thirty-seven patients (40%) had disease limited to the spine; 24 (26%) had other sites of osseous involvement; and 31 (34%) had evidence of pulmonary and/or other visceral metastases.

Surgical Techniques

The surgical approaches used for the different levels of the spinal segments are shown in Table 3. Since most patients (80%) underwent a thoracotomy or a thoracoabdominal procedure, this exposure is described in detail. All operations are performed under general endotracheal anesthesia with the patients positioned in the lateral position on an Olympus beanbag. The choice of side for surgery is based on the radiological findings of a paravertebral tumor mass if one is evident. Otherwise, the right side is usually chosen for chest surgery, while the left side is chosen for the thoracoabdominal and lower lumbar approaches.

A standard posterolateral thoracotomy is performed, with the skin incision centered over the interspace above the level of spinal cord compression. For the lower thoracic segments (T9-12), two interspaces above the level of involvement are selected for entering the chest. Although rib resections have been suggested for extensive exposure, we prefer to resect only the posterior 4 to 5 cm of the rib to facilitate closure (Fig. 1). The resected segment of rib is preserved for possible later use as a bone graft to augment the fusion. Self-retaining thoracic retractors are placed, and the thoracic cage is gradually opened. A specially designed malleable retractor (Hurson) is useful at this stage of the procedure. The visceral pleura is then reflected as shown, and intact discs above and below the involved segments are isolated (Fig. 2). Intercostal vessels are carefully coagulated with the bipolar current and clipped. The intervertebral discs are first removed with curettes and pituitary rongeurs. The vertebral bodies are thus isolated and removed with sharp curettes and rongeurs. All devitalized bone and tumor is removed down to the dura. In patients who have not received prior therapy, gross total tumor resection is easily accomplished. In those who have received RT previously, the posterior longitudinal ligament is often tenaciously adherent to the dura and may be relatively difficult to remove. By tracing the tumor backward and removing the lateral masses, it is possible to decompress the dura circumferentially. The anterior longitudinal ligament is usually left intact if it is not involved by tumor. Removal of the vertebral body is generally subtotal for metastatic tumors, and a shell of bone is usually left on the opposite side. The dura is covered with Gelfoam for protection. Steinmann pins varying in diameter from 1 to 5 mm are then selected and appropriate lengths cut. They are bent at either end in the shape of hockey sticks, and introduced into the vertebral bodies above and below, with the aid of two heavy needle-holders (Fig. 3 left). After the introduction of the Steinmann pins, which straddle the healthy vertebral bodies above and below the resected body or bodies, methyl methacrylate is molded away from the Gelfoam-covered dura using curved Penfield dissectors. During the heat of polymerization, copious saline irrigation is used to dissipate heat. Hemostasis is then secured with bipolar cautery, but no attempt is made to pack the epidural space tightly or create a loculated space where blood or fluid may be trapped. Chest tubes are inserted, and the thoracotomy incision is closed in routine fashion.
Postoperative care is generally that of a standard thoracotomy procedure. Patients are allowed to ambulate within 48 to 72 hours, and a Knight-Taylor brace is generally used for patient comfort. In the thoracolumbar region, a variety of surgical approaches including resection of the 10th, 11th, or 12th ribs may be chosen. For lesions involving the lower lumbar segments, a retroperitoneal flank approach is used. For surgery at the L-5 vertebra, a transabdominal procedure by laparotomy provides the best exposure. Broad-spectrum antibiotics are routinely used intraoperatively and for 72 hours postoperatively. In patients who have not received prior therapy, RT may be commenced a week after surgery. Fluoromyelography is usually carried out to evaluate clearing of the myelographic block, and spinal alignment is checked on regular x-ray films.

Operative Results

Three parameters were evaluated following surgery: improvement in neurological function; relief of pain; and stability of the molded acrylic on plain radiography. Of the 32 ambulatory patients who had radicular deficits or plexopathy, 22 (69%) had postoperative restoration of normal motor strength in the involved extremity. Of the 46 non-ambulatory patients, 32 (70%) were considered improved. Improvement in non-ambulatory function was defined as the restoration of ambulation (with or without support) at the time of discharge from the hospital. Surgical therapy was considered to have failed if the patient demonstrated partial neurological improvement in motor function without the ability to walk, showed improvement in sensory modalities only, or improved to the point of ambulation but died of complications while still in the hospital.

Improvement in neurological grade paralleled the preoperative neurological deficit (Table 4). In some patients with brachial plexus infiltration, a portion of the plexus was deliberately sectioned to allow resection of the tumor. With that exception, no patient experienced increased neurological deficits following surgery. In the entire series, 78 patients (78%) left the hospital ambulatory. Assessment of pain relief was subjective and was not documented by specific parameters such as decreased requirement for narcotics. Most patients continued to receive narcotic medication, and many had received steroid therapy before and after surgical treatment. In such patients the precise role of surgery in alleviating pain was difficult to evaluate; nevertheless, we consider that 85% of patients with significant back or radicular pain had relief following the procedure. Since an effort was made in these patients to identify the source of pain and to document immediately after surgery and stabilization whether the pain was relieved, we believe these results are valid. Postoperative radiography showed clearing of the myelographic block in almost all patients in whom it was performed, and a

<table>
<thead>
<tr>
<th>Neurological Deficit</th>
<th>No. of Cases</th>
<th>Improved No.</th>
<th>Percent</th>
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<tr>
<td>ambulatory patients</td>
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<tr>
<td>radicular deficit or plexopathy</td>
<td>32</td>
<td>22</td>
<td>69</td>
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<td>non-ambulatory patients</td>
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<tr>
<td>radicular deficit</td>
<td>4</td>
<td>4</td>
<td>100</td>
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<td>cauda equina compression</td>
<td>12</td>
<td>10</td>
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<td>8</td>
<td>67</td>
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<td>moderate paraparesis</td>
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<tr>
<td>severe paraparesis</td>
<td>9</td>
<td>3</td>
<td>33</td>
</tr>
<tr>
<td>total cases</td>
<td>46</td>
<td>32</td>
<td>70</td>
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</table>

TABLE 4
Postoperative improvement in neurological deficit

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FIG. 6. Left: Myelogram showing an almost complete spinal block. Right: Computerized tomography scan in the same patient discloses complete destruction of vertebral body by metastatic hypernephroma.

solid stable surgical construct was noted on plain x-ray films. In four patients, especially during the earlier phase of our experience, both the decompression and (as a result) the stabilization were technically inadequate. In five patients, methyl methacrylate fixation failed during the follow-up period. Three of these were known to have had additional posterior instability due to previous laminectomy or tumor involvement of the posterior elements; in one case the Steinmann pin used for fixation fractured as a result of kyphosis, and in another the esophagus was perforated by a dislodged Steinmann pin. As a result, we have electively chosen to perform posterior stabilization in 10% of the patients in this series, either with Harrington or Luque rods, in junctional segments such as the cervicothoracic and thoracolumbar junctions.

Eight deaths occurred during the 30-day period following surgery. One patient with chronic obstructive pulmonary disease died of respiratory failure; three died of gastrointestinal hemorrhage resulting from stress ulcers; one died of a pulmonary embolus; and three patients died of sepsis from postoperative pneumonia. An additional 10% of the patients developed surgical complications. Four patients developed wound dehiscences, two of which required reclosure; two patients developed pneumonia, of whom one required prolonged ventilatory support; and two patients suffered myocardial infarctions, but recovered uneventfully. In one patient with a postoperative iliopelvic thrombosis, bleeding occurred into the retroperitoneal space when heparin therapy was instituted. One patient required reexploration because of inadequate decompression at their first surgery.

The follow-up period ranged from 10 months to 4 years. Ninety-three patients (93%) have been followed for a minimum period of 1 year or until death. At time of analysis, 18 patients are still alive, 16 of whom remain ambulatory. The actuarial median survival time was 8 months, and 37% of the patients lived more than 1 year. The patient with the longest survival time is currently free of disease 4 years after surgery. The difference in survival times between those patients who left the hospital ambulatory and those who were paraparetic was statistically significant ($p < 0.01$) using the Wilcoxon test. This difference was still apparent if one considers only those patients with disease localized to the spine or those whose condition was otherwise stable. All but one of the non-ambulatory patients died within 6 months.

Discussion

This series describes a major surgical effort to improve upon the poor results of treatment of neoplastic cord compression that have been reported following laminectomy. In our view, both proper patient selection and choice of surgical approach based on the anatomic site of compression within the spinal canal are prerequisites for successful therapy. The criteria used in this series are guidelines for the selection of patients for vertebral body resection, and considerable overlap exists between the various subsets. Radiographic findings that indicate the need for an anterior as opposed to the more traditional posterior approach are illustrated in Figs. 4 through 8.

The overall ambulation rate of 78% in this series is superior to that following treatment by RT alone. Similar results have been reported by Siegal, et al.,36 and Harrington,24 suggesting that this procedure may be more appropriate for many patients with spinal metastases. Since the outcome of therapy is affected by several factors, of which the patient's pretreatment ambulatory status is the most important, another measure of the success of this approach may be obtained by comparing results in non-ambulatory patients; the 70% improvement is twice the rate generally reported for non-ambulatory patients who are treated by RT.20,37

The importance of providing immediate stability to the spine is a goal that has gained considerable emphasis over the past few years. Posterior stabilization with acrylic or by instrumentation (Harrington or Luque rods), and anterior stabilization with acrylic or bone grafts have been advocated for the treatment of pain.
postoperative radiation; a similar experience has been reported by Harrington. Invariably, recurrence of pain or alteration in alignment of the spine was associated with tumor recurrence in adjacent vertebrae, and not to mechanical factors.

We believe there are several reasons to consider surgery prior to RT in selected patients. The mortality and morbidity in this series, and in a comparable study of decompressive laminectomy, were related to prior treatment. Of the 23 patients who underwent surgery de novo, no mortality and minimal morbidity were encountered. In contrast, all postoperative deaths, wound dehiscences, and superinfections occurred in those patients who had received prior therapy (including RT, chemotherapy, or steroids). These findings should not be surprising. Patients who relapse shortly after RT or who deteriorate while receiving RT have frequently been on high-dose steroid therapy for prolonged periods. A recent report by Martenson, et al., concluded that the use of high-dose steroid therapy for periods exceeding 40 days was responsible for considerable morbidity in six (67%) of nine patients with spinal cord compression either from sepsis or gastrointestinal hemorrhage. Cancer patients who receive RT or chemotherapy not infrequently also develop neutropenia secondary to depression of their bone marrow; during this period, they are more susceptible to superinfection. The poorer performance status and more advanced cancer in those who had successful initial RT may further contribute to surgical morbidity. Levy, et al., have also suggested that ambulatory patients with epidural cord compression who undergo initial surgery maintain their ambulatory status over longer periods of time compared to those undergoing RT. Our data support their contention; of the 23 patients undergoing initial surgery, 90% were able to walk until the time they died or at their last follow-up examination. Of those who had RT, then relapsed and underwent surgery, the cumulative probability of developing recompression at the original site by 1 year approached 50%. These observations suggest that local RT plays an important role in preventing tumor recurrence, but may be more effective postoperatively.

At present, there are no controlled studies that demonstrate the superiority of combined modality treatment. The intrinsic variability in prognostic factors, such as type of primary cancer, degree of neurological deficit, speed of deterioration, and extent of cancer, make the design of such a prospective study difficult, and treatment must still be individualized. With increasingly accurate radiographic diagnosis, many patients with solitary sites of relapse in the spine are being identified. In those with purely intraosseous tumors, complete tumor resection (albeit intraslesional) can be carried out through an anterior approach with minimal morbidity. In selected patients, especially those with vascular tumors of the spine, preoperative angiography and embolization should be considered to minimize blood loss. With experience, the operating times for

and neurological deficits associated with structural changes in the spine secondary to metastatic disease. Clinical symptoms in these patients are frequently thought to result from “segmental spinal instability.” This syndrome can be suspected by the radiographic findings of collapsed vertebrae and the presence of severe pain that is aggravated by movement and relieved by bed rest, immobilization, or traction. Segmental instability is not usually demonstrated by flexion-extension radiographs, and myelography is frequently required to rule out epidural encroachment by tumor. In patients with minimal cord compression, relief of pain can be obtained by either posterior or anterior stabilization procedures. When anterior stability is lost due to vertebral body bone loss, posterior instrumentation may fail because of progressive kyphotic angulation. Since most patients also have myelographic evidence of anterior epidural encroachment caused by tumor, we regard acrylic stabilization following vertebral body resection as the procedure of choice.

Our technique for preventing dislodgement of the acrylic construct by using Steinmann pins is simple, rapidly applicable at all sites and in all patients, and one that has been independently reported by others. We do not believe it necessary to supplement the acrylic anteriorly with Harrington distraction or Knodt rods, nor was it possible to correct fixed kyphosis resulting from previous RT. Instead, it may be necessary to resect all vertebrae involved in an acute kyphotic deformity. Although Wang, et al., have recently reported that no additional stability is gained by posterior stabilization after adequate anterior fixation, posterior stabilization was required in 10% of our patients. There was no long-term displacement of the acrylic mold in those patients whose tumors were successfully controlled by postoperative radiation; a similar experience has been
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these procedures are comparable to patients undergoing laminectomy. These considerations should encourage more surgeons to use this approach in the management of patients with spinal metastasis and impending cord compression.

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