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Anterior approaches for thoracolumbar metastatic spine tumors

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Metastases account for most spinal tumors and are a significant source of morbidity in patients with cancer [1]. Metastatic deposits are found within the spinal column of up to 90% of cancer patients by the time of death [2,3]. Currently, more patients are diagnosed at an early stage because of the widespread use of magnetic resonance imaging (MRI). Advances in cancer treatment may prolong life expectancy and seem to result in more patients surviving long enough to present with spinal involvement.

In recent years, surgeons have become familiar with techniques to address anterior spinal pathologic findings. In addition, more effective means of spinal stabilization have become widely available [4]. Novel surgical treatments are also being evaluated in the setting of metastatic spinal disease [5–8].

The management goals for patients with metastatic spinal disease are palliative and include pain control and the preservation or restoration of neurologic function, including ambulatory capacity and bladder continence [1]. Although the most frequently cited role for surgery has been the relief of epidural compression, it is important to consider that pain, particularly axial or mechanical pain, is a significant cause of morbidity. Axial pain worsens with movement and is characteristically relieved at rest. The most common cause of axial pain in the cancer setting is metastatic vertebral body collapse [4].

During the last decade, we have implemented an aggressive multidisciplinary approach in the management of most medically fit patients with spinal metastases of favorable histology and minimal evidence of extraspinal disease so as to minimize local recurrence, neurologic compromise, and pain [1,4,6–9].

Patient selection

In an attempt to clarify indications for surgical treatment, several authors have attempted to delineate the factors that are most important in determining surgical success [10–13]. Tokuhashi et al [10] reported a scoring system for the preoperative prognostic evaluation of patients with metastatic spinal tumors. A novel surgical strategy for the treatment of patients with spinal metastases was recently proposed by Tomita et al [13] based on three factors: grade of malignancy, visceral metastases, and extraspinal bone metastases.

Selection criteria for surgical intervention are not rigid, and the treatment plan for patients with metastatic tumors remains highly individualized. General indications for surgical intervention (including tumor resection and spinal reconstruction) include (1) radioresistant disease, (2) spinal instability, (3) spinal cord compression by bone or disk fragments, (4) acute or progressive neurologic deterioration, (5) previous radiation exposure of the spinal cord, and (6) uncertain diagnosis.

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With regard to the latter, the diagnosis of malignancy can often be established with computed tomography-guided needle biopsy [14].

Patients with acute or progressive neurologic deficit deserve special note. The rate of ambulatory recovery with radiotherapy alone in paraplegic patients is less than 5% [1]. Even among patients harboring radiosensitive tumors, improvement from radiotherapy begins a few days after the initiation of treatment. Therefore, in acutely paraparetic patients who are otherwise medically fit, urgent surgical decompression should be considered.

All patients should be assessed for the extent of extraspinal disease, preferably by the treating oncologist. Host factors associated with poor outcome include advanced age, obesity, malnutrition, diabetes, bone marrow suppression, and steroid therapy [15]. Each patient needs to be assessed individually, and the decision to operate must be made only after weighing the risks of surgical morbidity and mortality with the potential for gains in the duration and quality of survival.

Selection of the anterior approach

Surgical approaches to the spine may be broadly categorized into anterior, posterior, and combined approaches. Each has its role, and no single approach is always applicable. The spinal level, position, and extent of the tumor mass or bony compression with respect to the spinal canal determine the best approach. In addition, it is important to consider the integrity of the spinal column and thus the need to perform spinal reconstruction or stabilization.

The anterior approach has several advantages compared with posterior approaches. It provides the most direct access for resection of metastatic tumors located within the vertebral body and allows effective reconstruction of the weight-bearing anterior spinal column. Short-segment fixation devices may be applied. Surgical blood loss is theoretically reduced because (1) epidural venous pressures are lower in patients placed in a lateral decubitus position versus the prone position, (2) the surgeon is provided with direct access to the segmental vessels for ligation before tumor resection, and (3) enhanced access to the disease-containing vertebral body allows for expeditious tumor removal. The risk of wound infection or wound healing problems is also reduced with anterior versus posterior approaches [16]. In a nonrandomized single-institutional comparison, a higher incidence of wound infection, persistent cerebrospinal fluid leakage, and graft dislodgement as well as longer hospitalization time and reduced 1-year survival were found among patients who underwent the single-stage posterolateral approach compared with those who received a transthoracic approach for the treatment of spinal metastases [9,17].

Location of the tumor

The region of the spinal column most frequently involved with metastases is the vertebral body, likely because of its vascularity and large size relative to the posterior elements. Epidural spinal cord compression most often results when tumors extend dorsally from the vertebral body into the spinal canal [18]. Thus, an anterior approach provides the most direct access to the pathologic findings in most patients.

Spinal level

For lesions located at T1 or T2, a combined sternotomy and anterior neck dissection affords good exposure [19]. The favored entry site is on the left side of the neck, because approaching the spine from the patient's right side increases the risk of stretch injury to the right recurrent laryngeal nerve (Fig. 1).

The T3 to T4 region is mostly hidden behind the great vessels and is difficult to reach with either a transsternal approach or a high posterolateral thoracotomy. The ''trap door'' exposure (a combination of the anterolateral cervical approach, a partial median sternotomy, and an anterolateral thoracotomy) provides relatively wide access to the T3 and T4 vertebral bodies (Fig. 1B) [20]. Unlike other ventral approaches to the cervicothoracic junction, the trap door exposure spares the sternoclavicular junction and does not require transection of the clavicle. The associated morbidity and lengthy postoperative convalescence associated with this procedure are somewhat inconsistent with the basic aim of palliation for cancer patients with a limited life expectancy, however. Consequently, posterolateral surgical techniques are generally favored for metastatic disease in the T3 toT4 region.

The T5 to L4 levels may be effectively approached by thoracotomy (T5–T10) (Fig. 1C), the thoracoabdominal approach (T11–L1) (Fig. 1D), and the retroperitoneal approach (L2–L4), as

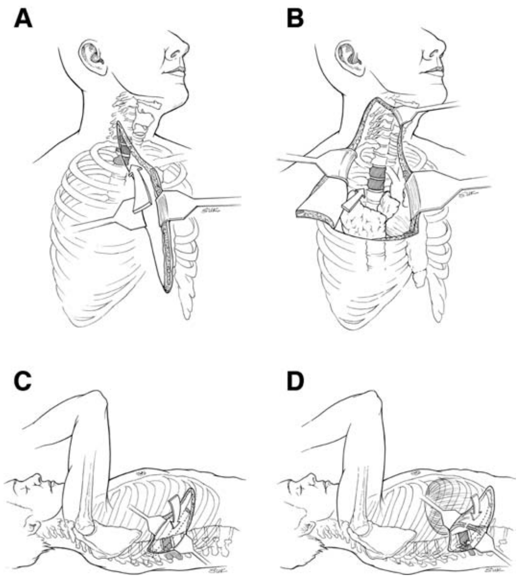

Fig. 1. Artist's illustrations showing various ventral/ventrolateral approaches to the thoracic spine depending on the level(s) involved in the neoplastic process. (*A*) Ventrolateral surgical approach combined with median sternotomy for lesions at C7 through T2. (*B*) "Trap door" exposure (ventrolateral cervical approach combined with median sternotomy and ventrolateral thoracotomy) for tumor located at T3 through T4. (*C*) Dorsolateral thoracotomy for lesions at T5 through T11. (*D*) Thoracoabdominal approach for lesions located at the thoracolumbar junction. The crus of the diaphragm is taken down to expose this region.

described below. Although direct anterior exposure at L5 can be obtained with a transperitoneal approach, we have generally used posterolateral exposures for lower lumbar and lumbosacral metastatic disease. Retraction of the thecal sac allows easy access to vertebral body pathologic findings in this region, and effective spinal stabilization involves posteriorly applied devices [7].

Extent of disease

Vertebral body disease involving one or two contiguous levels is usually best approached from the front (with the exceptions noted previously). An anteriorly applied prosthesis provides the most effective reconstruction of the weight-bearing capacity of the spine and is most favorable from the biomechanical point of view. When disease involves three or more contiguous levels, the surgeon should appreciate that fixation of the anterior construct will be tenuous despite the use of anterior stabilizing devices, such as plates or rods. In this circumstance, posterior spinal fixation is necessary to supplement the reconstruction. Depending on the life expectancy and the medical fitness of the patient to tolerate two procedures, it may be best to perform a single-stage posterolateral resection and stabilization in this circumstance.

Is posterior stabilization also indicated?

In addition to the case of multilevel anterior constructs, there are other several other circumstances in which the surgeon should anticipate the need to augment the stabilization with posterior fixation [4]. For example, the bony integrity of the vertebral bodies adjacent to the decompressed segment may be diseased to such an extent that fixation of an anterior reconstruction prosthesis is not possible.

The presence of significant kyphosis with vertebral collapse should alert the surgeon that the posterior ligamentous complex has been compromised and may contribute to progressive kyphosis despite vertebral reconstruction and plate fixation (Fig. 2). This is particularly true for lesions at the thoracolumbar junction because of the more sagittal orientation of the facet joints in this region and the presence of increased biomechanical stress between the relatively rigid thoracic levels and the more mobile lumbar segments. In most of our patients with thoracolumbar junction metastases, supplemental posterior stabilization is performed along with resection and reconstruction of the vertebral body [9].

Whenever a significant portion of the adjacent chest wall has been included in the tumor resection, such as for Pancoast tumors [21] or locally invasive sarcomas that involve the chest wall [8], posterior spinal fixation should be considered because of the risk of kyphoscoliosis.

In the authors' recent review of 100 consecutive cases involving pedicle screw fixation for malignant thoracolumbar disease, the rate of screw-related late instrumentation failure was only 2% [7]. The low rate of pedicle screw failure, even among long-term survivors, was attributed to an emphasis on the concurrent use of anterior approaches to reconstruct the weight-bearing capacity of the spine.

Patient fitness

The surgical approach may be influenced by local or systemic patient debility. The risk of

Fig. 2. Preoperative anteroposterior and lateral plain radiographs (*A*) and magnetic resonance imaging (MRI) scans (*B*) of a 39-year-old woman with a history of breast carcinoma. The patient presented with acute-onset low back pain, bilateral lower extremity weakness, and bowel and bladder dysfunction. Plain radiographs show complete collapse of the L2 vertebra, whereas MRI reveals severe compression of the cauda equina. The patient underwent a two-stage procedure: (1) retroperitoneal approach, L2 corpectomy, reconstruction with distractable cage, correction of kyphotic deformity, and fixation with plate/screws and fusion and (2) posterior thoracolumbar pedicle screw fixation and fusion. (*C*) Postoperative plain radiographs show the final construct. One year later and after additional radiotherapy locally, the patient was neurologically intact and free of pain.

wound dehiscence within previously irradiated fields has been well documented and may be a decisive factor in choosing an anterior approach in some cases [7,22,23]. Some patients may be medically unsuitable for transthoracic, thoracoabdominal, and retroperitoneal approaches; however, these exposures are generally well tolerated in most patients.

Surgical technique

Irrespective of the surgical approach used, a measure of safety is added by employing intraoperative neurophysiologic monitoring with somatosensory or motor evoked potentials [24]. Preoperative spinal angiography and embolization are invaluable in certain cases, especially with tumors known to be highly vascularized, such as renal cell carcinoma, thyroid tumors, sarcoma, and melanoma [7–9].

Transthoracic approach (T5–T10)

The sidedness of the approach is primarily chosen based on any asymmetry of the disease process. Access via the left hemithorax is generally preferred, especially in the lower thoracic spine, where the liver may act as a significant obstacle to exposure. The aorta, on the left, is also more easily identified and protected compared with the relatively fragile inferior vena cava, on the right. In patients who have had previous chest operations, we prefer an approach via the contralateral hemithorax to avoid problems with postoperative air leaks that would require an extended duration of chest tube placement and could increase the risk of contaminating the spinal hardware.

The patient is placed in the lateral decubitus position. A curvilinear incision is made from the anterior axillary line to the border of the paraspinal muscles, posteriorly over the rib to be resected. For lesions involving T5 and T6, the fifth rib is removed. For T7 and T8, the rib located one level above the tumor epicenter (the sixth or seventh rib, respectively) is removed. For T9 and T10, the rib two levels above (the seventh or eighth rib, respectively) is removed. The latissimus dorsi muscle is mobilized and transected over the line of incision. The lateral margin of the trapezius muscle is identified and may be transected if necessary. The posterior border of the serratus anterior muscle is mobilized, and the space between this muscle and the underlying rib cage is developed. The periosteum over the rib is incised longitudinally and elevated with periosteal elevators. Rib cutters are used to transect the rib at the costochondral junction anteriorly and at the angle of the rib posteriorly. The parietal pleura is opened, and the ribs are spread using a self-retaining thoracotomy retractor.

The lung may be manually deflated; however, in most cases, simple retraction with padded retractors provides sufficient exposure of the aorta and the vertebral bodies. The azygous vein and thoracic duct lie to the right of midline, immediately anterior to the vertebral bodies. The segmental vessels are draped over the midportion of each vertebral body.

At the completion of the vertebrectomy and reconstruction, chest tubes are placed one or two intercostal spaces above and below the incision. The superior tube is directed toward the apex of the lung to collect air, and the inferior tube is placed at the posterior corner of the diaphragm to collect blood. A purse-string suture is used to secure the drains to the skin. The ribs are reapproximated with heavy reabsorbable suture. The periosteum and intercostal muscles are closed with a running suture for an airtight closure. The rest of the closure is completed in a layered fashion.

Thoracoabdominal approach (T11–L1)

Exposure of the lower thoracic or upper lumbar region is complicated by the presence of the diaphragm. Although a right-sided approach can be used if dictated by the sidedness of the tumor, left-sided exposures are preferred. The liver, on the right side, is large and difficult to retract. The vena cava, also on the right side, may be difficult to locate and is easily injured.

The patient is placed in the lateral decubitus position. The incision begins dorsally near the midline, and extends obliquely following the appropriate rib to the upper abdomen: for lesions involving T11, the ninth or tenth rib should be removed; for T12 lesions, the eleventh rib should be removed; and for L1 lesions, the twelfth rib should be removed. The incision extends from the paraspinal muscles posteriorly to the anterior margin of the rib cage.

The muscle layers are transected in line with the skin incision. Most superficially are the latissimus dorsi and external oblique muscles, the next layer contains the serratus posterior inferior and internal oblique muscles, and the deepest layer is the transversus abdominis. After transaction of the appropriate rib, the endothoracic fascia and parietal pleura are opened. The ribs are spread with a self-retaining retractor, and the lung is deflated and retracted.

The left diaphragmatic crus extends to the second lumbar vertebral body. If exposure of T12 or L1 is required, a portion of the diaphragm needs to be opened. The retroperitoneal space, which usually contains fat, may be entered at the level of the diaphragmatic incision. The retroperitoneal space is developed by blunt dissection posterior to the renal fascia. The abdominal contents are retracted medially using a broad padded retractor.

Closure is similar to the transthoracic approach, with the additional closure of the diaphragm in an airtight fashion using interrupted sutures.

Retroperitoneal approach (L2–L4)

The side of surgery is primarily dictated by any laterality to the tumor; however, a left-sided approach is preferable to avoid retraction of the liver and the fragile vena cava.

The patient is placed in the lateral decubitus position. It is helpful to flex the upper hip to relax the psoas muscle. The table should be flexed slightly to open the space between the ribs and the iliac crest. The incision begins in the interval between the iliac crest and the costal margin. The ventral direction of the incision is determined by the level of the tumor. This may range from an essentially transverse incision that follows the twelfth rib and ends above the umbilicus for the exposure of L2 to a caudally oblique incision that reaches the interval between the symphysis pubis and the umbilicus for the exposure of L4. The incision should extend no further ventrally than the lateral border of the rectus fascia.

The muscle layers are opened in line with the skin incision. Beginning superficially, these are the (1) latissimus dorsi, (2) external oblique, (3) internal oblique, and (4) transversus abdominis muscles. The distal half of the twelfth rib, located just below the fibers of the latissimus dorsi muscle, may be resected subperiosteally. The peritoneum is located deep to the transversus abdominis muscle.

Great care is taken to leave the peritoneum intact while dissection proceeds bluntly along the transversalis fascia. A common mistake is to enter the perirenal fat; however, the correct plane is just in front of the quadratus lumborum and psoas muscles. Likewise, it is possible to mistake the transverse processes for vertebral bodies and to enter the retropsoas space, a blind pouch between the quadratus lumborum and psoas muscles. The ureter is identified and retracted medially with the retroperitoneal fat. Gently stroking the ureter produces characteristic peristaltic movements that aid in its identification. The genitofemoral nerve is identified on the surface of the psoas muscle and should be protected.

The lumbar spine is medial to and partially obscured by the psoas muscle. The psoas muscle can be mobilized with subperiosteal dissection to facilitate exposure of the ventrolateral borders of the spine. The sympathetic trunk is located ventrally, medial to the psoas muscle, and should be preserved if possible. The segmental vessels run over the midportion of each vertebral body; these should be identified, ligated, and transected with minimal retraction or manipulation. After ligation of the segmental vessels, the aorta can be mobilized slightly medially to facilitate the ventral exposure of the spine.

Vertebrectomy and reconstruction proceed in the standard fashion, as described below. The muscle closure is performed in multiple layers.

Vertebrectomy

When the identity of the vertebral lesion is in doubt on gross inspection, fluoroscopic guidance or an intraoperative x-ray film is highly recommended. Once the appropriate level has been reached, the segmental vessels are identified at the vertebrectomy site and at the levels immediately above and below it. The vessels are doubly ligated and transected. This allows greater exposure with mobilization of the aorta.

Leksell rongeurs are used for the initial removal of soft tumor from the vertebral body. A high-speed power drill with a diamond burr attachment is employed for the bone resection. The diamond burr is superior to the cutting burr, because there is much less chance of entraining adjacent soft tissue. The rostral and caudal end plates are drilled away until soft annulus is encountered. Likewise, the posterior longitudinal ligament should be exposed directly in front of the thecal sac.

A common mistake is to drill away portions of the vertebral body at the base of the contralateral pedicle incompletely. Tilting the bed slightly facilitates visualization of this region. After bone removal, discectomies are completed with a number 15 blade scalpel, pituitary forceps, and curettes. Finally, the posterior longitudinal ligament is carefully incised with the scalpel and dissected away from the dural sac. It is important to open the posterior longitudinal ligament and visualize the nerve roots exiting at the level of the resection to ensure complete decompression of the thecal sac.

Vertebral body reconstruction

The vertebral body may be replaced with various materials, including autograft or allograft bone, polymethylmethacrylate (PMMA), or spacers [4]. Recently, distractible or telescoping cages (Synex cage; Synthes Spine, West Chester, PA) have become available. A bone graft is often recommended for patients with a life expectancy beyond 6 months; however, in our experience, anterior reconstruction with PMMA may remain durable for many years [9].

A number of methods to fix PMMA to the vertebral body have been described. Of these, the chest tube technique [25] has been used extensively by the authors, with excellent results [9]. A 32- to 36-French chest tube is used, depending on the size of the vertebral bodies. A right-angle drill is used to make a centrally placed "anchoring hole" through the end plates above and below the defect. The depth should be approximately to the center of each vertebral body. The chest tube is cut to the appropriate length to fill the two holes and span the defect. Small notches are made at both ends of the chest tube, and a center hole is fashioned with a Leksell rongeur—the center hole is necessary to accommodate the 60-mL syringe through which the PMMA is injected. The PMMA must extrude through both ends of the chest tube to provide a cement-bone interface within the anchoring hole in each vertebral body. The space directly in front of the thecal sac is kept free of PMMA with two wooden tongue blades while Penfield number 2 or 3 instruments are used to fashion the cement filling the vertebrectomy defect to the appropriate shape. Copious irrigation should be used while the PMMA polymerizes to prevent thermal injury to the neural structures.

PMMA reconstruction is ideal in the cancer setting because it accomplishes immediate stabilization after radical tumor resection, allowing patients to ambulate without the use of external orthoses and permitting the administration of radiation therapy without delay [4]. Although PMMA is stable in compression, we advocate the addition of anterior fixation (locking plate and screws inserted into the rostral and caudal vertebral bodies) to prevent distraction failure and provide increased rigidity.

Simultaneous anterior-posterior approach

Combined anterior-posterior approaches are traditionally performed in a staged fashion either during the same anesthetic session or at a separate surgical session. Recently, a simultaneous anterior-posterior approach to the thoracic and lumbar spine for the resection of malignant tumors has been described [8]. Patients are placed in the lateral decubitus position for the procedure. The standard incision for a posterolateral thoracotomy, thoracoabdominal, or retroperitoneal approach (depending on the spinal level) is combined with a posterior midline incision, forming two triangular skin flaps. Advantages of such an approach include (1) direct visualization of all the relevant neurovascular and visceral structures, (2) the ability to resect lesions involving all three spinal columns and any involved regions of the adjacent paraspinal soft tissues or chest wall completely in a circumferential fashion (optimizing hemostasis), and (3) the capacity to complete the dorsal and ventral reconstruction and stabilization all in one procedure.

Superior sulcus (Pancoast) tumors are complex bronchogenic carcinomas that may invade the lower roots of the brachial plexus, sympathetic chain, mediastinal structures, spinal column, adjacent ribs, and chest wall. For such tumors, a combined approach that includes a posterolateral thoracotomy, apical lobectomy, chest wall resection, laminectomy, vertebrectomy, anterior spinal column reconstruction with PMMA, and placement of spinal instrumentation has been described [21].

Postoperative care and complication avoidance

Postoperative complications among patients with metastatic tumors have been extensively studied [7,9,15,16,22,23,26–28].

Local complications

Intraoperative blood loss may be reduced by preoperative embolization, especially for characteristically hemorrhagic tumors, such as renal cell carcinoma [7–9]. The maintenance of meticulous hemostasis throughout surgery should be stressed.

Neurologic complications during surgery may be reduced with careful surgical technique and the routine use of somatosensory evoked potential monitoring. Spinal cord ischemia secondary to ligation of the segmental intercostal vessels is a potential threat, although it is rare with unilateral vessel ligation.

Complications of transthoracic exposures include atelectasis, pneumonia, and airway obstruction. Complications specific to the thoracoabdominal and retroperitoneal exposures include injury to the spleen, kidney, and ureters. A postoperative ileus is not uncommon. In the thoracoabdominal approach, herniation of visceral structures may occur if the diaphragm is not closed carefully.

Wound dehiscence and infection are among the most frequently cited complications in metastatic tumor series, with rates reported as high as 25% to 34% [7,9,15,16,22,23,26–28]. The risk is highest among patients with dorsal wounds compared with those who undergo ventral approaches [7,9,17]. Several authors [7,16,22,27,28] have found an association between radiation therapy (especially preoperative radiotherapy [23,27,28]) and subsequent wound breakdown and infection. High intraoperative blood loss [15], nutritional depletion [15], corticosteroid use [15], advanced age [16], and the presence of paraparesis [16] have also been associated with wound complications. Our findings and those of others emphasize the importance of avoiding preoperative radiation therapy in patients who are candidates for surgery as first-line therapy. Unfortunately, surgeons are often asked to evaluate patients after the patients have already received radiation treatment.

Systemic complications

Close postoperative monitoring and constant vigilance are required for the early detection of cardiac or respiratory problems, including congestive heart failure, pulmonary edema, and pneumonia [7].

The frequency of postoperative confusion in patients undergoing surgery for metastatic spinal tumors is reported to be as high as 10% [27], although it resolves within 72 hours in most cases.

Thromboembolic complications may be reduced with the routine use of external sequential pneumatic compression stockings. Low-molecular-weight heparin is recommended for paraplegic patients, although the initiation of anticoagulant prophylaxis should probably be delayed for at least 48 to 72 hours after surgery [29].

In an effort to control pain and maintain neurologic function, most clinicians use corticosteroid therapy as a supplement to surgery or radiation therapy for patients with metastatic spinal tumors. High-dose corticosteroid therapy carries a significant risk of toxicity. The incidence of serious toxic side effects was 14% in one study [30] and included one fatal ulcer hemorrhage, rectal bleeding, and gastrointestinal perforation. These risks must be weighed against the anticipated benefits. In addition to the dose, the duration of steroid therapy determines its toxicity. A significant increase in severe complications, including fatal sepsis, has been noted when dexamethasone was used for more than 40 days to treat malignant epidural spinal cord compression [31]. Because major complications may occur with prolonged therapy, the use of steroids should be discontinued as rapidly as possible or tapered down to the lowest possible level compatible with clinical benefit.

Summary

The management of patients with metastatic disease of the thoracolumbar spine should be highly individualized and depends on several factors, including the clinical presentation, duration of symptoms, tumor type, anticipated radiosensitivity, tumor location, extent of extraspinal disease, integrity of the spinal column, and medical fitness and life expectancy of the patient. Although no single approach is always applicable, anterior approaches provide several advantages, including minimal removal of uninvolved bone, rapid extirpation of the tumor, improved hemostasis, effective reconstruction of the weight-bearing anterior column, short-segment fixation, and improved wound healing. Wider acceptance and judicious use of current surgical techniques for metastatic spine disease may improve the quality of life of patients too often denied such treatment [28,32].

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