Chapter 16 Primary and Metastatic Tumors of the Spine: Total En Bloc Spondylectomy

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BACKGROUND

- Conventionally, curettage or piecemeal excision has been the usual approach to vertebral tumors.
- These approaches have clear disadvantages, however, including high risk of tumor cell contamination to the surrounding structures and residual tumor tissue at the site due to difficulty in demarcating tumor from healthy tissue.
- These contribute to incomplete resection of the tumor as well as high local recurrence rates of the spinal malignant tumor.
- To reduce local recurrence and to increase survival, we have developed total en bloc spondylectomy (TES).[10,11,14]
- In this method, the entire vertebra or vertebrae containing the malignant tumor are resected, together with en bloc laminectomy, en bloc corpectomy, and bilateral pediculotomy using a T-saw through the posterior approach.[9]
- Using this technique, we are able to excise the tumor mass together with a wide or marginal margin.

ANATOMY

- The following tissues serve as barriers to spinal tumor progression: the anterior longitudinal ligament (ALL), the posterior longitudinal ligament (PLL), the periosteum abutting the spinal canal, the ligamentum flavum (LF), the periosteum of the lamina and spinous process, the interspinous ligament (ISL), the supraspinous ligament (SSL), the cartilaginous endplate, and the cartilaginous annulus fibrosus. However, both the PLL and the periosteum on the lateral side of the vertebral body are "weak" anatomic barriers. In contrast, the ALL, cartilaginous endplate, and annulus fibrosus are "strong" barriers. In the spine one vertebra could be regarded as a single oncologic compartment and the surrounding tissues as barriers to tumor spread (**FIG 1**).[5]

INDICATIONS

- Surgical indication for primary tumors
  - The surgical strategy for primary spinal tumors used at the authors' institution is based on Enneking's concept of musculoskeletal tumors[3] (Table 1).
- Surgical indication for metastatic tumors
  - Surgical strategy for spinal metastases (Table 2) consists of three prognostic factors: (1) grade of malignancy; (2) visceral metastases; and (3) bone metastases.[12]
  - The extent of the spinal metastases is stratified using the surgical classification of spinal tumors (Table 3), and technically appropriate and feasible surgery is employed, such as en bloc spondylectomy, piecemeal thorough excision, curettage, or palliative surgery.

IMAGING AND OTHER STAGING STUDIES

- Plain radiography
- CT/MRI
- Bone scan
- Angiography and other studies
- Biopsy

SURGICAL MANAGEMENT

- The TES operation was designed to achieve complete tumor resection en bloc, including main and satellite microlesions in a vertebral compartment to avoid local recurrence.
- The primary candidates for TES are primary malignant tumor (stage 1, 2); aggressive benign tumor (stage 3); and isolated metastasis in a patient with long life expectancy (see Tables 1 and 2).
- From the viewpoint of tumor growth (see Surgical classification; Table 3), TES is recommended for types 3, 4, and 5 lesions; and relatively indicated for types 1, 2, and 6 lesions.
- Type 1 or 2 still can be a candidate for radiation therapy, chemotherapy, corpectomy, or hemivertebrectomy.
- TES is not recommended for type 7 lesions. Systemic treatment or hospice care may be the treatment choice for these lesions.[10,11,13] However, the final decision can be made individually based on discussion among the patient and his or her family and doctors.

Preoperative Embolization

- Segmental arteries above and below the feeding artery, as well as the feeding artery itself, should be embolized preoperatively. This embolization technique dramatically reduces intraoperative bleeding without compromising spinal cord function.[4,8,15]

Positioning

- The patient is placed prone over the Relton-Hall four-poster frame for the posterior approach to avoid compression to the vena cava.

Approach

- The surgical approach is decided based on the degree of tumor development or affected spinal level.

Single Posterior Approach

- For TES above L4, a single posterior approach is preferred rather than a postero–anterior combined approach, as long as the tumor does not involve major vessels or segmental arteries.

Anteroposterior Double Approach

- In type 5 or 6 tumors that involve major vessels or segmental arteries, anterior dissection followed by posterior TES is indicated. Currently, a thoracoscopic or mini-open approach is preferred for anterior dissection.

Posteroanterior Double Approach

- Posterior laminectomy and stabilization followed by anterior en bloc corpectomy and placement of a vertebral prosthesis is indicated in spinal tumors at the level of L5 or L4 because of the technical challenge presented by the iliac wing and lumbosacral plexus nerves.

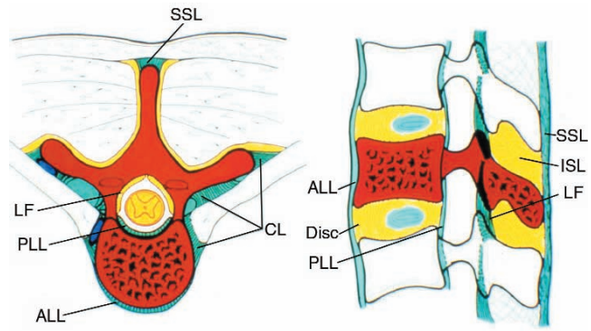


FIG 1 • Compartment and barrier.

Table 1 Surgical Strategy for Primary Spinal Tumors

Surgical Staging	Contamination/ Residual Tumor	Surgical Margin	Spinal Cord Salvage Surgery
Benign tumor			
1. Latent			Don't touch!
2. Active	OK/OK	Intralesional	Debulking (piecemeal)
3. Aggressive	No/no	Intralesional or marginal	Thorough exision (piecemeal/en bloc)
Malignant tumor			
I. Low grade	No/no		
II. High grade	No/no	Marginal or wide	Total en bloc excision
III. With metastases	No/no	(Radical: impractical)	

Table 2 Surgical Strategy for Spinal Metastases

Minimum requirement :

ECOG Performance Status 0 — 3 — 5

or

Karnofsky Performance Scale : 0 — 30 — 0%

Prognostic Scoring System			
Factor / Point	Primary tumor	Mets. to vital organ	Bone mets.
1	slow growth	no met : 0	isolated
2	moderate growth	controllable	multiple
3	rapid growth	uncontrollable	

Total P. Score	Life Expentacy	Treatment Aim	Surgery
2	2y <	**Long**-term local control	**En bloc exc.**
3			
4	1–2y	**Middle**-term loca control	**Debulking**
5			
6	6–12m	**Short**-term palliation	**Palliative decomposition**
7			
8	< 3m	**Terminal** care	**No** surgical treament
9			
10			

Table 2 Appendix Points for each primary tumor

1 point = slow growth
- Breast ca.*
- Thyroid ca.*
- Prostatic ca, Testicular ca.

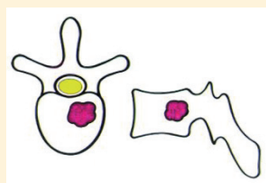
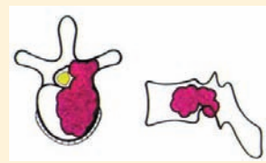
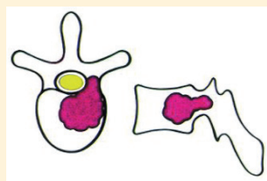
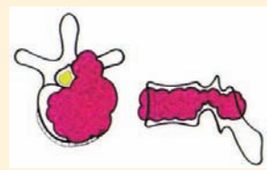
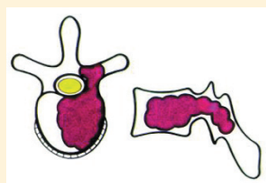
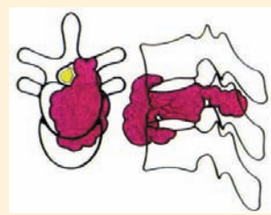
2 points = Moderate growth
- Renal cell ca.*
- Uterus ca. Ovarian ca.
- Colorectal ca

4 points = Rapid growth

ex.
- Lung ca.
- Gastric ca. Esophageal ca.
- Nasopharyngeal ca.
- Hepatocellular ca
- Pancreas ca.etc
- Bladder ca.
- Melanoma
- Sarcoma (osteosarcoma, Ewing sarcoma, Leiomyosarcoma, etc)
- Primary unknown metastasis
- other rare ca.
- ….etc.

*Rare types of the following ca. should be given "4 points" as a rapidly growing cancer: 1 Breast ca.;inflammatory type, 2 Thyroid ca.;undifferentiated type, 3 Renal cell ca.;inflammatory type

Table 3 Surgical Classification of Spinal Tumors

Intra-Compartmental		Extra-Compartmental		Multiple
Type 1 vertebral body		**Type 4** spinal canal extension		**Type 7** 
Type 2 pedicle extension		**Type 5** paravertebral extension		
Type 3 body - lamina extension		**Type 6** adjacent vertebral extension		

TECHNIQUES

Exposure

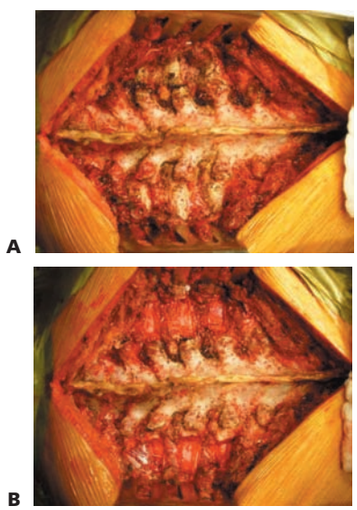
- A straight vertical midline incision is made over the spinous processes and is extended three vertebrae above and below the involved segment(s).
- The paraspinal muscles are dissected from the spinous processes and the laminae, and then retracted laterally.
- If the patient underwent a posterior route biopsy, the tracts are carefully resected in a manner similar to that used in limb-salvaging procedures.
- After a careful dissection of the area around the facet joints, a large retractor, the *articulated spinal retractor,* which has a uniaxial joint in each limb and was designed for this surgery, is applied.
- By spreading the retractor and detaching the muscles around the facet joints, a wider exposure is then obtained.
- The operative field must be wide enough on both sides to allow dissection under the surface of the transverse processes.
- In the thoracic spine, the ribs on the affected level are transected 3 to 4 cm lateral to the costotransverse joint, and the pleura is bluntly separated from the vertebra (**TECH FIG 1**).
- To expose the superior articular process of the uppermost vertebra, the spinous and inferior articular processes of the neighboring vertebra are osteotomized and removed with dissection of the attached soft tissues, including the ligamentum flavum.

Introduction of the T-saw Guide

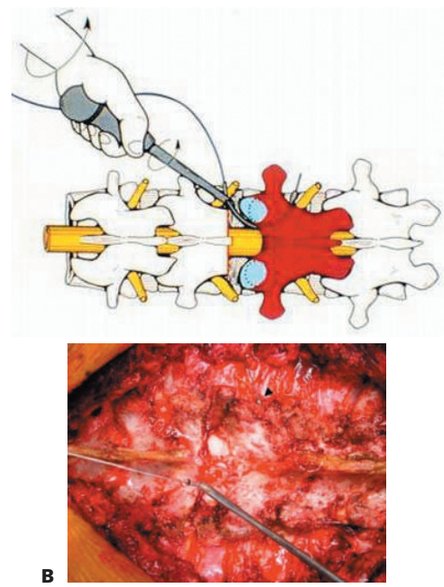
- To make an exit for the T-saw guide through the nerve root canal, the soft tissue attached to the inferior aspect of the pars interarticularis is dissected and removed, using utmost care so as not to damage the corresponding nerve root.
- A C-curved malleable T-saw guide is then introduced through the intervertebral foramen in a cephalocaudal direction.
- In this procedure, the tip of the T-saw guide should be introduced along the medial cortex of the lamina and the pedicle so as not to injure the spinal cord and the nerve root (**TECH FIG 2**).
- After passing the T-saw guide, its tip at the exit of the nerve root canal can be found beneath the inferior border of the pars interarticularis.
- A T-saw is passed through the hole in the wire guide and is clamped with a T-saw holder at each end.
- The T-saw guide is removed, and tension on the T-saw is maintained.

Cutting the Pedicles and En Bloc Laminectomy

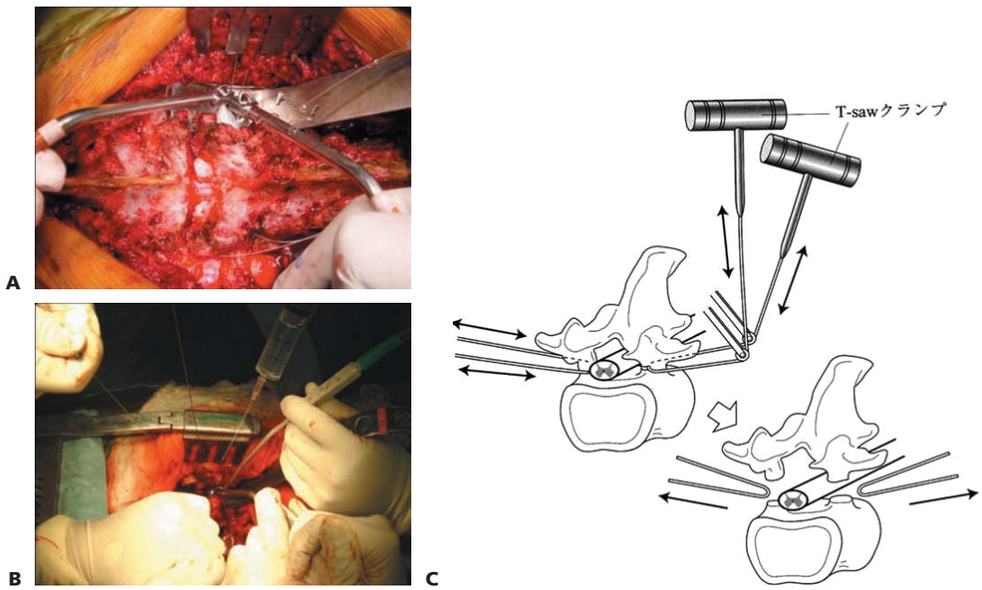
- While tension is maintained, the T-saw is placed beneath the superior articular and transverse processes with a specially designed T-saw manipulator. With this procedure, the T-saw placed around the lamina is wrapped around the pedicle.
- With a reciprocating motion of the T-saw, the pedicles are cut, and then the whole posterior element of the spine (the spinous process, the superior and inferior articular processes, the transverse process, and the pedicle) is removed in one piece (**TECH FIG 3**).
- The cut surface of the pedicle is sealed with bone wax to reduce bleeding and to minimize contamination by tumor cells.[1]



TECH FIG 1 • **A.** Exposure. **B.** Ribs on the affected level are transected 3 to 4 cm lateral to the costotransverse joint.



TECH FIG 2 • **A.** Schematic diagram depicting introduction of the the T-saw guide. **B.** A C-curved malleable guidewire is introduced through the right intervertebral foramen in a cephalocaudal direction.



TECH FIG 3 • **A,B.** Right pedicle is cut with a reciprocating motion of the T-saw. **C.** Schematic drawing of the pediculotomy.

- To maintain stability after segmental resection of the anterior column, a temporary posterior instrumentation ("two above and two below" segmental fixation) is performed.

Blunt Dissection Around the Vertebral Body

- The spinal branch of the segmental artery, which runs along the nerve root, is ligated and divided. In the thoracic spine, the nerve root is cut on the side from which the affected vertebra is removed.
- The blunt dissection is done on both sides through the plane between the pleura (or the iliopsoas muscle) and the vertebral body (**TECH FIG 4**).
- Usually, the lateral aspect of the body is easily dissected with a curved vertebral spatula.
- Then the segmental artery should be dissected from the vertebral body.
- By continuing dissection of both lateral sides of the vertebral body anteriorly, the aorta is carefully dissected posteriorly from the anterior aspect of the vertebral body with a spatula and the surgeon's fingers.
- When the surgeon's fingertips meet with each other anterior to the vertebral body, a series of spatulas, starting from the smallest size, are inserted sequentially to extend the dissection.
- A pair of the largest spatulas is kept in the dissection site to prevent the surrounding tissues and organs from iatrogenic injury and to make the surgical field wide enough for the surgeon to manipulate the anterior column.

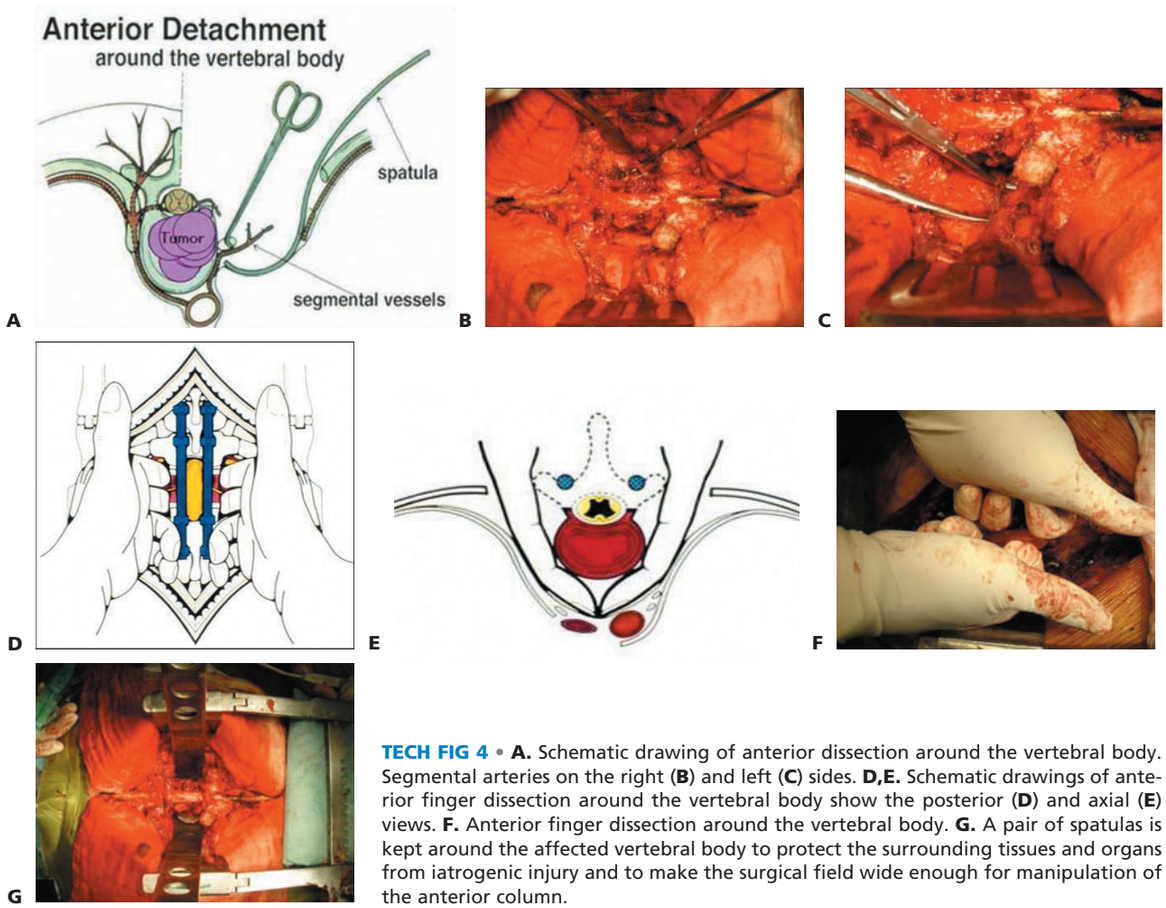
Dissection of the Spinal Cord and En Bloc Corpectomy

- Using a cord spatula, the spinal cord (dura mater) is mobilized from the surrounding venous plexus and the ligamentous tissue.
- T-saws are inserted at the proximal and distal cutting levels of the vertebral bodies after confirmation of the disc levels with needles. Recently, a diamond T-saw is now available for corpectomy.
- The teeth-cord protector, which has teeth on both edges to prevent the T-saw from slipping, is then applied.
- The anterior column of the vertebra is cut by the T-saw, together with the anterior and posterior longitudinal ligaments (**TECH FIG 5**).
- The freed anterior column is rotated around the spinal cord and removed carefully to avoid injury to the spinal cord.
- With this procedure, a complete anterior and posterior decompression of the spinal cord (circumspinal decompression) and total en bloc resection of the vertebral tumor are achieved.

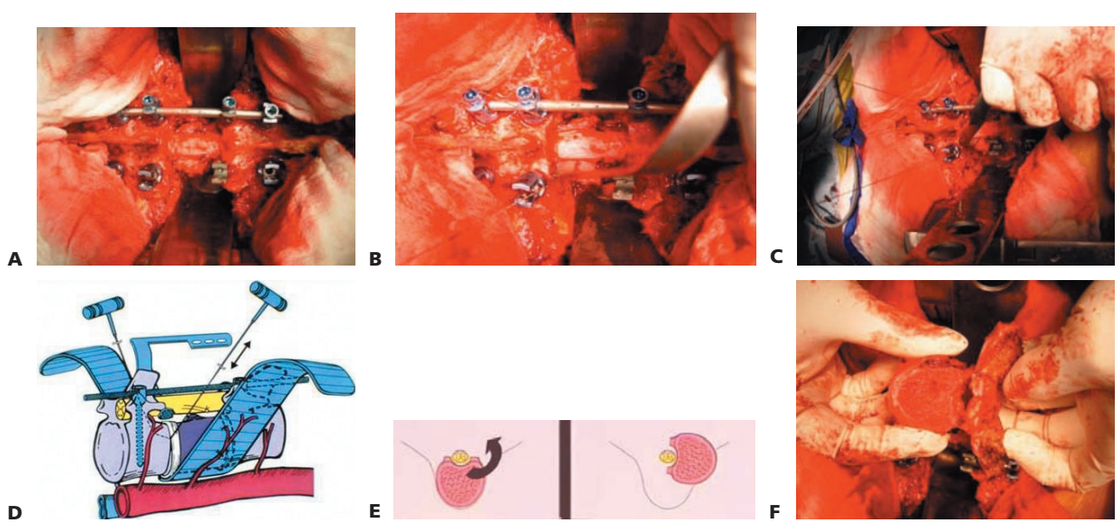
Anterior Reconstruction and Posterior Instrumentation

- An anchor hole on the cut end of the remaining vertebra is made on each side to seat the graft. A vertebral spacer such as a titanium mesh cylinder cage with autograft, allograft, or cement (**TECH FIG 6**) is properly inserted to the anchor holes within the remaining healthy vertebrae.
- After checking the appropriate position of the vertebral spacer radiographically, the posterior instrumentation is adjusted to slightly compress the inserted vertebral spacer.
- By this "spinal shortening" procedure, the block cylinder is caught tightly and the anteroposterior 360-degree spinal reconstruction is completed. [2,7]
- If two or three vertebrae are resected, it is recommended that the connector device be applied between the posterior rods and anterior spacer (artificial pedicle).

TECHNIQUES

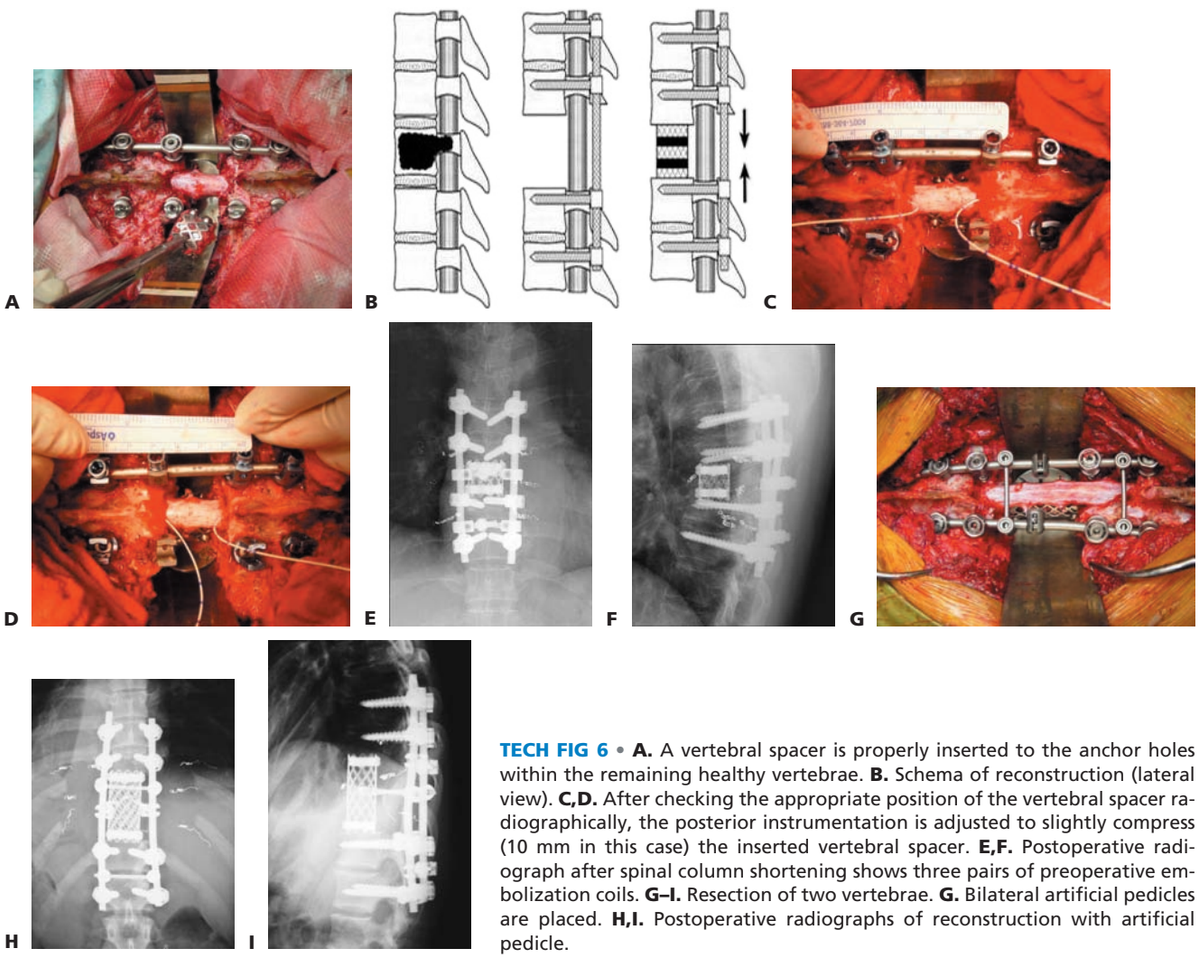


TECH FIG 4 • **A.** Schematic drawing of anterior dissection around the vertebral body. Segmental arteries on the right (**B**) and left (**C**) sides. **D,E.** Schematic drawings of anterior finger dissection around the vertebral body show the posterior (**D**) and axial (**E**) views. **F.** Anterior finger dissection around the vertebral body. **G.** A pair of spatulas is kept around the affected vertebral body to protect the surrounding tissues and organs from iatrogenic injury and to make the surgical field wide enough for manipulation of the anterior column.



TECH FIG 5 • **A.** A temporary posterior instrumentation is performed to maintain stability after segmental resection of the anterior column. **B,C.** The anterior column of the vertebra is cut by the T-saw, together with the anterior and posterior longitudinal ligaments. The teeth-cord protector, which has teeth on both edges to prevent the T-saw from slipping, is then applied. **D.** Schematic drawing of cutting the anterior column. **E.** Diagram of en bloc corpectomy. **F.** Intraoperative photograph of specimen from the resected T7 vertebra. *(continued)*

TECH FIG 5 • *(continued)* **G.** Specimens resected along with the compartment and barrier concept. **H,I.** Radiographs of resected specimens from metastatic tumor of T7 showing the complete vertebra in horizontal (**H**) and lateral (**I**) views.



TECH FIG 6 • **A.** A vertebral spacer is properly inserted to the anchor holes within the remaining healthy vertebrae. **B.** Schema of reconstruction (lateral view). **C,D.** After checking the appropriate position of the vertebral spacer radiographically, the posterior instrumentation is adjusted to slightly compress (10 mm in this case) the inserted vertebral spacer. **E,F.** Postoperative radiograph after spinal column shortening shows three pairs of preoperative embolization coils. **G–I.** Resection of two vertebrae. **G.** Bilateral artificial pedicles are placed. **H,I.** Postoperative radiographs of reconstruction with artificial pedicle.

PEARLS AND PITFALLS

Bleeding from the epidural venous plexus[12]	■ 1.5 mL of fibrin glue injected manually into the epidural space in both the cranial and caudal direction of the targeted vertebra after en bloc laminectomy helps reduce oozing from the epidural venous plexus.
Blunt dissection around the vertebral body	■ Careful step-by-step dissection with anatomic consideration is an important fundamental. ■ Preceding TES by a posterior approach, vessels around the vertebral body are managed anteriorly using thoracoscopy or a minimally open approach. This is safer than performing TES by a single posterior approach in a patient in whom the segmental artery(ies) may be involved by the tumor. ■ At lesions of L1 and L2, the diaphragm insertions should be dissected from the vertebral body before the lumbar arteries are dissected, because the segmental arteries run between the vertebral body and diaphragm insertion.[6]
Ligation of the segmental arteries	■ Ligation of the segmental arteries up to three vertebral levels, even including a branch of the artery of Adamkiewicz, may not affect the spinal cord evoked potentials and spinal cord function.[4,8,15]
Spinal cord injury	■ Mechanical damage to the neural structures, especially shifting aside, twisting, and hanging down or upward of the cord, should be avoided. ■ Spinal cord stretching causes irreversible mechanical damage. Excessive nerve root traction also damages the cord due to the root avulsion mechanism.
Risk of tumor cell contamination[13]	■ Double rinsing with distilled water and highly concentrated cisplatinum is recommended to eradicate contaminated cancer cells.
Spinal shortening	■ The posterior instrumentation is adjusted to compress the inserted vertebral prosthesis slightly (5–10 mm) to secure it as a final step of spinal reconstruction using TES. ■ This process of spinal shortening provides two important advantages: (1) increased spinal stability of the anterior and posterior spinal column; and (2) increased spinal cord blood flow, which is desirable to improve spinal cord function.[7]

POSTOPERATIVE CARE

- Suction drainage is used for 3 to 5 days after surgery.
- The patient is allowed to start walking within 1 week after surgery.
- The patient wears a thoracolumbosacral orthosis for 3 to 6 months until bony union is attained.

OUTCOMES

- From 1989 to 2003, 284 patients with spinal tumors (primary, 86 patients; metastasis, 198 patients) were surgically treated and followed for a minimum of 2 years.
- Total en bloc spondylectomy was performed in 33 of the 86 patients with a primary tumor; 17 patients with malignant tumors (3 osteosarcoma, 3 Ewing sarcoma, 3 plasmocytoma, 2 chondrosarcoma, and 1 case each of 6 other tumors) and 16 patients with aggressive benign tumors (4 patients with giant cell tumor, 3 patients with osteoblastoma, 3 patients with symptomatic hemangioma, and 1 case each of 6 other tumors).
- Five-year survival of the 17 patients with primary malignant spinal tumors (stages 1 and 2) who underwent TES was 67%, and that of the 16 patients with aggressive benign tumors (stages 2 and 3) was 100%.
- In the same periods, TES was performed in 64 of 198 patients with spinal metastases. Of the 64 cases with a metastatic tumor, the primary organs were as follows: kidney, 18 cases; breast, 15 cases; thyroid, 9 cases; lung, 4 cases; liver, 4 cases; and other carcinoma, 14 cases.
- Forty-three patients with the 2, 3, 4 points out of 64 patients who underwent TES resulted in 2-year survival of 66.6% and 5-year survival of 46.6%.
- Ninety-two of 97 patients (95%) had no tumor recurrence until death or last follow-up.
- Five of 97 patients (5%) had local recurrence; the mean length of the recurrence was 22.1 months after operation.
- In all five patients with local recurrence, the recurrence arose from residual tumor tissue.

COMPLICATIONS

- Excessive bleeding
- Injury of the major vessels during blunt dissection of the vertebral body
- Spinal cord injury
- Injury of lung or pleura
- Postoperative hematoma
- Liquorrhea
- Pleural effusion
- Chylothorax
- Instrumentation failure
- Infection, especially after preoperative radiation therapy

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