J Orthop Sci (2006) 11:3–12
DOI 10.1007/s00776-005-0964-y

JOURNAL OF
ORTHOPAEDIC SCIENCE

Invited review

Total en bloc spondylectomy for spinal tumors: improvement of the technique and its associated basic background

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Introduction

Conventionally, curettage or piecemeal excision of vertebral tumors has been commonly practiced. However, clear disadvantages of these approaches include a high risk of tumor cell contamination of the surrounding structures and residual tumor tissue at the site due to the difficulty of distinguishing tumor from healthy tissue. These factors contribute to incomplete resection of the tumor as well as high local recurrence rates of spinal malignant tumors.[1–3]

Roy-Camille et al.,[4,5] Stener,[6–8] Stener and Johnsen,[9] Sundaresan et al.,[10] and Boriani et al.[11,12] have described total corpectomy or spondylectomy for reducing local recurrence of a vertebral tumor, with excellent clinical results. Our own group has developed a new surgical technique of spondylectomy (vertebrectomy) termed total en bloc spondylectomy (TES).[2,3,13–16] Our technique is different from the spondylectomy mentioned above in that it involves en bloc removal of the lesion, that is, removal of the whole vertebra, both body and lamina as one compartment.

The TES procedure has been increasingly gaining recognition and is now widely accepted by spinal and musculoskeletal tumor surgeons a decade and a half after its development in 1989. This surgery is regarded as one of the most sophisticated and demanding operations; it requires a high level of technical ability and adequate knowledge and consideration of surgical anatomy, physiology, and biomechanics of both the spine and spinal cord. This level of understanding is not limited to oncological surgery but should be applied when surgically managing conditions of the spine and the spinal cord. The surgical skill of spine surgeons improves during the process of learning each step of these surgical techniques. A review of the developmental process of this operation leads to recognition of the tips, pitfalls, and solutions. We review here the principal concepts of TES for spinal tumors, as well as their related basic works that support the rationality of this operation.

Offprint requests to: K. Tomita
Received: August 4, 2005

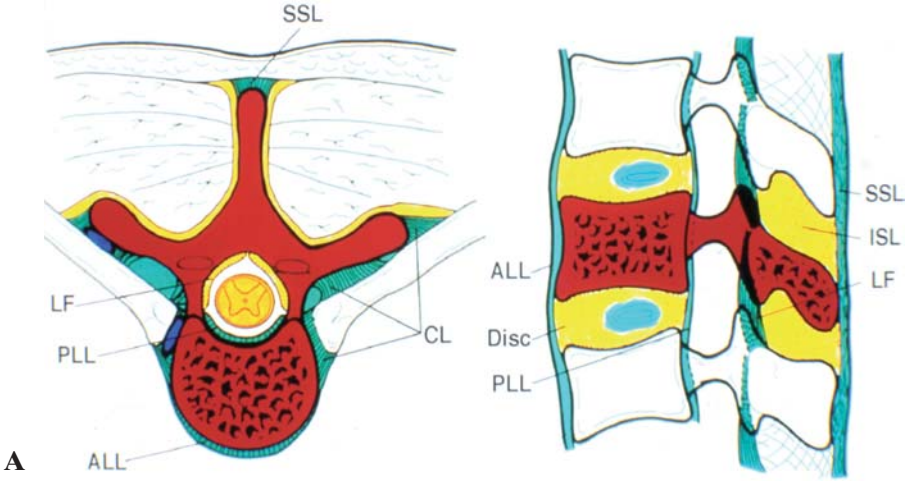
Principal concept

1. Oncologic concept of spinal tumors (compartment and barriers)

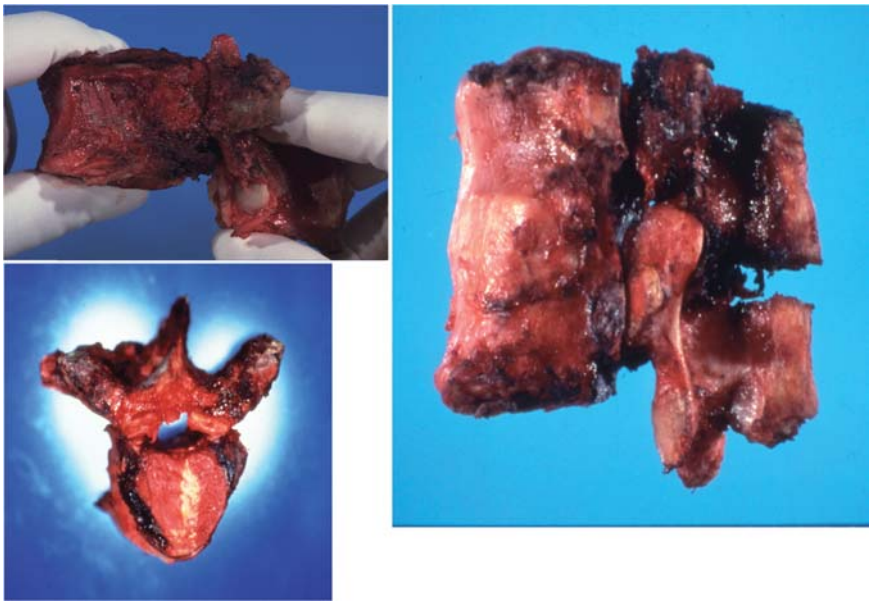
Enneking et al. examined the process of local spread of primary bone and soft tissue tumors of the extremities and proposed a "surgical staging system" and "the concept of compartment and anatomic barriers."[17] Applying this concept to the spine, we studied the histology of 19 vertebral tumor specimens resected by TES. We found that the following tissues served as barriers to spinal tumor progression;[1] the anterior longitudinal ligament (ALL), posterior longitudinal ligament (PLL), periosteum abutting the spinal canal, ligamentum flavum, periosteum of the lamina and spinal process, interspinous ligament, supraspinous ligament, cartilaginous endplate, and cartilaginous annulus fibrosus. However, both the PLL and the periosteum on the lateral side of the vertebral body were weak anatomical barriers. In contrast, the ALL, cartilaginous endplate, and annulus fibrosus were much stronger barriers.[1] We concluded that in the spine one vertebra could be regarded a single oncologic compartment and the above-mentioned surrounding tissues as barriers to tumor spread (Fig. 1).

2. Surgical classification of spinal tumors

We devised a surgical classification of spinal tumors[2,3] based on both the pattern of local vertebral tumor



A



B

Fig. 1. **A** Compartment and barrier. *SSL*, supraspinous ligament; *LF*, ligamentum flavum; *PLL*, posterior longitudinal ligament; *ALL*, anterior longitudinal ligament; *ISL*, interspinous ligament; *CL*, costotransverse ligament. **B** Specimens resected along with the compartment and barrier concept

progression and the type of surgery used to excise it. Primary or secondary malignant tumors frequently grow or settle in the middle posterior part of the vertebral body, from where they can easily extend to the posterior arch through the pedicles ("intracompartmental lesions, type 1, 2, and 3 lesions"). This tumor then generally grows outside the compartment (extracompartmentally) into the spinal canal (type 4) or extends outside of the vertebra (type 5) and finally to the adjacent vertebra(e) (type 6). "Multiple" (type 7 lesions) naturally implies multiple-skip lesions in the spinal column, which may be skipping, secondary, or tertiary metastases (Fig. 2).

A wide surgical margin or at least a marginal margin[1,17] is achievable around the affected vertebra when the lesion is intracompartmental (type 1, 2, or 3), particularly when the vertebra is cut at the healthy part of the pedicle or lamina. For type 4 or for a tumor invading the paravertebral areas (types 5 and 6), a marginal margin may be possible only if the lesion is well encapsulated with a fibrous reactive membrane.[1,17]

3. Surgical strategy for spinal tumors

1) Surgical strategy for primary spinal tumors

Surgical strategy for primary spinal tumors was modified from the Enneking concept of musculoskeletal tumors,[1] which is shown in Table 1. The main modification is that we make a distinction between the potential of local recurrence from residual tumor tissues and that from tumor cell contamination after tumor surgery. This is particularly clear in stage 3 of benign tumors such as the giant-cell tumor. Total tumor resection including the tumor capsule, whether in en bloc or

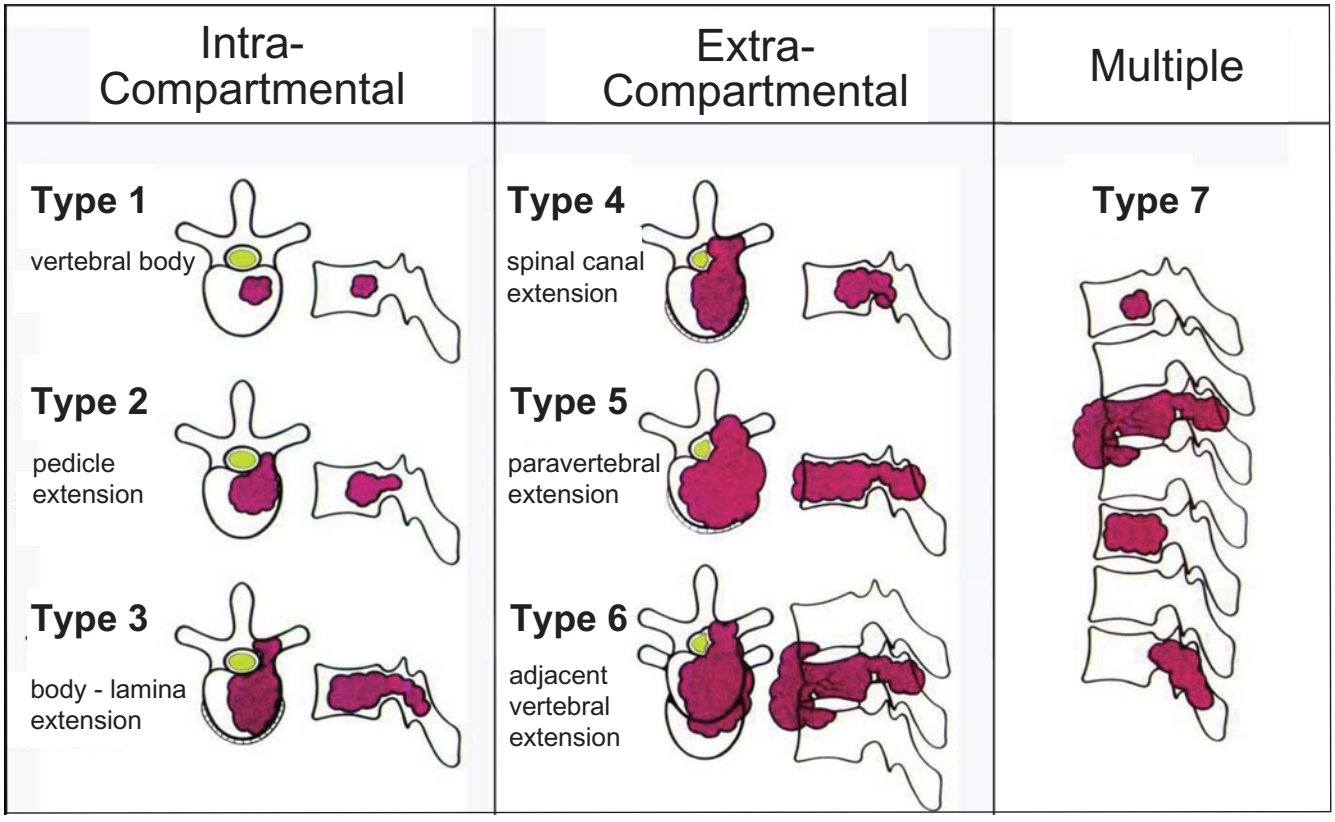


Fig. 2. Surgical classification of spinal tumors

piecemeal fashion, is mandatory; otherwise, local tumor invariably recurs from the residual tumor tissues left behind in this grade of tumors.

Salvage surgery for tumor recurrence in the spine causes great difficulty because recurrent tumor grows in the postsurgical scar tissue that adheres to the surrounding critical structures (e.g., dura, aorta, vena cava), in contrast to the long bones. Therefore, first time en bloc excision to include all tumor margins is most desirable to prevent local recurrence of malignant spinal tumors or even aggressive benign tumors, such as the giant-cell tumor.

2) Surgical strategy for spinal metastases

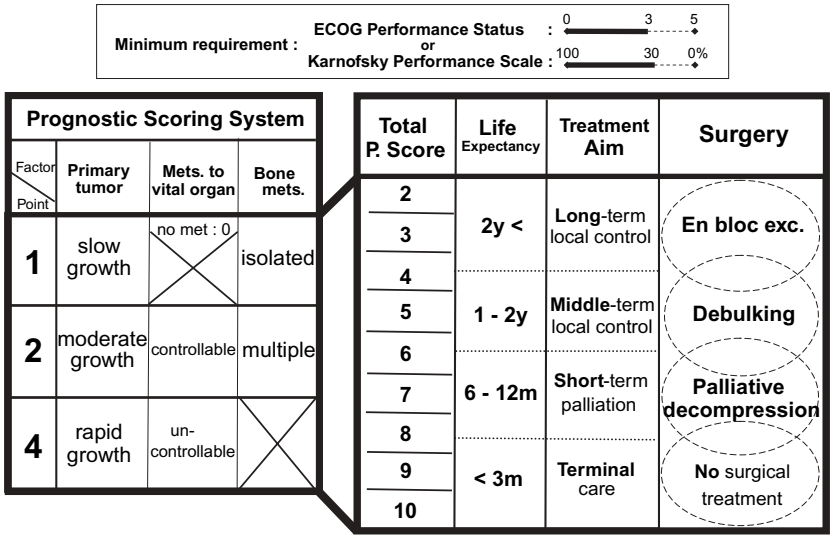
In the past, the indication for surgical management of spinal metastases was based on signs of neurological deficit, the presence of intractable pain, and spinal instability, as shown by Harrington.[18] Tokuhashi et al.[19] originally proposed a prognostic scoring system for preoperative evaluation of patients with metastatic spine tumors. We tried to take this approach one step further and proposed a surgical strategy for spinal metastases based on a prognostic scoring system to provide "rough but appropriate and practically easy" guidelines for the treatment in all patients with various histological varieties of spinal metastases (Fig. 3).[20]

When considering surgery for a patient with spinal metastasis, our prerequisite is a minimum of 3 points or less in the Eastern Cooperative Oncology Group (ECOG) performance status test[21] or 30% or more in the Karnofsky performance scale,[22] which are the same requirements for administrating chemotherapy. Our scoring system consists of three prognostic factors, which are regarded as the most influential factors for life expectancy. These scores are given by each hazard ratio: (1) pathological/clinical grade of malignancy (low grade/slow growth), 1 point; intermediate grade/moderate growth, 2 points; high grade/growth, 4 points); (2) visceral metastases (no metastasis, 0 points; treatable, 2 points; untreatable, 4 points); (3) bone metastases (isolated, 1 point; multiple, 2 points). These three factors are added together to give a prognostic score of 2–10 points. We found that neurological deficit is not be an influential factor for life expectancy, so, it is not counted. The treatment aim for each patient is set according to this prognostic score and life expectancy.[20]

After deciding on the surgical strategy for each patient along with the treatment aim, the extent of the spinal metastasis is stratified using "the surgical classification of spinal tumors." Finally, the most technically appropriate and feasible surgery is employed, such as en bloc excision, debulking (aggressive piecemeal exci-

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	OK / No	intralesional or marginal	Thorough excision (piecemeal / en bloc)
Malignant tumor:			
I. Low grade	No / No	marginal or wide (radical: impractical)	Total en bloc excision
II. High grade	No / No		
III. With metastases	No / No		



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: examples: Lung ca., Gastric ca., Esophageal ca., Nasopharyngeal ca., Hepatocellular ca., Pancreas ca., Bladder ca., Melanoma, Sarcoma (osteosarcoma, Ewing sarcoma, Leiomyosarcoma, etc), Other rare ca., Primary unknown metastasis

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

Fig. 3. Surgical strategy for spinal metastases

sion), palliative surgery (decompression), or no surgical treatment. This scoring system should be considered only as a guideline. The final treatment decision should be made on an individual case-by-case basis, taking the family's will into consideration.

Surgical technique of TES

Each step of the TES technique has been described in detail in several published articles.[2,3]

1. Surgical indications

The TES operation was designed to achieve oncological complete tumor resection en bloc including main and satellite microlesions in a vertebral compartment to avoid local recurrence. Primarily, lesions with the following pathologies are candidates: primary malignant tumor (stage I or II); aggressive benign tumor (stage 3); isolated metastasis with long life expectancy (Table 1, Fig. 3).

From the viewpoint of tumor growth (surgical classification), TES is recommended for type 3, 4, and 5

lesions; and it is relatively indicated for type 1, 2, and 6 lesions. Type 1 or 2 lesions can still be a candidate for radiotherapy, chemotherapy, corpectomy, or hemivertebrectomy. TES is not recommended for type 7 lesions; systemic treatment or hospice care may be the treatment of choice for these lesions (Fig. 2).[2,3]

2. Surgical approach

The TES technique consists of two steps including en bloc resection of the posterior element and en bloc resection of the anterior portion to salvage the spinal cord. In some cases, a small part (pedicle in most cases) becomes intralesional deliberately, but it must be unavoidable to salvage the spinal cord. The surgical approach is chosen based on the degree of tumor development or the affected spinal level.

1) Single posterior approach

We prefer a single posterior approach rather than a posteroanterior combined approach for TES above L4, when the tumor does not involve major vessels (most type 1, 2, 3, and 4 tumors and some type 5 and 6 tumors). The main advantage of this approach is that the spinal cord can be observed carefully throughout the procedure, especially during anterior spinal column osteotomy, corpectomy, and spinal reconstruction by posterior instrumentation.

2) Anteroposterior double approach

Anterior dissection followed by posterior TES is indicated for a type 5 or 6 tumor when it involves major vessels or segmental arteries. Nowadays, thoracoscopic or a mini-open approach is preferred for anterior dissection.[14]

3) Posteroanterior double approach

Posterior laminectomy and stabilization followed by anterior en bloc corpectomy and placement of vertebral prosthesis is indicated for spinal tumors at the level of L5 (L4) because of the technical challenge presented by the iliac wing and lumbosacral plexus nerves.[14]

Major risks and possible solutions

The major risks associated with the TES operation are (1) excessive bleeding; (2) injury of the major vessels during blunt dissection of the vertebral body; (3) spinal cord injury; (4) possible contamination by tumor cells especially intralesional cutting at the pedicle; (5) complete spinal instability resulting from spinal osteotomy. Possible solutions are described as follows based on our basic research.

1. How to reduce excessive bleeding

1) Preoperative embolization

Intraoperative bleeding is sometimes excessive in patients with hypervascular spinal tumors during TES surgery. There is no doubt that preoperative embolization of the feeding artery at the affected vertebra is mandatory, but it does not seem be sufficient to stop bleeding altogether. In a canine study, we found that when bilateral segmental arteries at three levels were ligated blood flow of the middle vertebra was reduced to 25% of that of the control group[23] while maintaining 80% of spinal cord blood flow. Moreover, spinal cord function was not damaged at all.[24]

Based on these data, not only a feeding artery alone but also segmental arteries above and below at three levels were embolized preoperatively.[23,24] Our clinical results showed that this embolization technique dramatically reduced intraoperative bleeding from the tumor-involved vertebra without compromising spinal cord function.

2) Hypotensive anesthesia

It has become common practice to manage relatively hypotensive anesthesia (systolic blood pressure 80–100 mmHg). This does not influence the spinal cord blood circulation as once was thought.

3) Fibrin glue tamponade into the epidural space

Bleeding from the epidural venous plexus is sometimes profuse. Meticulous hemostasis by tamponade in the epidural space using Oxycell cotton® or Aviten® is mandatory. We developed an additional hemostatic technique of epidural fibrin glue injection tamponade to reduce epidural bleeding. It was observed in rats[25,26] that the combination of the two solutions of thrombin and fibrinogen changes from sol to gel immediately after epidural injection and has a tamponade effect to reduce bleeding from the vertebral venous plexus. In clinical practice, 1.5 ml fibrin glue was manually injected into the epidural space in the craniocaudal direction of the targeting vertebra, respectively, using a silastic catheter just after en bloc laminectomy.[25] This helps reduce oozing from the epidural venous plexus.

2. How to avoid damage of major vessel and segmental vessels

Blunt dissection of the anterior part of the vertebral body is another risky maneuver during TES using a single posterior approach. Of course, careful step-by-step dissection is an important fundamental key, and each anatomical relation between the vertebra and the visceral organs, the major vessels, and the segmental arteries and its spinal branches should be well acknowl-

edged.[27–29] Based on our anatomical studies on cadavers, it became clear that the dissection is less likely to damage the thoracic aorta or azygos vein between T1 and T4. However, the segmental artery must be carefully detached and clipped anteriorly in areas caudal to T5 before manipulation of the affected vertebra. It might be helpful to remember the use of Prejet® patching over the pinhole of the aorta in a case of pulling out the segmental artery. With a lesion 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. Utmost care is necessary to dissect around the vertebral body in the lumbar spine because both the aorta and the vena cava are located close to and in front of the lordotic spine.

After all structures surrounding the vertebral body are dissected, the following processes are continued under the protection barricade by a vertebral spatula (recompartmentalization), which is also useful for limiting the amount of bleeding.

3. How to avoid spinal cord injury

1) Atraumatic handling of the spinal cord

The spinal cord compressed by a tumor is extremely delicate and fragile. It is common knowledge that one must avoid mechanical damage to the neural structures, especially shifting aside, twisting, and hanging the cord down or up. We also learned from spinal cord monitoring during surgery that stretching the spinal cord causes irreversible mechanical damage. Too much nerve root traction also damages the cord owing to root avulsion.

2) Circumferential (360°) spinal cord decompression

Spinal cord damage had been associated with circumferential spinal cord decompression and "suspension bridge" shape deformity after TES. However, we have had many patients with thoracic myelopathy caused by combined thoracic ossification of the posterior longitudinal ligament and the yellow ligament who had remarkable neurological recovery after circumferential spinal cord decompression.[30] It has been confirmed that spinal cord function does not fall into critical condition even if all the anatomical structures around the cord are removed. Encouraged by these experiences, the tumor compressing the cord is totally removed together with all barrier structures during TES. Spinal cord monitoring proved that there was remarkable improvement of spinal cord function after circumspinal decompression.

3) Ligation of the radicular artery and Adamkiewicz artery

Possible circulatory compromise after ligation of the radicular artery is another concern. In the cat model, we[16,31] found that ligation of the Adamkiewicz artery reduced spinal cord blood flow by approximately 81% of the control value, and this decrease did not affect spinal cord evoked potentials.[16,31] Woodard and Freeman[32] reported that animals (adult mongrel dogs) that underwent sectioning of one to four sets of adjacent nerve roots showed either no neurological deficits or the deficits were extremely transient; animals with five sets of adjacent nerve roots sectioned frequently showed transient neurological deficits.[32] It is because the blood supply of the spinal cord is protected by three arterial plexus layers: intercanal, dural, and pial arterial plexus. These structures compensate for the blood supply lost by ligation of one or two radicular arteries.[33] There has been no neurological degradation due to spinal cord ischemia in any of the 97 patients in this series who underwent TES.

4. Risk of tumor cell contamination/tumor tissue residue

1) T-saw cutting

To cut the vertebral bone sharply while reducing the risk of spinal cord and nerve root damage, we designed the T-saw.[34] It is composed of multifilament twisted stainless steel wires and has a smooth surface to cut bone with minimal damage to the surrounding soft tissue. Its diameter is 0.5 mm, so the cutting loss is negligible. The T-saw is used during pediculotomy for en bloc laminectomy and during anterior column osteotomy for en bloc corpectomy. This T-saw has now been improved as a "diamond T-saw" for easier cutting.

2) Residual tumor tissue and contaminated tumor cells

Residual tumor tissue and contaminated tumor cells are different entities from the viewpoint of oncological regrowth. Residual tumor is certain to regrow if it exists, whereas the potential of regrowth is low from contaminated tumor cells. Residual tumor tissue does not remain after TES with an adequate oncological margin, even if the tumor vertebra is divided into two blocks by the T-saw (anterior and posterior parts). However, the risk of tumor cell contamination does exist during this process.

The potential for tumor growth after "intralesional" cutting by a T-saw, Gigli saw, and scalpel was compared using nude mice.[35] The number of tumor cells attached was significantly less with the T-saw than with the Gigli saw or scalpel. Furthermore, most of the tumor cell debris created by the T-saw was fragmented and had low potential for regrowth. Hence, the incidence of

tumor regrowth after rubbing subcutaneous tissue with a tumor surface cut with a T-saw was less than that with a Gigli saw or a scalpel. These findings show that tumor recurrence is less likely after intralesional tumor cutting with a T-saw than with a Gigli saw or scalpel. The T-saw is thus a safer tool for intralesional tumor cutting than the Gigli saw or scalpel even when intralesional tumor cutting becomes necessary.[35]

3) Rinsing with distilled water and anticancer drug

Contamination might be minimal but still a possible cause of local recurrence after TES surgery. To eradicate contaminated cancer cells, a new local chemotherapy was developed: double-rinsing with distilled water and highly concentrated cisplatinum.[36] In an in vitro experiment, no tumor cells remained alive after they were exposed to distilled water for 2.5 min followed by highly concentrated cisplatinum (0.5 mg/ml) for 2.5 min. The reason is that osmosis of the tumor cell membrane is increased by contact with distilled water, and the permeability of the membrane to cisplatinum moving into the cytoplasm of the tumor cells is increased, resulting in eradication of contaminated tumor cells.[36]

We have experienced local recurrence in only 5 of 97 patients who underwent TES surgery. All of our local recurrences were at the edge of an unsuccessfully excised tumor margin, that is, from residual tumor tissue. Therefore, preoperative planning of the surgical margin is the most important factor for preventing local recurrence caused by residual tumor tissue.[1]

5. Spinal column instability

1) Spinal column reconstruction

The TES operation includes complete resection of the affected vertebra(e) and the surrounding musculoligamentous supportive tissues.[1] Primary rigid reconstruction is required for complete spinal instability.[37] The authors[38] investigated the stiffness of eight pedicle screws (L1–L5) with an anterior prosthesis alone [multilevel posterior instrumentation (MPI)] using finite element analysis. We concluded that the above reconstruction method was stable enough for primary fixation, but the reconstructed section might fail because of fatigue; therefore, biological bony fusion was required for long-term maintenance of stability.[39,40]

To achieve grafted bone union, rigid immobilization of the graft(s) is required.[41] At the same time, adequate stress must be transmitted to the grafted bone during the reparative period to stimulate the repair as well.[41] The balance between these two factors is most important.

The authors' experiment[39] shows that a reconstruction method using additional anterior instrumentation with posterior pedicle screws [single posterior and anterior instrumentation (SPAI) or multilevel posterior instrumentation with anterior instrumentation (MPAI)], shields stress on the cancellous bone inside the anterior prosthesis (a titanium mesh cage) to a greater degree than does the system using posterior pedicle screw fixation alone (MPI). Thus, a reconstruction method with no anterior fixation (MPI) might be better for allowing stress for remodeling of the bone graft inside the titanium mesh cage. Spinal reconstruction of MPI with an anterior titanium mesh cage with autogenous bone inside is employed in our series in expectation of long-term maintenance of stability by biological fusion.[39,40]

2) Spinal shortening

The posterior instrumentation is adjusted to compress the inserted vertebral prosthesis slightly to secure it during a final step of spinal reconstruction by TES. This process of spinal shortening contains two important advantages: (1) it increases spinal stability of the anterior and posterior spinal column and (2) there is an increment in spinal cord blood flow (SCBF), which improves spinal cord function. The safety limits and physiological effects of spinal shortening on the spinal cord were studied in dogs.[42] Acute spinal column shortening can be characterized into three phases.

Phase 1 (safe range): spinal shortening within one-third of the vertebral segment, which is characterized by no deformity of the dural sac or the spinal cord

Phase 2 (warning range): spinal shortening between one-third and two-thirds of the vertebral segment, which is characterized by shrinking and buckling of the dural sac and no deformity of the spinal cord

Phase 3 (dangerous range): spinal shortening in excess of two-thirds of the vertebral segment, characterized by spinal cord deformity and compression by the buckled dura

Our experiment revealed the interesting and important fact that spinal shortening within the safe range increases SCBF. As mentioned above, the posterior instrumentation is adjusted to compress the inserted vertebral prosthesis slightly during a final step of spinal reconstruction of TES. This maneuver results in slight spinal shortening, from 5 mm to 10 mm, which is within the safe range of the spinal shortening that leads to increased SCBF. Numerous authors have demonstrated that reperfusion of SCBF was of paramount importance for the recovery of spinal cord function after spinal cord injuries.[43–48] In our series, neurologically compromised patients had a significant recovery after circumspinal decompression and shortening of the spinal column in patients undergoing TES.[2,3,16] This may be partly due to

an increase of SCBF achieved by limited (phase 1 and 2) shortening.

Results

From 1989 to 2003, a total of 284 patients with spinal tumors (primary tumors in 86 patients; metastasis in 198 patients) had been surgically treated and followed for a minimum of 2 years at Kanazawa University Hospital. TES was performed in 33 of the 86 patients with a primary tumor; 17 patients with a malignant tumor (3 osteosarcomas, 3 Ewing sarcomas, 3 plasmocytomas, and 2 chondrosarcomas, among others); 16 with aggressive benign tumors (4 giant-cell tumors, 3 osteoblastomas; and 3 with symptomatic hemangiomas, among others).

The 5-year survival for the 17 patients with primary malignant spinal tumors (stages I and II) who underwent TES was 67%, and that of 16 patients with aggressive benign tumors (stages 2 and 3) was 100%.

During the same periods, TES was performed in 64 of 198 patients with spinal metastasis. Among the 64 patients with a metastatic tumor, the primary organ was the kidney in 18 cases, the breast in 15, the thyroid in 9, the lung in 4, the liver in 4, and others in 14. Debulking was primarily performed in 70 patients and palliative surgery (e.g., posterior decompression and stabilization) in 64 patients with spinal metastasis (Fig. 4). Altogether, 43 of the 64 patients with the prognostic sore of 2, 3, or 4 points who underwent TES had a 2-year survival of 66.6% and a 5-year survival of 46.6% (Fig. 5).

Of the 97 patients, 92 (95%) had no tumor recurrence until death or at last follow-up. Five patients (5%) had a local recurrence, and the mean interval from operation to the recurrence was 22.1 months. All five patients had the local recurrence from residual tumor tissue. In two patients the tumor extended farther into the adjacent level than we expected; in another two the tumor recurred from the dural area. Inadequate spinal osteotomy was performed followed by curettage of the remainder of the tumor in one patient.

There was no neurological deterioration postoperatively except in one patient who had hyperesthesia immediately after the operation resulting from distraction spinal cord irritation due to a large prosthesis. This patient recovered completely after immediate revision surgery with spinal shortening. Of the 32 patients with preoperative paraparesis, 23 improved neurologically by more than one grade using the Frankel grading system.

Excessive blood loss is often associated with TES. Blood loss during TES at the thoracic level of a single segment was 2800 ml on average during the early phase of our experience. After using epidural hemostasis by fibrin glue injection, it decreased to 2300 ml. Preoperative embolization of three segments reduced blood loss still more, to 1300 ml on average (360–1600 ml).

Spinal instrumentation failure after TES was experienced as rod breakage in two cases, screw breakage in one case, and dislodgment of the vertebral spacer (AWGC artificial vertebra) in one case. However, since titanium mesh cage has been applied as the vertebral spacer (beginning in 1995), we have not experienced dislodgement, and fusion of the grafted bone inside the cage has been demonstrated by three-dimensional computed tomography.

Conclusions and future perspectives

We have reviewed our challenging work on spinal tumor surgery for the last 15 years. Our starting-line message is that "spinal metastasis is not necessarily an

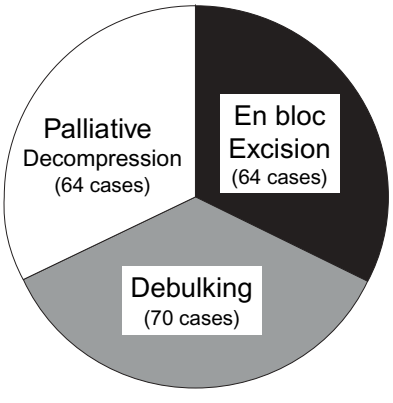


Fig. 4. Number of patients who underwent each surgery for spinal metastases (1989–2003). *TES*, total en bloc spondylectomy

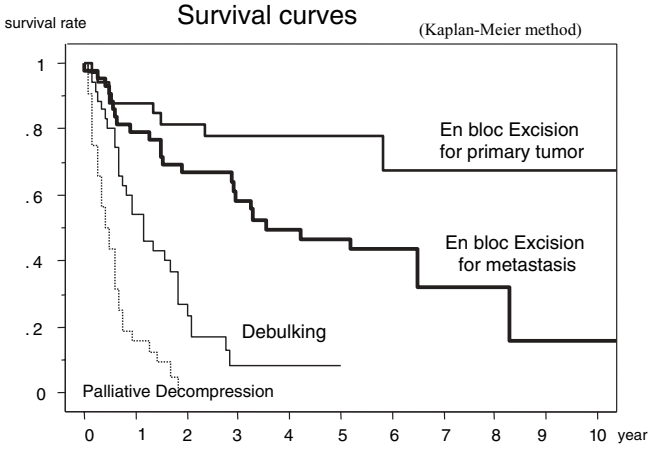


Fig. 5. Survival curves (Kaplan-Meier method)

end-stage condition even if the patient is already paraplegic"; and our key principle is that "first-time curative oncologic surgery is the most important of all." At the beginning, this goal seemed almost impossible to achieve for us as spinal surgeons preoccupied with preserving the cord. However, as oncologic surgeons we understood that en bloc removal of a vertebral tumor, whether primary or metastatic, was necessary at all costs. Hence, we had been in a dilemma whether to salvage spinal cord function at the cost of leaving residual tumor behind or remove the tumor radically to save life. Thus, TES has become one of the solutions and a milestone for us.

While establishing the validity of the TES procedure, we have faced many difficult problems scientifically and technically. Each time, however, we considered the problem "a top priority research theme" and started experiments and discussions until we found reasonable solutions[1–3,13–16,20,23,24,28,30,34,35,39,40,42] (published in 22 English-language articles).

At the beginning, TES surgery took more than 20 h to complete, and we struggled with more than 5000-ml blood losses. After refining our experience in many ways, it now only takes 6–8 h and 1300 ml of possible blood loss. Of course, we continue to improve this surgery — not only by devising surgical instruments but also looking for the possibility of applying techniques learned with minimally invasive surgery or endoscopic surgery.

We must remind ourselves that once there is local recurrence of a spinal tumor salvage revision surgery becomes extremely difficult or almost impossible. Therefore, successful first-time TES is the best option for the patient and should be performed if possible despite the technical difficulties faced.

At present, TES is regarded as one of the most demanding techniques among spine surgeons. It may be true, however, that as young surgeons learn this surgery step by step they will eventually master the surgery and apply it to all spinal conditions, such as deformity, trauma, infection, degenerative and multioperated back surgery, and spinal cord surgery. At best, without realizing, you find yourself "a real spinal surgeon to the back bone."

As medical science develops, the treatment for cancer will continue to progress. In future, effective adjuvant therapy will play a more important role than ever before, and survival of metastatic cancer patients will improve greatly. Eventually, the demand and the chance to treat spinal metastasis will increase. In such a circumstance it is ideal that a general disease and local lesion integrated multidisciplinary treatment strategy be established.

In the near future, local curative surgery such as TES will be indicated for an "apparent mass-sized spinal tumor" that is life-threatening regardless of whether it produces neurological or biomechanical symptoms. At the same time, aggressive curettage by minimally invasive surgery or endoscopic surgery may become another option supported by highly effective adjuvant therapy to treat residual tumor tissue, thereby avoiding local recurrence or tertiary metastasis. As a result, those patients may survive longer as well.

In patients with "smaller lesions" with no symptoms or signs, radiotherapy or interventional treatment will assume a main role as a local treatment. Stereotactic radiosurgery with such instruments as the Novalis® or Cyber-knife® will become more available. For "seed-sized disseminated foci or occult microscopic foci," more effective systemic treatment such as chemotherapy, hormonal therapy, immunotherapy, or gene therapy must play a major role.

Once we can apply all these treatment tactics more systematically and effectively, we can say to the patient that even the presence of multiple spinal metastases no longer represents a life-threatening disease or an end-stage condition.

Acknowledgments. The authors deeply thank all of the doctors in the Department of Orthopaedic Surgery of Kanazawa University who contributed to this work.

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