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Total Spondylectomy for Solitary Spinal Metastasis of the Thoracolumbar Spine: A Preliminary Report

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Abe, E., Sato, K., Murai, H., Tazawa, H., Chiba, M. and Okuyama, K. *Total Spondylectomy for Solitary Spinal Metastasis of the Thoracolumbar Spine: A Preliminary Report.* Tohoku J. Exp. Med., 2000, **190** (1), 33-49 —— Eight cases of solitary spinal metastasis with neurological deficit in thoracolumbar spine in which total en bloc spondylectomy (TS) was performed by bisecting the affected vertebra through both pedicles using fine thread wire saws were reviewed. Patient age ranged from 40 to 78 (mean, 62) years. Primary lesions were in the lung (2), kidney (2), thyroid (3) and prostate (1). TS was performed through a posterior approach in 5 cases (T6-7, T12, L2, L2 and L2-3) and through a one-stage anterior and posterior combined approach in the others (L2, L3 and L4). The spine was reconstructed with a ceramic vertebral prosthesis and a pedicle screw fixation system in 5 cases, and with augmented anterior spinal instruments in 3 cases. There were neither surgical complications nor surgical mortality. All patients became ambulatory and pain-free after surgery. Histologically, a marginal surgical margin was achieved in only one case. The other 7 cases had intralesional margin at the osteotomized pedicles. Four patients died from causes unrelated to local recurrence 4 to 44 (mean, 19) months after surgery. Effectiveness of surgery was maintained until death in all 4 of these patients. Asymptomatic local recurrence occurred in 2 patients with renal cancer at 10 and 33 months after surgery. These preliminary results suggest that TS for solitary spinal metastasis can achieve good control of local recurrence without major complications and is clinically acceptable surgery. ———— metastasis; vertebral tumor; total spondylectomy; en bloc resection; spinal instrumentation

As conventional surgical treatment for spinal metastasis with neurological deficit, palliative decompression and intralesional partial resection with radiation therapy and spinal stabilization have been the most common practice. As the life expectancy of patients with malignant tumor is prolonged by advances in on-

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cological treatment, the risk of local recurrence has been increasing continuously. Spinal instrumentation currently allows gross total resection and reconstruction at all levels of the spine.

Total spondylectomy (TS) with piecemeal resection of the tumor (piecemeal TS) was reported by Liévre et al. (1968), Magerl and Coscia (1988), Sundaresan et al. (1989) and Roy-Camille et al. (1990). However, piecemeal TS can result in tumor cell contamination, massive bleeding that is difficult to control, and incomplete resection. TS with en bloc excision of the tumor (en bloc TS) seems to promote more complete resection of the tumor than piecemeal TS, with good control of bleeding, decreased local recurrence and also possibly improve survival. Stener and Johnsen (1971), Stener (1989), Fidler (1994), Boriani et al. (1996b) and Tomita et al. (1997) have reported good results with en bloc TS for primary spinal tumors. However, en bloc TS is not generally used for spinal metastasis. In the present study, we reviewed 8 cases of en bloc TS for solitary spinal metastasis and discussed its clinical indications, surgical procedure, and local control of the tumor.

Subjects and Methods

Patients

The 8 patients were 3 females and 5 males, aged from 40 to 78 (average, 62) years at the time of surgery. The primary locations of spinal metastases were the kidney in 2 cases, the lung in 2 cases, the thyroid in 3 cases and the prostate in a case (Table 1). All the patients had preoperative neurological deficits. Five patients had single-level lesions, and 2 had two-level lesions. The level of the lesions ranged from T6 to L4 (T6-7, T12, L2, L2, L2, L2-3, L3 and L4). Preoperative examination revealed no other metastatic lesions in any of the

Table 1. *Details on 8 patients who underwent*

Case No.	Age (year) /Sex	Level	Origin	WBB Stage	Approach	Spinal reconstruction	Op. time (hours)
1	73/M	T6–7	Renal Ca.	4–11, ABCD	P	PS+AW	8.0
2	40/M	T12	Renal Ca.	5–7, ABC	P	PS+AW	10.5
3	66/F	L2	Lung Ca.	8–12, ABCD	P	PS+AW	8.5
4	63/M	L2	Prostate Ca.	4–7, ABCD	A and P	PS+K+AW	9.8
5	52/M	L3	Thyroid Ca.	5–11, ABCD	A and P	PS+K+AW	9.5
6	78/F	L4	Lung Ca.	2–8, ABCD	A and P	PS+Z+AW	9.0
7	67/M	L2	Thyroid Ca.	2–10, ABCD	P	PS+AW	9.2
8	58/F	L2–3	Thyroid Ca.	2–10, ABCD	P	PS+AW	8.5

WBB stage, Weinstein-Boriani-Biagini staging system; Local rec., local recurrence; monal therapy; Neurological grade, modified Frankel scale by Bradford (1987); Renal Ca., fixation; K, Kaneda device; Z, Zielke instrumentation. *The period after surgery until

patients at the time of surgery on ^{99m}Tc bone scintigraphy and MR imaging. The primary lesion had already been resected in 3 cases and could be resected surgically in the others. Hormonal therapy was performed in one prostate cancer case, and irradiation (40–50 Gy) was administered in the others, before surgery in one case and after surgery in 6 cases.

The spinal lesion was classified according to the Weinstein-Boriani-Biagini (WWB) staging system (Boriani et al. 1996a), in which the vertebrae in the transaxial plane are divided into 12 radiating zones (numbered 1-12, clockwise) and into 5 layers (A-E from the paravertebral to the dural involvement), and a tumor is identified by the number of sectors occupied, the letters of the layers involved, and the vertebrae involved in its longitudinal extent. The numbers 5 to 8 include the vertebral body; 4 and 9 include the pedicles; 3 and 10 include the transverse process; 1, 2, 11 and 12 include the lamina and spinosus process; 1 to 6 indicate the left side; and 7 to 12 indicate the right side. The letter A indicates extraosseous soft tissue tumor extension; B indicates intraosseous (superficial) extension; C indicates intraosseous (deep) extension; D indicates epidural extension; and E indicates intradural extension.

Spinal pain was evaluated by Denis' pain scale (Denis et al. 1984; Table 2). Neurological assessments were made according to the modified Frankel grading system, supplemented by manual muscle tests and bladder function assessments (Bradford and McBride 1987). All the resected vertebrae were subjected to a histological study of the surgical margins. The patients were followed up for 1 to 5 years, except the four who died. Local recurrence, including subclinical stages, was evaluated by plain x-rays, CT scans and MR images.

total spondylectomy of solitary spinal metastasis

Bleeding (ml)	Ajuvant therapy	Emboli-zation	Neurological grade	Pain scale	Local rec. (year)	Final follow-up (year)
			Preop/Postop	Preop/Postop		
1200	RaAS (40 Gy)	No	D2/E	P5/P1	+ (0.8)*	Dead 1.0
2120	RaBS (45 Gy)	+	D3/E	P4/P2	+ (2.8)*	Dead 3.8
1800	RaAS (40 Gy)	No	D3/E	P5/P2	No	Dead 1.2
2660	Hormonal T	No	D1/E	P5/P1	No	Alive 6.5
2286	RaAS (45 Gy)	+	D2/E	P4/P1	No	Alive 6.5
1511	RaAS (45 Gy)	No	D2/E	P5/P2	No	Dead 0.3
3100	RaBS (45 Gy)	No	D3/E	P4/P1	No	Alive 1.2
3550	RaAS (45 Gy)	No	D1/D3	P5/P1	No	Alive 1.0

RaBS, radiotherapy before surgery; RaAS, radiotherapy after surgery; Hormonal T, horrenal cancer; P, posterior; A and P, anterior and posterior combined; PS, pedicle screw asymptomatic local reccurrence was detected for the first time by CT or MRI.

Surgical procedure

En bloc TS was performed in 3 cases via the posterior approach (posterior en bloc TS) for lesions in T6 to L2 and in 5 cases via the one-stage anterior and posterior combined approach (combined en bloc TS) for L2 to L4 lesions. With the combined method, first the posterior then the anterior approach was taken.

Posterior en bloc TS. This procedure is the same as Tomita's method (Tomita et al. 1994). Namely, posterior component and lateral components of the spine were removed en bloc by pediculotomy using a fine thread wire saw 0.54 mm in diameter designed by Tomita et al. (1994) (Koshiya, Kanazawa). However, if the unilateral pedicle was affected by the tumor, osteotomy was performed through a neighboring healthy lamina, and the cut surface was blocked with bone wax immediately after osteotomy. If there was tumor invasion into the bilateral pedicles and the pedicle and lamina, a knife of electric cautery was inserted into the affected pedicle and coagulated tumor tissue inside the pedicle before pediculotomy in order to prevent tumor cell contamination by pediculotomy. In these cases, the nerve root involved sometimes had to be ligated and cut, and the dura pulled to the healthy side. After removal of the posterior bony column, meticulous coagulation of the epidural and foramonal vessels was performed by bipolar diathermy. En bloc resection of the residural vertebral body was performed the same method as Tomita's procedure.

Spinal reconstruction for posterior en bloc TS was performed by replacement of the vertebral body using an apatite-wollastonite glass ceramic (AWGC) vertebral prosthesis (Lederle, Tokyo) and posterior stabilization according to the principle of "two above, two below" using a Cotrel-Dubosset (CD) pedicle screw system (Sofamor Danek, Memphis, TN, USA). Bone graft harvesting from fibula was performed in the interlaminar space (Fig. 1).

Combined en bloc TS. In L3 and L4 vertebral tumors, en bloc TS was performed through the one-stage anterior and posterior combined approach. The posterior procedure used was similar to Tomita's method (Tomita et al. 1994). After removal of the posterior bony column, the psoas muscles with segmental vessels were dissected as anteriorly as possible on the contralateral side of the anterior approach. The posterior longitudinal ligamentum and the posterior and contralateral part of the adjacent intervertebral discs were cut through the posterior approach. After posterior stabilization according to the principle of "one above, one below" using a pedicle screw system, the anterior procedure, including en bloc corpectomy and reconstruction of the anterior column, was performed by replacement of the affected vertebral body using an AWGC vertebral prosthesis and a Kaneda device (Mizuho, Tokyo) or Zielke's instrumentation (Ulrich, Ulm, Germany). The anterior fixation area included one vertebra above and one below the affected vertebra.

Postoperative management

After one week, when the general condition of the patient had improved, ambulation was allowed according to patient tolerance and paraparesis. Patients with lumbar lesions wore a fabric corset until adequate protective muscle tone was attained.

Results

Table 1 provides the details on each patient. All the vertebrae were resected completely. In each case, there was no visible tumor spill. Bone cementing around the posterior instrument was performed in one osteoporotic spine (Case 3). The other 7 patients received bone grafting (fibula or resected ribs). The duration of surgery ranged from 8.0 to 10.5 (mean, 9.1) hours. Blood loss varied from 1200 to 3550 (mean, 2277) ml. There was no significant difference in blood loss and surgical time between posterior en bloc TS and combined en bloc TS. There were neither significant complications nor bleeding that was difficult to control. Programmed sacrifice of the involved nerve roots was performed in 4 cases without obvious functional deficit.

The final follow-up of the 4 living patients was 1.0 to 6.0 years (mean, 3.6). Two died from causes unrelated to the tumor 4 and 12 months following surgery (Cases 1 and 6), and 2 others died from multiple metastases 44 and 15 months after surgery (Cases 2 and 3). There was also no instrument failure including loosening of screws or major dislodgment of the artificial vertebral prosthesis at the final follow-up examination. The grafted bone was fused completely in all 6 cases. Five patients with a P5 Denis' pain score attained P1 or P2 after surgery. Three patients with P4 attained P2 or P1. Spinal pain was well controlled in all patients throughout the follow-up or until death. Six patients with neurological involvement showed complete recovery from class D_{1-3} before surgery to class E after surgery, and one recovered from D_1 to D_3.

In the histological assessment of the surgical margin of the resected specimens, the vertebral bodies showed a marginal margin in 6 cases and a wide one in

Table 2. *Denis' pain scale*

Grade	Criteria
P1	No pain
P2	Occasional, minimal pain; no need for medication
P3	Moderate pain, occasional medication, no interruption of work or ADLs
P4	Moderate to severe pain, frequent medication, occasional absence from work, significant change in ADLs
P5	Constant or severe incapacitating pain, chronic medication

From Denis et al. (1984)
ADL, activities of daily living.

2 cases in the horizontal plane; the pedicles showed an intralesional one in 7 cases and a wide margin in one; the transverse process showed a wide margin in 2 cases, marginal in 5 cases and intralesional in one case; the lamina and spinous process exhibited a marginal margin in 6 cases and a wide one in the other 2. The upper margin of the lower end of the vertical plane was wide in all patients (Table 3). Local recurrence was detected in renal cancer (Cases 1 and 2) at the site of extravertebral tumor extension in the anterior column (layer A and zone 5–8 as classified by WWB system), but was asymptomatic until death. The surgical effectiveness in the 6 survivors persisted for 1.0 to 6.5 years (mean, 3.8 years). The rate of local recurrence of posterior en bloc TS for the tumor extended layer A was 40% (2/5 cases).

Case Reports

Case 1

A 73-year-old man with a 3-month history of severe back pain. Tomograms showed a T6 vertebral tumor with an osteolytic lesion and disappearance of the vertebral body. MR images demonstrated tumor extension into the spinal canal (Fig. 2A). CT scans showed that the osteolytic lesion occupied the vertebral body, pedicles and lamina and extended out of the right vertebral body (Fig. 2B), and the extent of the lesion was zone 4–11, layer ABCD as classified by the WBB system. The histology of the transpedicular open biopsy samples was of clear cell carcinoma. Posterior en bloc TS of the involved T6–7 vertebrae was performed (Figs. 1A, 1B and 1C). The bilateral 6th nerve roots were sacrificed for en bloc resection of the anterior column. Surgical margin was marginal except at the T6 pedicles (Figs. 2C and 2D). Spinal reconstruction was performed by replacement of the vertebral body with an AWGC vertebral prosthesis and pedicle screw

Table 3. *Histological assessment of surgical margins of the resected specimen*

Case No.	Horizontal Plane					Vertebral plane		Local recurrence	Final follow-up (year)
	Vertical body	Pedicle	Transverse process	Lamina and spinous process	Spinal canal	Upper end	Lower end		
1	M	I	M	M	M	W	W	+	1.0
2	M	W	W	W	W	W	W	+	3.8
3	M	I	M	M	M	W	W	No	1.2
4	M	I	W	W	M	W	W	No	6.5
5	W	I	I	M	M	W	W	No	6.5
6	M	I	M	M	M	W	W	No	0.3
7	W	I	M	M	M	W	W	No	1.2
8	M	I	M	M	M	W	W	No	1.0

W, wide margin; M, marginal margin; I, intralesional margin.

fixation from T4 to T9 (Fig. 1D). The patient recovered completely from his neurological disturbance, and bone fusion around the vertebral prosthesis was accomplished (Fig. 2E). At 9 months after surgery, asymptomatic local recurrence was found at the site of the tumor extension outside the affected vertebral body (zone 8-9) on MR images. He died of causes unrelated to the cancer or surgery one year after surgery.

Case 4

A 63-year-old man with a one-month history of lower back pain, bilateral leg pain and motor weakness. Plain radiograms, MR images and CT scans revealed an L2 pathological fracture with mixed osteolytic and osteoplastic lesions and extension into the epidural space (Figs. 3A and B). The location and extent were classified as zone 4-7 and layer ABCD by the WBB staging system. Combined en bloc TS was performed. Histological examination revealed prostate cancer. Spinal reconstruction was performed by replacement of the vertebral body with an AWGC prosthesis and fixation with a Kaneda device and pedicle screw system. The surgical margin was marginal except for the pedicles. He recovered completely from neurological disturbance and was free from symptoms without local recurrence at the 6-year follow-up visit (Fig. 3C).

Discussion

Conventional incomplete resection of spinal metastasis has a high incidence of local recurrence and reduced effectiveness of surgery. Sundaresan et al. (1986) reported that the rate of local recurrence of malignant spinal tumors was more than 80% after decompressive laminectomy and curettage of the tumor, and paralysis caused by local recurrence induced fatal complications. King et al. (1991) reported that symptomatic tumor recurrence occurred in 49% of 33 patients with spinal metastases from renal cancer at an average of 5 months postoperatively. The main cause of failure was recurrence in the posterior component when anterior corpectomy had been performed and in the anterior component after posterior laminectomy. Hosono et al. (1995) reported that local recurrence of corpectomy in 84 patients with spinal metastasis was observed in 24% (20/84) at an average follow-up period of 26.2 months. Prolonged life expectancy of patients with malignant tumors due to advances in oncological treatment increases the risk of symptomatic local recurrence after conventional incomplete resection of spinal metastasis. Recently, Sundaresan et al. (1989) reported that piecemeal TS extended the average life expectancy of patients with spinal metastasis more than 2 years. In our opinion, since piecemeal TS can result in tumor cell contamination, massive bleeding that is difficult to control, and incomplete resection, en bloc TS is a much more effective treatment for the control of local recurrence.

The greatest disadvantage of Tomita's en bloc TS (Tomita et al. 1994) is that the affected vertebra must be divided into 2 blocks at least, often resulting in an intralesional surgical margin in the osteotomized pedicle. In our series, 7 of 8

patients had an intralesional margin at the osteotomized pedicle. Tomita et al. (1994) also reported that the surgical margins of posterior en bloc TS were intralesional at the osteotomized pedicles in all 20 cases. However, local recurrence in this area was not detected in any case in our series or in Tomita's series at follow-up studies from 3 to 30 months (mean, 13 months) after surgery. Although local recurrence was detected in 2 renal cancer cases in our series, they did not originate from the osteotomized pedicle, but the anterolateral side of the vertebral body, whose surgical margin was marginal.

There is controversy over the best surgical approach for TS for lesions in which the tumor extends to the anterior and posterior columns. Roy-Camille et al. (1990) reported that posterior en bloc TS in the lumbar spine was unfeasible because it is the origin of the psoas muscle and in close proximity to the major abdominal vessels. Stener (1990) reported posterior en bloc TS for lesions at L3 or the cephalad, and combined en bloc TS at L4. Tomita et al. (1994) reported that posterior en bloc TS was possible even at L4. We successfully performed posterior en bloc TS for lesions at T6-7, T12, L2, and L2-3, and combined en bloc TS for lesions at L2, L3 and L4. However, sacrifice of the nerve root was necessary in 4 of 5 cases of posterior en bloc TS, and longer fusion is always necessary, that required for combined TS for stable spinal reconstruction. Since the L3 and L4 vertebral bodies are larger than the vertebrae of the rostal side, the risk of nerve root injury is high when it is rolled out around the dural tube between the nerve roots. Although sacrifice of the single nerve root above the L2 level is not accompanied by serious neurological deficits, sacrifice of the L3 or L4 nerve root seems to result in serious deficits. It seems to be important to reserve motion segments in the lower lumbar spine by minimal segmental fusion. Moreover, there are limitations to the lateral exposure of the lower lumbar spine due to the bilateral iliac bone. For these reasons, we believe that a good indication for posterior en bloc TS is upper lesions above L3, and that for combined en bloc TS is L3, L4 and L5 lesions. When the vertebral tumor is growing outside the anterior circumference of the vertebral body (layer A in the WBB staging system), we need to choose combined en bloc TS at any spinal level lesion in order to excise the affected vertebra including the segmental vessels, because the rate of local recurrence of posterior en bloc TS was as high as 40% in our series. Althogh the pleura and psoas muscles were easily dissected by marginal margin, the segmental vessels were closer to the tumor and highly involved in the tumor and difficult to be excised with the tumor.

Some spinal surgeons are concerned about a blind approach to the main vessels and their branches, exposing to the risk of intraoperative complication, particularly when fibrous adhesive changes are found in the tumor pseudo capsule during posterior en bloc TS procedure. We found that wide lateral exposure around the affected vertebrae makes the blind point small and allows easy access to control bleeding in the anterior site of the vertebral body. Other surgeons are

concerned about impairing blood supply to the spinal cord and the neurological complications thereof. However, bilateral ligation of segmental arteries in one or two spinal segments in our 8 cases caused no neurological complications. No such complications in TS in 88 patients were reported (Magerl and Coscia 1988; Stener 1989; Sundaresan et al. 1989; Roy-Camille et al. 1990; Fidler 1994; Tomita et al. 1994, 1997; Boriani et al. 1996b; Grunnenwalt et al. 1996).

Early ambulation after surgery without external support seems to be extremely important for patients with spinal metastasis with a limited life expectancy. We achieved spinal reconstruction to make early ambulation possible using a vertebral spacer with "two above, two below" pedicle screw fixation or "one above, one below" anterior-posterior combined spinal instrumentation. Recently, this spinal reconstruction has proven to be proper in in vitro biomechanical studies (Vahldiek and Panjabi 1998; Oda et al. 1999).

Although resection completely outside the tumor capsule was difficult in most cases by this type of en bloc TS, this procedure is valuable for minimizing local recurrence without major complications. Since en bloc TS is major surgery, it seems to be important to choose the indication carefully. We believe that the following criteria should be satisfied: Solitary spinal lesion localized to one or two contiguous levels; no metastasis to any other vital organ; no spread into adjacent visceral organs, including the intradural area, vena cava or aorta; and a physical condition good enough to tolerate major surgery. Two patients with lung cancer in our series died at 0.3 and 1.2 years after surgery. Tomita et al. (1994) reported that 2 of 3 patients with lung cancer died at 3 months after posterior en bloc TS. Hosono et al. (1995) reported that half of 8 patients with lung cancer died within 6 months after surgery. Therefore, we would hesitate to recommend en bloc TS for spinal metastasis of lung cancer.

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Illustrations follow

Fig. 1. Surgical procedure through the posterior approach alone for T6 spinal metastasis.
(A) Intraoperative photograph showing the dural tube and the two involved vertebre isolated with curved vertebral retractors after removal of the posterior column by pediculotomy and insertion of the pedicle screws into the upper and lower vertebrae. (B) Tomita's fine threadwire saws were passed underneath the anterior spinal column, and the spinal column was stabilized by connecting a right unilateral rod to the upper and lower pedicle screws before cutting through the adjacent upper and lower intervertebral discs. (C) The resected vertebre were removed by rotating them around the spinal cord. (D) Posterior spinal reconstruction was achieved by replacement of the affected vertebral bodies and onlay fibula grafts and a CD pedicle screw fixation system.

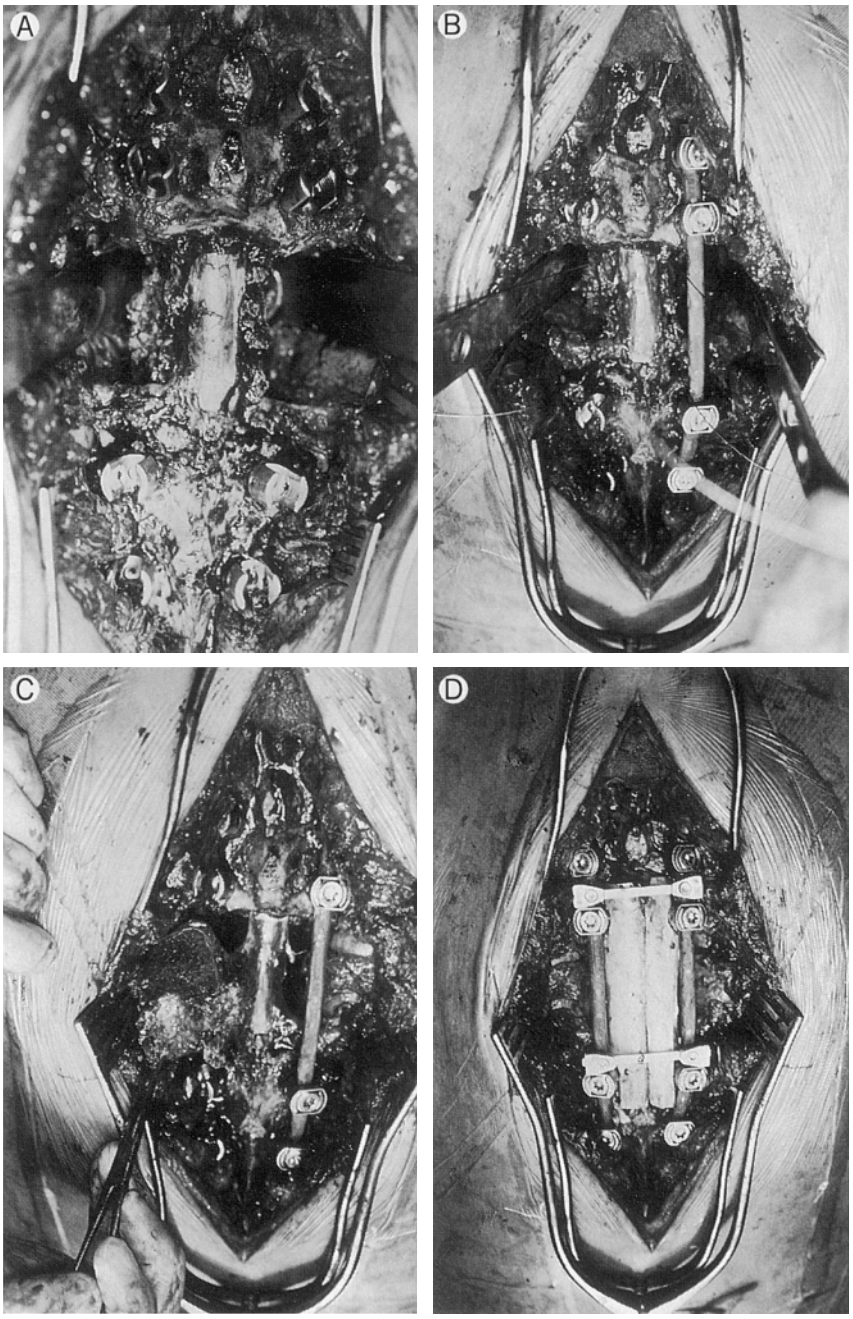
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Fig. 2. Case 1, T6 metastasis of renal cancer.
(A) T1-weighted MR image showing posterior tumor extension into the spinal canal. (B) CT scan demonstrates a tumor involving the vertebral body, both pedicles, the lamina and right lateral extension outside the vertebral body. (C, D) Lateral and axial radiographs of the resected T6–7 vertebrae, including the lower endplate of the T5 vertebra. (E) AP radiograph at 10 months after surgery showing fusion of bone graft around the ceramic vertebral prosthesis.

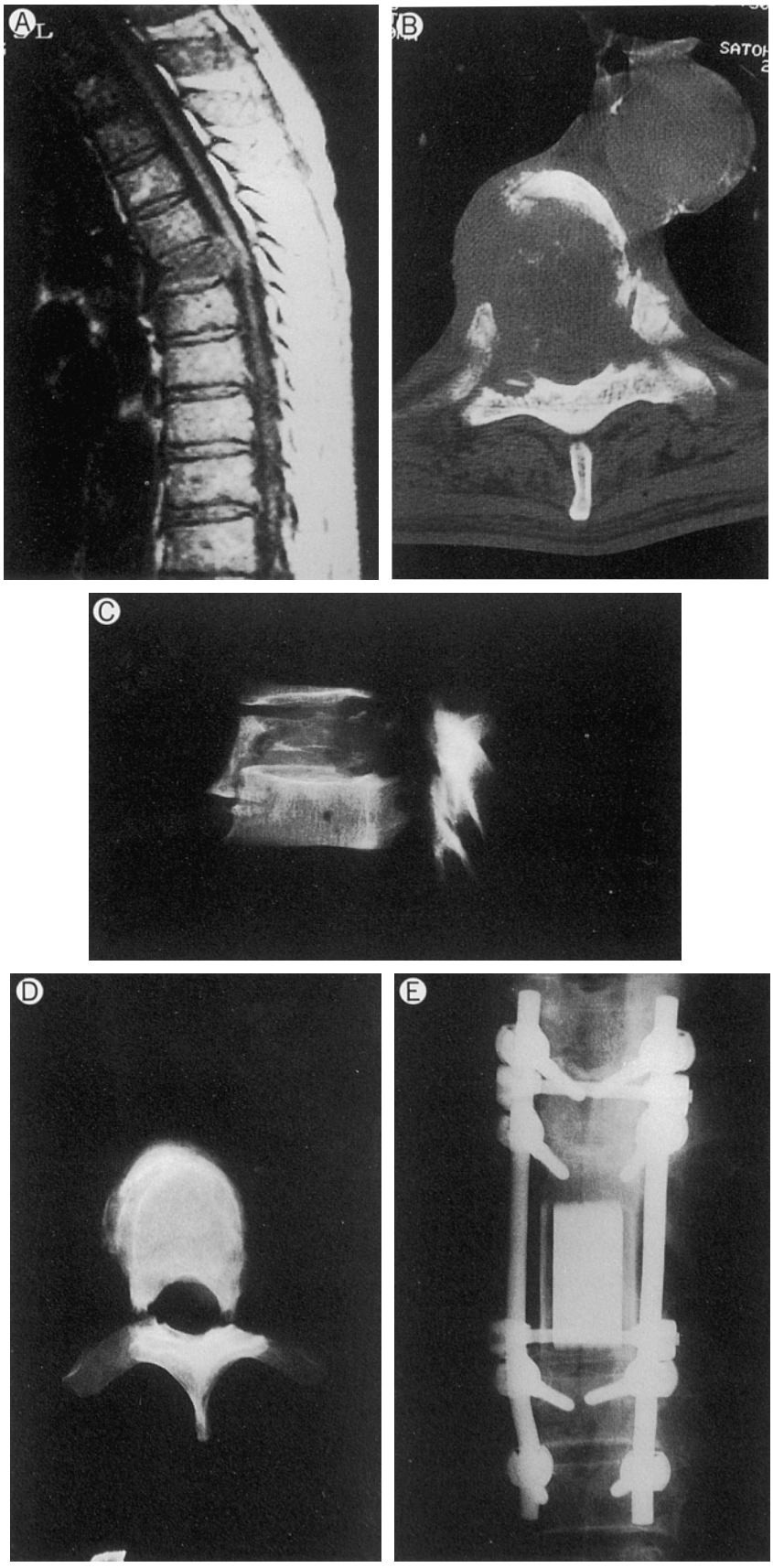
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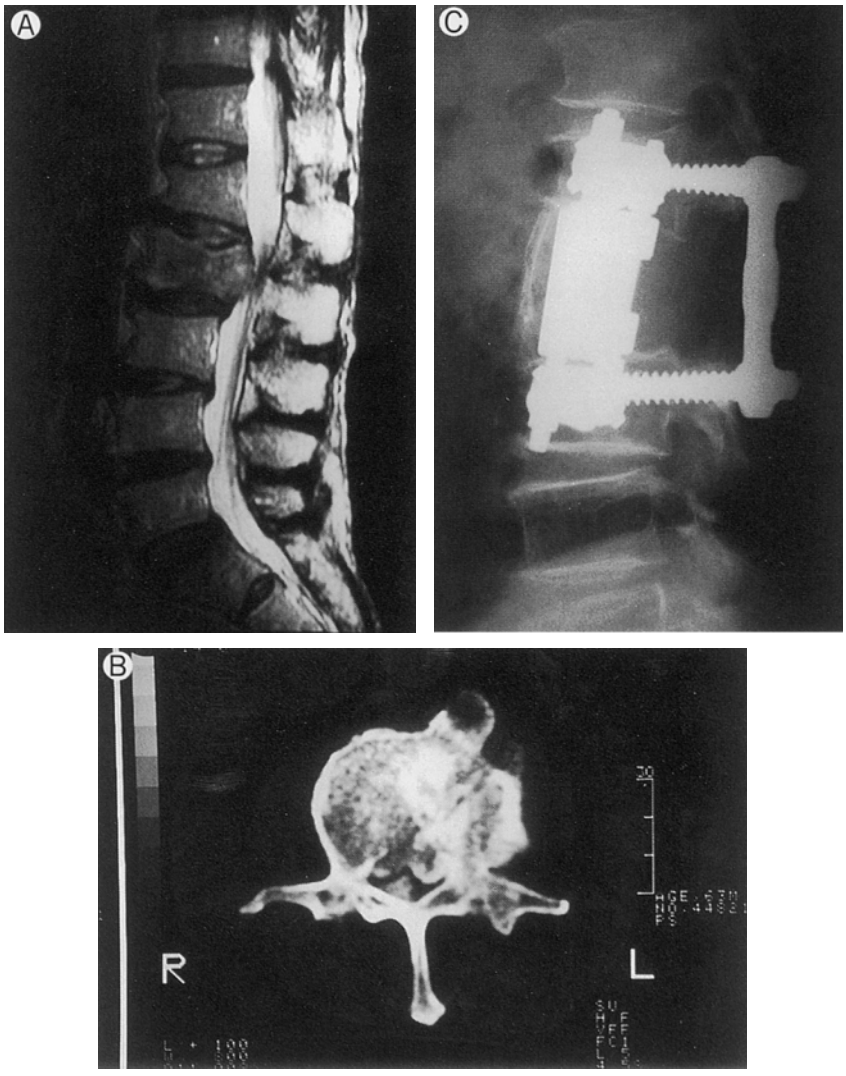
Fig. 3. Case 4, L2 metastasis of prostate cancer.
(A) T2-weighted MR image showing L2 vertebral tumor with epidural extension. (B) CT scan of the involved vertebra showing an osteoplastic lesion in the vertebral body with intracanal and left extravertebral extension. (C) AP and lateral radiograph at 6-year follow-up shows solid bone fusion around the AWGC vertebral prosthesis with an anterior Kaneda device and a pedicle screw fixation system.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