International Orthopaedics (SICOT) (1994) 18: 291–298

International
Orthopaedics

Total en bloc spondylectomy for solitary spinal metastases

K. Tomita, N. Kawahara, H. Baba, H. Tsuchiya, S. Nagata, and Y. Toribatake

Department of Orthopaedic Surgery, School of Medicine, Kanazawa University, 13-1 Takaramachi, Kanazawa, Ishikawa 920, Japan

Accepted: 8 March 1994

Summary. *We have developed a technique for total en bloc spondylectomy through a posterior approach and now report our experience of 20 patients with a solitary or localised metastasis in the thoracic or lumbar vertebrae. There are two steps: an en bloc laminectomy, followed by en bloc resection of the vertebral body with an oncological wide margin and the insertion of a vertebral prosthesis. Pain was relieved in the 17 patients who could be assessed; 11 of the 15 patients with a neurological deficit were much improved, impending paralysis being prevented in 5 patients. There have been no local recurrences. Nine patients are at present alive with a mean follow up of 17.4 months.*

Résumé. *Nous avons mis au point une technique chirurgicale de spondylectomie totale par voie postérieure. Nous présentons ici notre expérience de 4 ans portant sur 20 patients ayant des métastases localisées sur une vertèbre dorsale ou lombaire. Notre spondylectomie est une résection radicale de la vertèbre en deux parties, avec une large marge oncologique, afin d'obtenir la guérison locale. Elle s'effectue en deux étapes: 1) laminectomie en bloc avec instrumentation rachidienne postérieure pour la stabilisation, 2) corporectomie en bloc et remplacement par une prothèse vertébrale. Onze des 15 patients ayant des déficits neurologiques ont présenté une amélioration remarquable, et un soulagement de la douleur a été obtenu dans les 17 cas évaluables. Une paralysie imminente a pu être évitée chez 5 malades. Il n'y a eu aucune récidive tumorale locale après l'intervention. Neuf patients sont actuellement en vie, avec un recul moyen de 17.4 mois. Ces résultats cliniques prouvent que la résection radicale en bloc d'une métastase rachidienne localisée ou isolée peut constituer une stratégie thérapeutique efficace.*

Introduction

The spine is one of the most frequent sites for metastases from carcinoma. Formerly, the patients were considered to be in the terminal stages of their disease and surgical treatment, such as spinal cord decompression or stabilisation of the spine by instrumentation, was palliative. The use of MRI and CT scanning has made earlier diagnosis possible and, because there is improved survival with chemotherapy and irradiation, aggressive surgery for limited metastases may be beneficial.

New techniques in spinal surgery, reliable instrumentation and vertebral prostheses together with spinal cord monitoring have encouraged the development of a radical surgical procedures. In this paper we present our technique of total en bloc spondylectomy through a posterior approach which we have used in 20 patients.

Patients and methods

The indications for the surgical treatment of spinal metastases are the signs of a neurological deficit, intractable pain and spinal instability. The oncological factors to be considered include the success of treatment of the primary tumour, whether the metastases are solitary and localised, if the metastases are limited and can be controlled, and if there is a life expectancy of at least 6 months. The extent of the lesion in the

Reprint requests to: K. Tomita

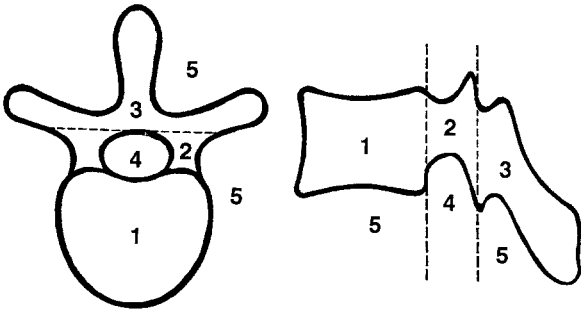

Fig. 1. Anatomical regions of a vertebra: *1*, vertebral body; *2*, pedicle; *3*, lamina, spinous process; *4*, epidural space; *5*, paraspinal area

vertebra is important and we have developed a classification of vertebral tumours similar to the surgical staging of musculoskeletal tumours of the extremities. It derives partly from Enneking's system for the grading of skeletal resections, Denis's three column theory [1], and Weinstein's surgical approach by zone classification [13, 14].

The vertebra is divided into 5 anatomical areas (Fig. 1), (1) the vertebral body, (2) the pedicle, (3) the lamina, the transverse and spinal processes, (4) the epidural space, and (5) the paraspinal area. The progression of any solitary vertebral tumour or metastasis is determined by the involvement of these sites.

The classification consists of 7 types (Fig. 2) which is based on the most common patterns of longitudinal and horizontal spread of the tumour:

Type 1 – localised inside the body or lamina (site 1, 2, or 3).
Type 2 – the lesion extends into the pedicle (sites 1+2 or 3+2).
Type 3 – the extension is throughout the vertebra (sites 1+2+3).
Type 4 – there is epidural extension.
Type 5 – the paraspinal area is affected (sites 1+2+3+4+5).
Type 6 and 7 lesions show multilevel involvement.

Lesions in the vertebral body, pedicle and/or lamina are considered intracompartmental, and those extending to the paraspinal area are extracompartmental. The epidural space is considered as intracompartmental when the growth is negligible or is encapsulated by reactive tissue.

Anterior en bloc corporectomy is indicated for a type 1 (site 1) lesion, while en bloc laminectomy is indicated for a type 1 (site 3) lesion. In type 2, en bloc corporectomy or laminectomy, or even en bloc spondylectomy can be carried out. For type 3 and 4, total spondylectomy by curettage or piecemeal resection through an anterior or posterior approach, either combined or in two stages, is an accepted method. In type 5 lesions the tumour has already extended through the ligaments to the pleura, mediastinum or extraperitoneal areas, so en bloc spondylectomy is not positively indicated, but if the tumour is well localised and the patient's condition is satisfactory with a good prognosis after adequate treatment, total en bloc spondylectomy may be considered. This operation is obviously not indicated in multilevel or widespread metastases (types 6 and 7). A patient with generalised metastases would not be considered for operation. The best indications for a total en bloc spondylectomy through a posterior approach are type 3 and 4 lesions, in some advanced type 2 and for carefully selected type 5 lesions.

Operative technique for total en bloc spondylectomy

Selective angiography and embolisation of the feeder segmental arteries is imperative for all cases 3 days before operation.

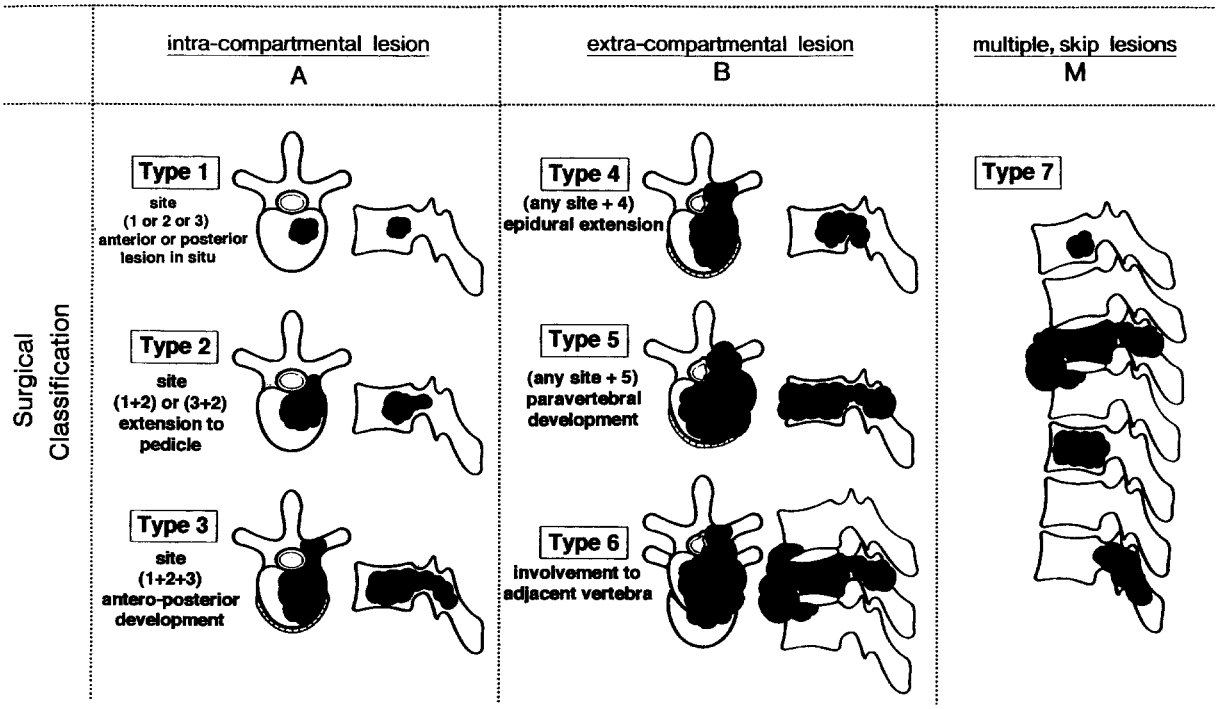

Fig. 2. Classification of vertebral tumours

Most of the surgical procedures are carried out outside the barrier tissue without exposing any tumour tissue. There are two steps in the operation and these are described for a thoracic lesion; the procedure is similar for the lumbar spine, except for dealing with the rib and pleura.

Step 1 – en bloc laminectomy and posterior spinal instrumentation

(i) *Exposure of the whole lamina and posterior elements.* With the patient prone, the laminae of the affected vertebra and two levels above and below, at least five laminae in all, are exposed through a midline incision. Both superior articular facets of the affected vertebra are exposed by removing the proximal lamina and inferior articular processes with a chisel. The transverse processes are exposed on both sides.

(ii) *Rib resection and the intercostal vessels.* The ribs of the affected vertebra are cut off 3 to 4 cm lateral to the costotransverse joint and their heads removed by cutting through the costotransverse and costocapital ligaments. The parietal pleura is then separated from the lateral side of the vertebra, clearing the pedicle and intervertebral foramen. The posterior intercostal artery and its branches, both the dorsal ramus and the spinal intercostal artery and its branches which enter the vertebral body and the nerve root, are cauterised and divided so that the artery can be displaced downwards with the pleura.

(iii) *Pediculotomy and en bloc laminectomy.* The intervertebral foramen, pedicle and transverse process of the affected vertebra should all be identified. A specially made flexible smooth stainless-steel threadwire saw 0.54 mm in diameter (Fig. 3) is inserted into the epidural space beneath the lamina through a sublaminar guide, and is pulled out of the foramen. When both ends of the saw are pulled lightly in a lateral direction, it runs close to the inner side of the pedicle avoiding the nerve root. The saw makes a fine cut through the pedicle (Fig. 4). The lamina becomes mobile after the pedicle has been cut through on both sides. After removing the ligamentum flavum, the posterior components including the lamina, transverse process, superior and inferior intervertebral processes and the spinous process are removed en bloc.

(iv) *Posterior spinal instrumentation.* The pedicle screws of the Cotrel-Dubousset (CD) system are placed in two vertebrae above and below the affected vertebra. The CD rods are contoured to restore the normal spinal curvature and are fixed in position. A unilaminar claw facing to the operative side is recommended at the upper and lower ends of a rod, stopping the screw from loosening and increasing spinal stability. The instrumentation secures spinal stability which would otherwise be completely lost.

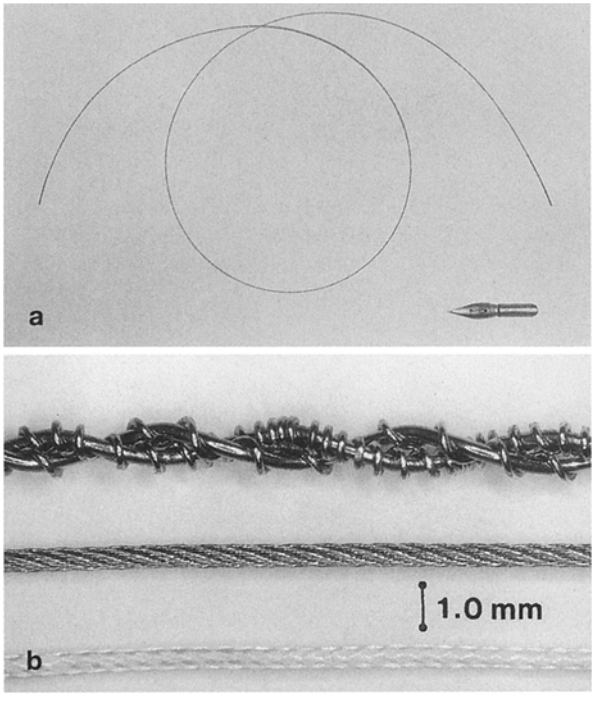

Fig. 3. a Flexible smooth stainless-steel threadwire saw developed by the senior author compared to a pen point. **b** upper – a Gigli saw, middle – threadwire, saw, lower – 1-0 Dexon suture

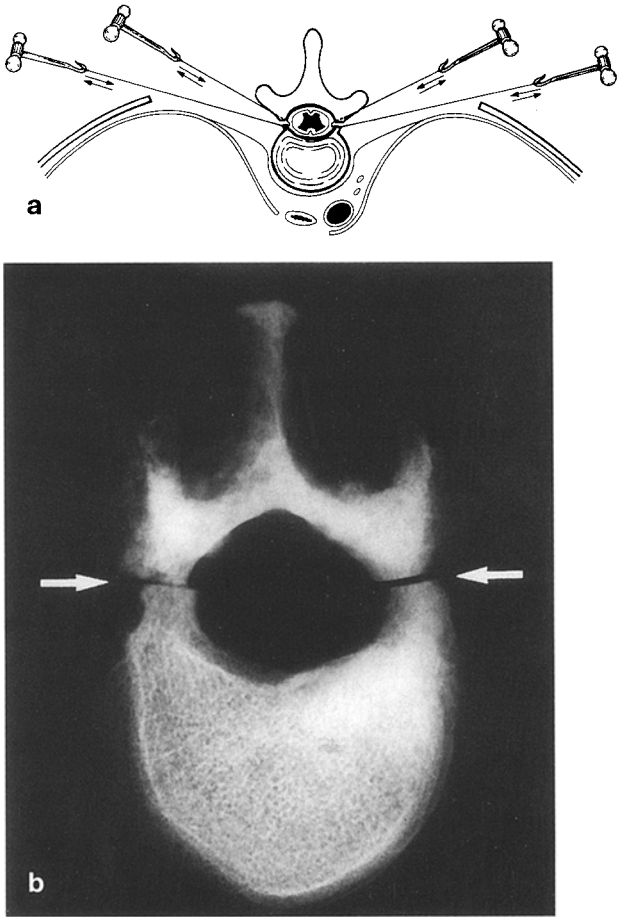

Fig. 4. a Diagram showing bilateral pediculotomy. **b** Radiograph of a resected T12 vertebra with a metastasis from breast cancer. *Arrows* indicate the pediculotomy

Step 2 – en bloc corporectomy and replacement by vertebral prosthesis

(i) *Extracompartmental exposure around the vertebral body* (Fig. 5). The pleura is separated carefully from the costovertebral and costotransverse ligaments and the anterior longitudinal ligament. The intercostal artery which runs across the vertebral body is freed and pushed down with the pleura. The intercostal nerves can remain in place or be divided. After digital extrapleural dissection, or using a specially designed instrument called a vertebral spatula, the surgeon's finger tips can be made to meet each other anterior to the vertebra from both sides. The pulsation of the aorta can be felt and care is taken to avoid damaging the azygos vein and inferior vena cava which cannot be seen or felt. After the affected vertebra is separated from the mediastinal structures, the vertebral spatula is inserted from both sides to protect the large vessels and other organs. All these procedures are outside the tumour capsule.

(ii) *Circumspinal decompression and protection of the spinal cord.* The dura mater and nerve roots at the affected vertebral level are separated from the posterior longitudinal ligament and the posterior part of the vertebral body. If tumour tissue or the pseudocapsule protrude into the spinal canal, it should be carefully separated from the dura. Circumspinal decompression is now achieved. A cord spatula is inserted between dura and vertebra to protect the spinal cord.

(iii) *Discotomy and en bloc corporectomy* (Fig. 6). Two threadwire saws are introduced in front of the vertebral body and are placed so that the upper and lower discs can be cut through from an anterior to a posterior direction; care must be taken as the saw approaches the posterior part of the vertebra. An assistant should hold the cord spatula firmly in position so that at the final moment the saw does not slip and injure the cord. The affected vertebra then becomes free and by rotating it around the cord it is removed together with the barrier tissue. A total en bloc spondylectomy and circumspinal decompression is thus accomplished. A meticulous check is made for residual tumour tissue and the area is washed with mitomycin or cisplatinum. The proximal and distal spinal columns are now only connected by the posterior instrumentation.

(iv) *Insertion of the vertebral prosthesis and adjustment of the anterior and posterior fixation.* Reconstruction is carried out using an apatite-wollastonite vertebral spacer (Lederle, Tokyo). The CD rods are readjusted to fix the prosthesis firmly. Strut and cancellous allografts are placed around the prosthesis and rods.

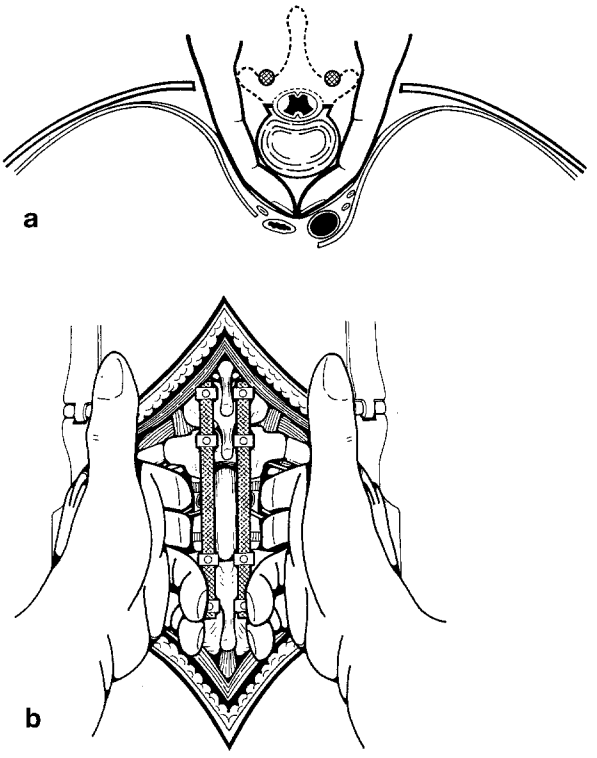

Fig. 5a, b. Extrapleural dissection around the vertebra

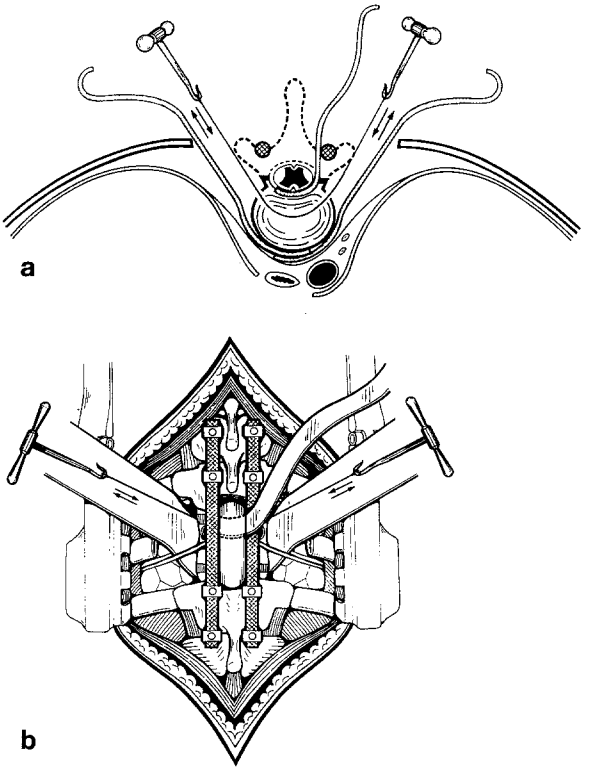

Fig. 6a, b. Discotomy at the upper and lower levels of the affected vertebra using a threadwire saw, followed by en bloc corporectomy

Postoperative management

After one week when the general condition has improved, the patient is allowed out of bed and to walk in a body cast, depending on the degree of nerve involvement and paraparesis. The patient is followed every month when radiological and oncological investigations are carried out.

Clinical experience

Twenty patients were treated surgically for isolated tumours of the thoracic (16) and lumbar (4) spine by total en bloc spondylectomy (Table 1). There were 12 men and 8 women with a mean age of 58.7 years (range 19 to 75 years). The primary tumours were cancer of the thyroid (3), lung (3), breast (2), prostate (2), kidney (2) and rectum (2); there were single ex-

Table 1. Details of the 20 cases of total en bloc spondylectomy

Case No.	Age/Sex	Primary	Level of surgery	Type[a]	Recon-struction	Spinal pain	Impending paralysis	Duration[b]	Frankel's grades	Maximal recovery[c]	Bladder function	Survival	Comments
1	19/M	rhabdo-myosar-coma	T7	4	Harrington + CS	improved		10 days	C to E	2 mos	improved	25 mos dead	
2	53/M	thyroid cancer	T9,10	4	Harrington + allograft	improved		4 wks	A to A		no recovery	12 mos dead	
3	58/M	leiomyo-sarcoma	T3	4	CD + CS	improved		3 wks	C to D	6 wks		30 mos surviving	L3-Stage I, en bloc corporect.
4	64/F	thyroid cancer	T5,6	4	CD + CS			3 wks	C			3 days dead	dead from DIC
5	63/F	lung cancer	T5,6	3	CD + CS	improved prevented		E to E				27 mos surviving	displace-ment of CD
6	65/M	prostate cancer	T4,5	4	CD + allo-graft	improved		4 wks	D to E	4 wks	improved	8 mos dead	
7	54/M	lung cancer	T3,4	4	CD + CS	improved		6 wks	C to C	4 wks	improved	3 mos dead	
8	58/M	rectal cancer	T3,4	4	CD + CS	improved		5 wks	D to E	6 wks	improved	11 mos dead	
9	67/M	cholangio-cellular carcinoma	T2	4	CD + CS	improved		2 wks	C to D	6 wks	improved	9 mos dead	
10	67/F	renal cell carcinoma	L3	4	CD + CS	none		4 wks	D to E	2 mos		25 mos surviving	and/post allograft fusion
11	52/F	breast cancer	T12	3	CD + CS + cancellous autograft	improved	prevented		E to E			24 mos surviving	L2-Stage II, en bloc lamin.
12	62/M	colon cancer	L2	5	CD + CS	improved		3 wks	C to D	4 wks		7 mos dead	
13	56/F	adrenal cancer	T7	4	CD + CS	improved		4 wks	B to D	6 wks	improved	6 mos dead	
14	55/F	rectal cancer	T1	3	CD + CS	improved	prevented		E to E			15 mos surviving	
15	67/M	lung cancer	T9	4	CD + CS	improved		6 wks	B to B		no recovery	3 mos dead	
16	67/M	prostate cancer	T11	3	CD + CS	none	prevented		E to E			11 mos surviving	
17	67/M	hepatocel-lular carci-noma	T10	4	CD + CS	improved		4 wks	B to D	8 wks	improved	4 mos dead	
18	75/M	renal cell carcinoma	L3	4	CD + CS	improved		4 wks	D to E	4 wks		9 mos surviving	
19	55/F	thyroid cancer	L2	5	CD + CS	improved		3 wks	D to E	4 wks		8 mos surviving	post. H-allograft
20	50/F	breast cancer	T8	3	CD + CS	improved	prevented		E to E			8 mos surviving	

CD: Cotrel-Dubousset instrumentation, CS: ceramic spacer, ant: anterior, post: posterior, lamin.: laminectomy, corporect.: corporectomy

[a] Surgical classification of vertebral tumour, [b] duration of paresis (wks; weeks), [c] postoperative time to reach maximal neurologic improvement (wks; weeks)

amples of rhabdomyosarcoma, leiomyosarcoma, cholangiocellular carcinoma, colon cancer, adrenal cancer and hepatocellular carcinoma. Two of the 16 with thoracic lesions also had lumbar lesions which had been treated previously by en bloc corporectomy or laminectomy (cases 3 and 11).

The neurological deficit depended on the level of the lesion and the degree of cord compression by the tumour or from collapsed cortical bone. The Frankel grading system [2], supplemented by walking ability and urinary continence, was used to assess the neurological outcome. One patient was classified as grade A, 3 as grade B, 6 as C, 5 as D and 5 as E. Nine patients had bladder/bowel dysfunction. The duration of paralysis before operation was from 10 days to 6 weeks. Pain was assessed according to the use of narcotic analgesics; 18 patients, including case 4, had severe constant pain requiring regular analgesics.

Every patient had plain radiographs, bone scans, myelograms and high resolution CT and MRI scans before operation. Embolisation of major tumour feeders was performed with small strips of surgical gelatin foam sponge 2 to 3 days before operation. Seventeen of the 20 patients had partial or complete embolisation.

For posterior stabilisation, a Harrington rod with segmental sublaminar wiring was used in the first 2 patients, and CD instrumentation in 18. Anterior stabilisation was achieved with an allograft in 2 patients and an A-W glass ceramic spacer in 18.

One patient had previously undergone anterior decompression and stabilisation with a ceramic prosthesis, but there was a local recurrence and neurological deterioration. All except one (case 4) were followed serially to look for local recurrences.

Results

Of the 18 patients with intractable pain before operation, all except one (case 4), had partial or complete relief after operation. Fifteen patients were free of pain after their recovery from operation, but 2 needed occasional non-narcotic analgesics. Local pain has been well controlled in every patient up to the present time, or until the patient's death (Table 1).

No neurological lesion became worse, and impending paralysis was prevented in the 5 patients in grade E, and 5 in grade D recovered completely. Of 10 patients unable to walk before operation, 6 could do so after. Seven out of 9 regained bladder control.

Operating time was from 5.6 to 10.3 h (mean 7.80 h). Blood loss varied from 590 to 3520 ml (mean 1650 ml) and was increased with longer spinal instrumentation.

There were major complications in 2 patients. One, who was aged 65 years, with thyroid cancer and T5-6 metastasis (case 4), had undergone anterior spinal decompression in another hospital. The tumour recurred and she died of disseminated intravascular coagulation (DIC) after spondylectomy. Case 5 was a woman aged 63 years with a metastasis from a lung cancer at T9. Two months after operation, the CD pedicle screws displaced; they were replaced using clawed laminar hooks after which her back pain disappeared. Three patients complained of transient intercostal neuralgia and sensory disturbance due to sacrifice of the intercostal nerves; this improved within 3 weeks of operation.

The final follow up of the 9 surviving patients was from 8 to 30 months (mean 17.4 months); their mean survival time was 8.8 months (range 3 to 25 months). Ten patients died with disseminated metastases, and one from DIC. Metastases in liver and/or lung occurred in 4 patients who died within 6 months (cases 7, 13, 15 and 17). There has been no radiological evidence of local recurrence, and no patient had either neurological deterioration or failure of instrumentation due to spread of the tumour at the operative level.

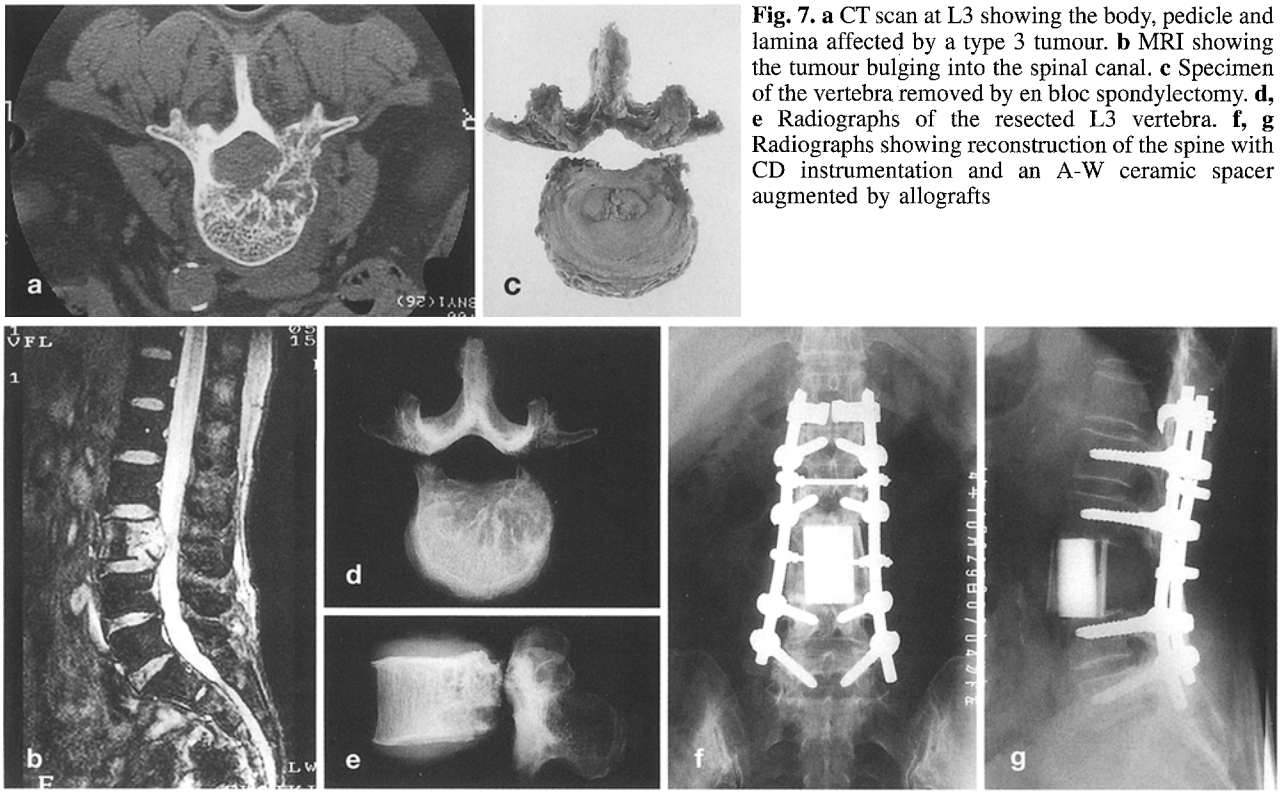

Fig. 7. a CT scan at L3 showing the body, pedicle and lamina affected by a type 3 tumour. **b** MRI showing the tumour bulging into the spinal canal. **c** Specimen of the vertebra removed by en bloc spondylectomy. **d, e** Radiographs of the resected L3 vertebra. **f, g** Radiographs showing reconstruction of the spine with CD instrumentation and an A-W ceramic spacer augmented by allografts

Discussion

The first total spondylectomy was carried out by Lièvre et al in 1961 by a piecemeal resection of a giant cell tumour in the 4th lumbar vertebra; 2 weeks after posterior resection, curettage of the vertebral body was carried out from anteriorly [4]. Next, Stener et al reported a onestage total spondylectomy for a giant cell tumour through a posterior approach [10]. Posterior components were resected together with an en bloc excision of the vertebral body using a Gigli saw, and reconstruction with a Roy-Camille plate [6, 7]. Pedicle arthroplasty was described by Steffee et al using special instrumentation [8], and an AO internal fixator with a methylmethacrylate block was advocated by Magerl et al. [5].

Stener recorded total spondylectomy in 5 patients with low grade malignant tumours (giant cell tumour 3, chordoma 1 and chondrosarcoma 1) with no recurrence after a follow up from 7 to 20 years; one patient with a plasmacytoma and one with a renal carcinoma died with metastases, at 5.5 years and 15 months respectively, after operation.

Sundaresan et al reported successful total spondylectomy, in 2 stages with varying intervals between the anterior and posterior procedures, for malignant tumour in 8 patients (primary in 4 and metastases in 4) [11, 12]. Six of their patients survived with a mean follow up of 36 months, but one each died of renal carcinoma and chondrosarcoma, at 2 and 3 years respectively, after operation. A more recent report by Roy-Camille showed that it was technically possible to carry out a total posterior spondylectomy [7], but most of these operations were based on intralesional curettage or piecemeal removal.

We first carried out total spondylectomy by the posterior approach using Stener's and Roy-Camille's technique, and made modifications with the idea of achieving radical en bloc resection of the whole vertebra. We believe that it is important for a malignant musculoskeletal tumour to be resected en bloc with a wide local or a radical compartmental margin. After animal experiments and clinical trials, we have developed a technique, which we have named total en bloc spondylectomy, using several newly designed instruments. This differs from conventional methods in 3 ways.

1) Total en bloc spondylectomy in two stages

The technique developed by Roy-Camille et al has achieved en bloc resection of the vertebral body at the thoracic level, but not of the posterior and lateral components. Piece by piece resection is carried out, with a laminectomy mainly for cord decompression, and piecemeal removal of the lateral component facilitating operation anteriorly. For type 3 lesions we must cut through the tumour at some parts during total spondylectomy. However, we have made every effort to develop a technique to minimise such intralesional invasion, and this is one of the most important principles of our operation. The ideal method should use as small a bone incision as possible with minimal contamination of the resected tumour. We chose division of the pedicle to satisfy these requirements because it is the smallest part of the vertebra and the narrowest for an intralesional incision; it is the bridge, and the weakest barrier, between the anterior and posterior components. Using pediculotomy in total en bloc spondylectomy from the thoracic to the lumbar area gives the least risk of contamination of the operative field.

2) Wide local compartmental excision

Our next aim was to remove the anterior and posterior parts of the vertebra according to correct oncological principles. To do this, we needed to find out how to resect the whole vertebra without exposing the tumour, removing the vertebra, together with its capsule, extracompartmentally. The most difficult step was dividing the pedicle and the vertebral disc safely and precisely. A threadwire saw has advantages over a Gigli saw because it has a smooth surface which causes less damage to the soft tissues, and it is more flexible and easier to manipulate; its diameter (0.54 mm) gives a sharp and thin cut. The pedicle can thus be cut safely and precisely near the spinal cord and nerve roots.

3) The results of total en bloc spondylectomy

In 1991, King et al. reported the results of either an anterior or posterior approach in 33 patients with spinal metastases from renal carcinoma [3]. The neurological symptoms were improved after operation in 60% of cases, but 48% developed recurrences at an average of 5 months after operation. The main cause of failure was recurrence in the posterior component when anterior corporectomy had been performed and in the anterior component after posterior laminectomy. Their conclusion was that further radical tumour resection was needed to prevent local recurrence. Our patients showed neurological improvement and had no local recurrences at the last follow up visit, or at the time of their death. There is no evidence

to suggest that death was related to the total en bloc spondylectomy. These findings suggest that our procedure for the radical removal of spinal metastasis is justified.

The life expectancy of a patient with a spinal metastasis is usually about 6 months, but in our group several patients have already survived for more than 2 years, indicating that survival may be prolonged by the operation.

Our new classification is based on the tendency of spinal tumours or metastases to have a pattern of growth in the vertebra. At present, we consider that en bloc spondylectomy is best indicated in type 3 and 4 lesions, and also for some type 2 or selected type 5.

Until recently, the aims of surgical treatment were to reduce the neurological symptoms and improve the patient's quality of life. Total en bloc spondylectomy will not affect general metastases or extend survival, but if patients are carefully selected and if the operation is part of a total programme of management, this procedure may achieve local control of metastases and extend the patient's survival. The favourable results in our 20 patients suggests that the operation, which nearly achieves extracompartmental excision, is valuable in minimising local recurrence. Oncological principles should be introduced into surgical practice in order to improve results of radical treatment in metastatic spinal disease.

References

1. Denis F (1983) The three column spine and its significance in the classification of acute thoracolumbar spinal injuries. Spine 8: 817–831
2. Frankel HL, Hancock DO, Hyslop G, Melzak J, Michaelis LS, Ungar GH, Vernon JDS, Walsh JJ (1969) The value of postural reduction in the initial management of closed injuries of the spine with paraplegia and tetraplegia. Paraplegia 7: 179–192
3. King GJ, Kostuik JP, Mcbroom RJ, Richardson W (1991) Surgical management of metastatic renal carcinoma of the spine. Spine 16: 265–271
4. Lièvre JA, Darcy M, Pradat P, Camus JP, Bénichou C, Attali P, Joublin M (1968) Tumeur à cellules géantes du rachis lombaire, spondylectomie totale en deux temps. Rev Rheum 35: 125–130
5. Magerl F, Coscia MF (1988) Total posterior vertebrectomy of the thoracic or lumbar spine. Clin Orthop 232: 62–69
6. Roy-Camille R, Saillant G, Bisserié M, Judet TH, Hautefort E, Mamoudy P (1981) Résection vertébrale totale dans la chirurgie tumorale au niveau du rachis dorsal par voie postérieure pure. Rev Chir Orthop 67: 421–430
7. Roy-Camille R, Mazel CH, Saillant G, Lapresle PH (1990) Treatment of malignant tumors of the spine with posterior instrumentation. In: Sundaresan N, Schmidek HH, Schiller AL, Rosenthal DI (eds) Tumor of the spine. WB Saunders, Philadelphia
8. Steffee AD, Stikowski DJ, Topham LS (1986) Total vertebral body and pedicle arthroplasty. Clin Orthop 203: 203–208
9. Stener B (1989) Complete removal of vertebrae for extirpation of tumors. Clin Orthop 245: 72–82
10. Stener B, Skien J (1971) Complete removal of three vertebrae for giant-cell tumour. J Bone Joint Surg [Br] 53: 278–287
11. Sundaresan N, DiGiacinto GV, Hughes JEO (1986) Surgical treatment of spinal metastasis. Clin Neurosurg 33: 503–522
12. Sundaresan N, DiGiacinto GV, Krol G, Hughes JEO (1989) Spondylectomy for malignant tumor of the spine. J Clin Oncol 7: 1485–1491
13. Weinstein JN (1989) Surgical approach to spine tumors. Orthopedics 12: 897–905
14. Weinstein JN, Mclain RF (1987) Primary tumors of the spine. Spine 12: 843–851