Radical en bloc resection for lung cancer invading the spine

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Objective: We reviewed our 8-year experience with en bloc partial and total vertebrectomy for lung cancer invading the spine and report outcome and survival.

Methods: Nineteen patients with lung cancers involving the spine underwent en bloc resection. Eleven received induction treatment (chemotherapy, n = 5; chemoradiotherapy, n = 4; and radiation, n = 2). Pneumonectomy was performed in 3 patients, lobectomy in 13 patients, and wedge resection in 3 patients. Hemivertebrectomy was performed in 15 patients, and total vertebrectomy was performed in 4 patients. The median number of resected vertebral bodies was 3 (range, 1-4). Tumor stage was IIIB in 14 patients, IIIA in 1 patient, and IIB in 4 patients (hemivertebrectomy is performed in the case of T3 disease to obtain free margins). Surgical nodal status was N0 in 13 patients, N1 in 3 patients, N2 in 1 patient, and N3 (supraclavicular) in 2 patients. Complete macroscopic and microscopic resection was achieved in 15 (79%) patients.

Results: There was no immediate postoperative mortality. Morbidity was observed in 10 patients, including 4 (21%) complications related to the spinal surgery. The median hospital stay was 30 days. Seven patients were alive after a mean follow-up of 26 months (range, 7-74 months). The 1- and 5-year predicted survivals (updated) are 59% and 14%, respectively. Nine local recurrences were observed.

Conclusions: En bloc resection of chest tumors with vertebrectomy is technically demanding, and postoperative morbidity should be critically addressed with this aggressive surgical intervention. However, an encouraging long-term survival observed in this series suggests that en bloc resection could be a valid option in selected patients with vertebral involvement of chest tumors.

Non–small cell lung cancers invading the thoracic inlet can easily involve spinal structures because of their particular anatomic situation. For this reason, most of the tumors invading the spine are located in the superior sulcus, although vertebral extension can be observed in tumors more caudally situated. Initial local control as a result of the first treatment provides the only possibility for survival for patients with superior sulcus tumors.[1,2] The best local control for resectable tumors is obviously achieved by surgical intervention, provided the resection is complete and respectful of oncologic principles.[3] Since the first descrip-

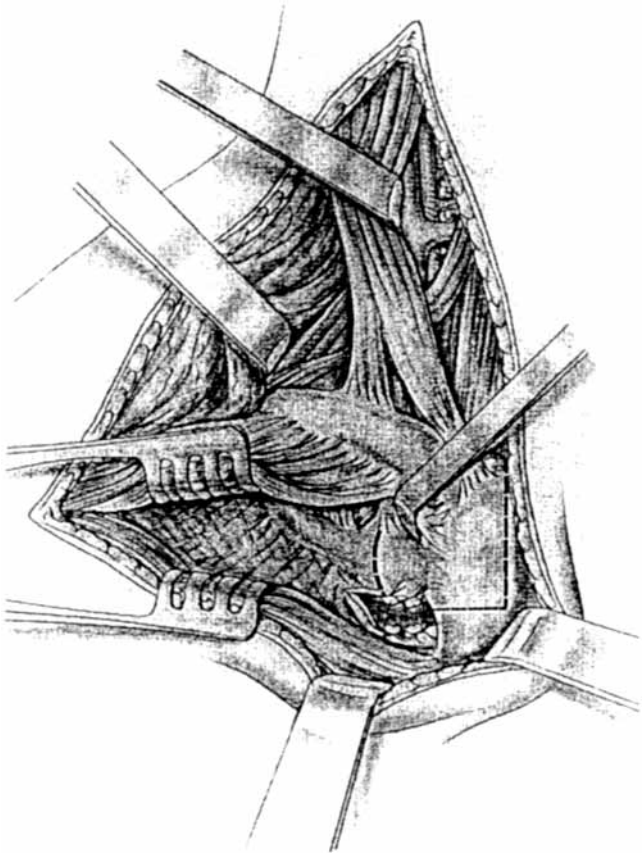

Figure 1. Transmanubrial approach: L-shaped incision on the manubrium and section of the first cartilage. Reprinted with permission from the Society of Thoracic Surgeons (*The Annals of Thoracic Surgery* 1997;63:563-6).[10]

tions of surgical resection in Pancoast tumors, several limitations to surgical resection have been successively surpassed.[4,5] Paulson,[6] in his classic article from 1975, identified contraindications to surgical intervention, which included invasion of the subclavian artery and invasion of the vertebrae. The anterior cervicothoracic approaches allowed dismissal of the vascular contraindication.[7] Tumors involving the transverse process or the lateral part of the vertebral body could be resected through an enlarged posterolateral thoracotomy.[8] However, direct major invasion of the vertebral body remained an absolute contraindication to surgical repair until the first report of a successful total vertebrectomy for en bloc resection of lung cancer invading the spine in 1996.[9] The surgical technique, initially described as a 3-step surgical approach, has been progressively simplified. We used this technique in 19 patients with non–small cell lung cancers of the upper lobe with associated vertebral invasion. The combination of a cervicothoracic transmanubrial approach and a midline posterior vertebral approach allows en bloc resection of the tumor, cervical vessels (if involved), pulmonary lobe, thoracic wall, and vertebral body or bodies, if necessary, without violating the tumor margins. This study reviews our 8-year multidisciplinary experience of en bloc vertebrectomy and spinal reconstruction for non–small cell lung cancer with vertebral invasion.

Patients and Methods

We reviewed all patients undergoing concomitant lung and vertebral resection for non–small cell lung cancer between 1993 and 2000 at the Institut Mutualiste Montsouris (Paris, France). The criteria for resection were (1) a histologic diagnosis of non–small cell lung cancer; (2) a tumor fixed to the vertebral column, as evidenced by radiographic findings; (3) absence of mediastinal nodal involvement; and (4) no distant metastasis. Initial evaluation included clinical examination, chest radiograph, computed tomographic (CT) scan of the thorax with 3-dimensional reconstructions, CT scan of the brain and abdomen, magnetic resonance imaging of the thorax, flexible bronchoscopy, pulmonary function tests, bone scintigraphy, and standard laboratory tests. Histologic diagnosis was established by either percutaneous fine-needle aspiration or surgical biopsy. Mediastinoscopy or thoracoscopy was used for nodal staging in the presence of mediastinal shadows of more than 1 cm on a CT scan. Venous angiography, arterial angiography, or both, confirmed invasion of the subclavian vessels.

Multimodality treatment, either induction chemotherapy or induction chemoradiotherapy, was proposed for patients with clinical stage IIIB disease.

The surgical technique evolved throughout the series. Initially, a 3-incision approach was performed with (1) a transclavicular anterior cervical approach, (2) a posterolateral thoracotomy through the fifth intercostal space, and (3) a midline posterior vertebral approach. The development of the transmanubrial cervicothoracic anterior approach allowed execution of the thoracic steps of the resection without a conventional thoracotomy.[10] With this previously described approach, one elevates an osteomuscular flap from the manubrium, including the entire clavicle, and the cervical muscles, sparing the sternocleidomastoid muscle and the sternoclavicular joint (Figure 1). Resection of the anterior part of the first rib and, if necessary, the second or even the third rib allows a formal upper lobectomy through the pulmonary fissure, as well as a hilar, carinal, paratracheal, and ipsilateral supraclavicular superior mediastinal lymph node dissection. The cervical step of the operation allows separation of the tumor from the cervical structures, vascular resection and reconstruction (if needed), division of the external part of the parietal thoracic wall according to the planned resection, and dissection of the anterior vertebral plane free of the posterior mediastinal organs (great vessels, aorta, and esophagus). The upper lobe is left attached to the thoracic apex by the tumor involvement, respecting oncologic principles (ie, without violating the tumor margins).

After closure of the cervicothoracic incision, the patient is turned to the prone position with a head holder.[11] Through a midline skin incision, muscle and fibrous tissue are cleared from the spine. Dissection is extended as far as 5 to 6 cm laterally on the ribs adjacent to the tumorous vertebra. The surgical technique

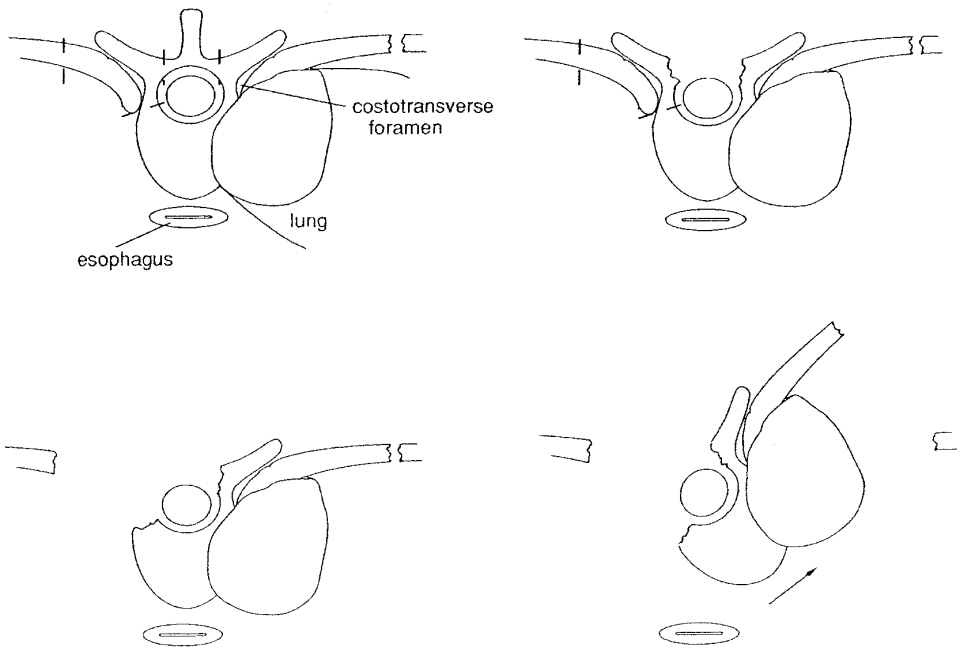

Figure 2. Technique of total vertebrectomy: patient in prone position after chest wall and lung have been sectioned. Reprinted with permission from the Society of Thoracic Surgeons (*The Annals of Thoracic Surgery* 1996;61:723-6).[9]

varies at this point according to the type of vertebrectomy necessary for en bloc resection on the basis of vertebral involvement.

In the case of total vertebrectomy, a bilateral complete laminectomy is performed.[12] It is extended far laterally on the facets, transverse processes, and pedicles on the side opposite the tumor. On the uninvolved side, after dislocation of the costovertebral joints, the ribs at the level of the involved vertebra and at the adjacent upper and lower levels are transected. At that time, the cord is exposed in the midline, with the roots emerging laterally. On the involved side, the transverse processes, as well as the pedicles and ribs, are carefully kept in place. Subcutaneous dissection of the ribs is performed from the midline and allows identification of the distal rib-resection zone. The anterior vertebral body plane, previously dissected through the anterior approach, is identified. It is now possible to go around the entire vertebral body. Disks adjacent to the resection are carefully identified. With a unilateral posterior plate and transpedicular screws, spinal fixation is performed before spondylectomy. After division of the roots entering the lateral aspect of the tumor and after ligation of the roots adjacent to the cord inside the canal, the spondylectomy is performed with a saw and osteotome from the posterior to the anterior side. After careful division of the posterior longitudinal ligament, which is anterior to the cord, the surgical specimen, including the parietal wall, the pulmonary lobe, the tumor itself, and the vertebral bodies, is translated forward, rotated about the cord, and extracted laterally en bloc (Figure 2). A contralateral plate with transpedicular screws completes stabilization of the spine and spinal cord. Vertebral body reconstruction is done with bone grafting.

Complete resection of the vertebral body is not necessary when the tumor is only attached to the lateral aspects of the spine with-

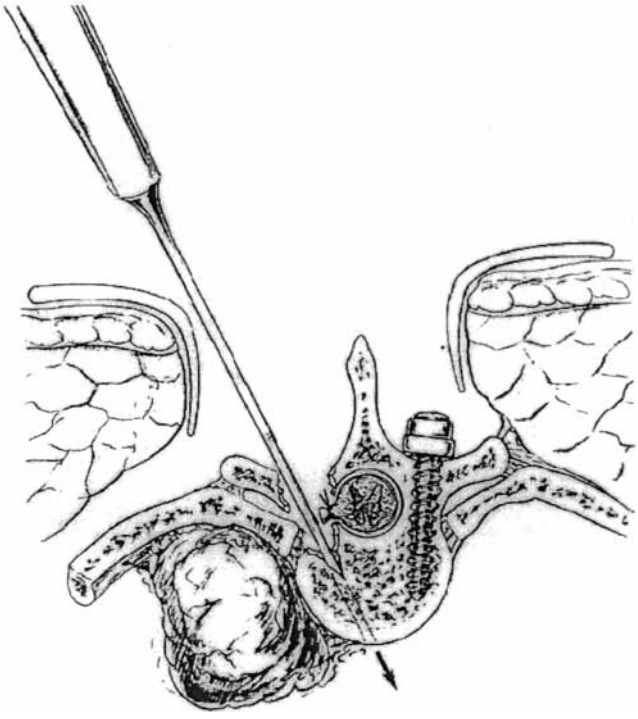

Figure 3. Oblique osteotomy of the vertebral body from posterior to anterior. A plate and transpedicular screws have been implanted on the opposite side of the tumor before osteotomy for stabilization.

TABLE 1. Postoperative complications

Patient	Complications	Consequence
1	None	—
2	Esophageal fistula	Reoperation
	Spinal instability	Reoperation
3	Chylothorax	—
4	Prolonged assisted ventilation	Tracheotomy
	Spinal instability	Reoperation
5	Axillary thrombophlebitis	—
6	Prolonged assisted ventilation	Tracheotomy
7	None	—
8	None	—
9	Pneumonia; prolonged assisted ventilation	—
10	Pneumonia; prolonged assisted ventilation	—
11	Bronchial fistula; pneumocephalon	Reoperation
12	None	—
13	None	—
14	None	—
15	None	—
16	Empyema	Thoracostomy
17	None	—
18	Chylothorax	Thoracic duct closure
	Mediastinitis (intercurrent cardiac surgery)	Reoperation
	Meningitis	—
19	None	—

out invasion of the vertebral body itself. In cases in which only the foramina and the costovertebral groove are involved, only a partial vertebrectomy or hemivertebrectomy is necessary to achieve an extended and complete resection. This should provide an adequate tumor-free tissue margin, thus respecting principles of oncologic surgery. Bilateral laminectomy and rib control are not necessary. After a bony furrow is cut from the facet joints on the tumorous side, corresponding roots are identified and divided after proximal ligation. An oblique osteotomy of the vertebral body is then performed from the posterior to the anterior side (Figure 3). The osteotomy is completed on the upper and lower parts of spine by transection of the vertebral isthmus. By this means, a variable portion of the vertebral body can be resected, according to the obliquity of the vertical osteotomy. A plate and transpedicular screws have been implanted on the opposite side of the tumor before osteotomy for stabilization, as described for complete vertebrectomy. Reconstruction is performed with autologous bone fixed laterally with screws on the remaining vertebral bodies before inserting a second transpedicular posterior plate.

Patients are immobilized in a plastic jacket up to bone graft fusion, 3 to 6 months postoperatively, depending on the extent of the vertebral resection.

Results

Nineteen patients with non–small cell lung carcinomas involving the spine underwent en bloc resection between June 1993 and June 2000. During the same period, a total of 40 vertebral resections were performed in our institution, including 21 resections for other tumors, and 2550 patients were treated for lung cancer, 1070 of whom underwent surgical intervention. Ages ranged between 36 and 65 years, with a mean of 49 years. Four patients had squamous cell carcinoma, 13 had adenocarcinoma, 1 had large cell carcinoma, and 1 had adenosquamous carcinoma. Eleven patients received preoperative induction treatment: 5 patients were treated with chemotherapy using vinorelbine and cisplatin (2 cycles); 4 patients received concomitant chemoradiotherapy (42 gray-bifractionated radiation therapy, concurrent cisplatin, 5-fluorouracil, and vinblastine, 2 cycles); and 2 patients received only preoperative radiotherapy.

The first 6 patients were operated on through a 3-incision approach (anterior cervicothoracic plus posterolateral thoracic plus midline posterior). However, since the development of the transmanubrial approach, a 2-incision approach (transmanubrial plus posterior midline) is generally performed. Pneumonectomy was performed in 3 patients, lobectomy in 13 patients, and wedge resection in 3 patients. Hemivertebrectomy was performed in 15 patients, and total vertebrectomy was performed in 4 patients. The median number of resected vertebral bodies was 3 (range, 1-4). Tumor stage was IIIB in 14 patients, IIIA in 1 patient, and IIB in 4 patients. Surgical nodal status was N0 in 13 patients, N1 in 3 patients, N2 in 1 patient, and N3 (supraclavicular) in 2 patients. These latter patients had positive lymph nodes contiguous to the tumor found at final pathologic examination of the specimen. Vascular reconstruction was necessary in 2 patients in whom subclavian artery resection was performed. An extra-anatomic reinforced polytetrafluoroethylene interposition graft was placed in each, and venous replacement was needed in only 1 patient, who required both arterial and venous reconstruction. Thoracic wall resection was done in all patients, including only the first rib in 1 patient, 2 ribs in 3 patients, 3 ribs in 9 patients, 4 ribs in 4 patients, and 5 ribs in 2 patients. Vertebral bodies involved were T1 only in 1 patient, T2 only in 1 patient, C7 to T3 in 1 patient, T1 to T3 in 3 patients, T1 to T4 in 1 patient, T2 to T3 in 2 patients, T2 to T4 in 2 patients, T2 to T5 in 1 patient, and T4 to T6 in 1 patient. Hemivertebrectomy was performed at one level in 1 patient (T1), at 2 levels in 1 patient (T1 to T2), at 3 levels in 10 patients (T1-T3 in 7 patients and T2-T4 in 3 patients), and at 4 levels in 3 patients (C7-T3 in 1 patient, T1-T4 in 1 patient, and T2-T5 in 1 patient). In the cases of total vertebrectomy, 1 vertebral body (T2) was resected in 1 patient, 2 in 2 patients (T2-T3), and 3 (T4-T5-T6) in the last patient.

Complete resection was achieved in 15 (79%) patients. The mean blood loss on the entire series was 2600 mL (range, 800-6200 mL). However, since 1995, the mean blood loss was reduced to 2100 mL. The mean duration of

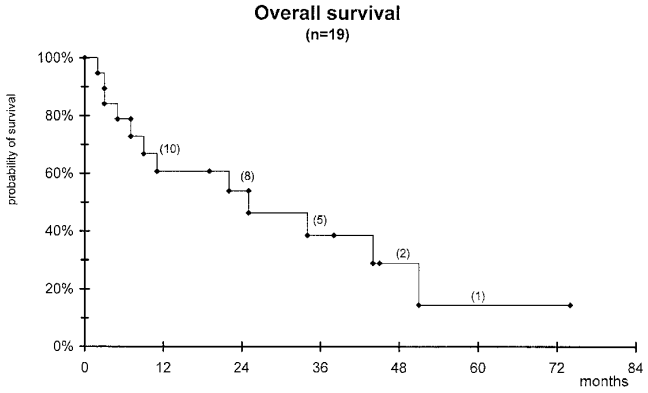

Figure 4. Overall survival of 19 patients undergoing en bloc vertebrectomy for lung cancer.

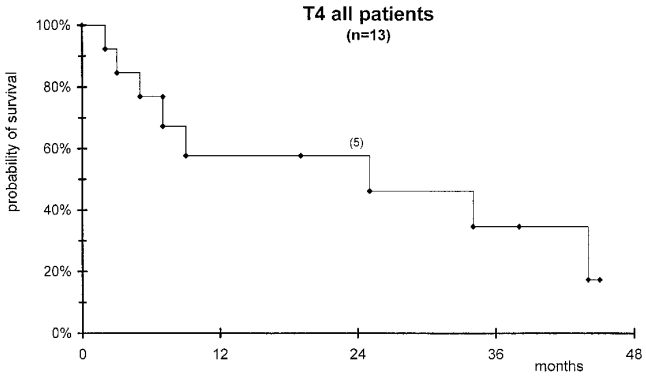

Figure 5. Survival of 13 patients with T4 involvement of vertebrae.

operation was 9.5 hours (range, 6.5-15 hours). Postoperative complications occurred in 10 patients and are summarized in Table 1. In 4 patients immediate postoperative acute respiratory failure required prolonged assisted ventilation for longer than 3 days, and a tracheotomy was performed on 2 patients. Five patients underwent reoperation a mean number of 2 times (range, 1-5 times), in 2 cases for spinal complications. No postoperative deaths occurred. The median length of postoperative hospitalization was 30 days, with a range of 15 to 160 days (mediastinitis caused by intercurrent aortic valve replacement in 1 patient).

Five patients received postoperative radiation therapy, 1 of them after adjuvant chemotherapy. At last follow-up, 7 patients were alive 7, 7, 19, 25, 38, 45, and 74 months after resection. Tumor recurrence was observed in 15 (79%) patients, local-regional in 7 (37%) patients, distant in 6 (32%) patients (including a tumor implantation on a chest drainage port), and both local and distant in 2 (11%) patients. The overall percentage of local-regional recurrences was 47%. Among the 9 patients who had a local recurrence, 4 (44%) patients had positive margins. Among the 15 patients who had negative margins, only 5 (33%) had a local recurrence. Considering only patients with T3 tumors, all resections resulted in negative margins histologically. Among these 6 patients, 2 local-regional relapses were identified. One patient had N3 supraclavicular lymph node involvement, and the other had a malignant pleural effusion observed after a 20-month follow-up. Four patients were alive and free of disease 7, 38, 45, and 74 months postoperatively. These included 3 patients with T4 involvement, 1 of whom had undergone complete resection of 3 vertebral bodies (45 months).

Overall 1-year, 2-year, and 5-year survivals were 59%, 53%, and 14% for the entire series, respectively (Figure 4). The median survival of all patients was 24 months. The 2-year probability of survival for all patients with T4 tumors

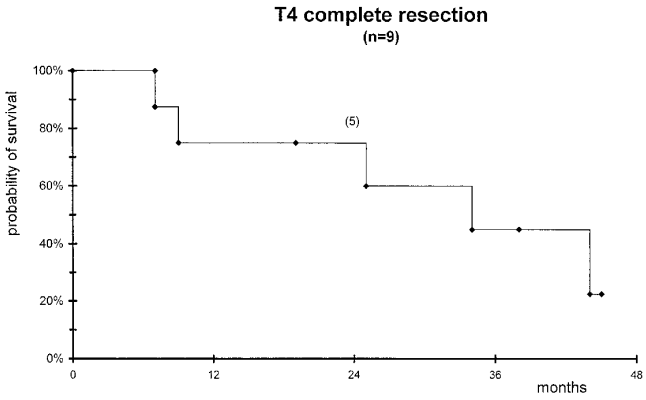

Figure 6. Survival of 9 patients with T4 involvement of vertebrae and histologic free margins.

invading vertebral bodies was 57%, with a median survival of 25 months (Figure 5). However, the 2-year survival and median survival for patients with complete resection of T4 disease (ie, patients whose specimens had negative margins) were 74% and 34 months, respectively (Figure 6). Finally, 6 (43%) of 14 patients with stage IIIB disease had local control of the disease at 2 years.

Discussion

Superior sulcus tumors with vertebral invasion were long considered a contraindication to surgical resection and thus associated with a poor prognosis.[2,7,13] The history of en bloc resection for chest tumors invading the thoracic apex started with the first success reported by Chardack and MacCallum[4] in 1953. Their patient survived more than 5 years after surgical intervention followed by radical irradiation. Shaw and colleagues[5] presented, in 1960, a series of 18 patients treated with irradiation followed by extended resection with partial vertebrectomy. The authors consid-

TABLE 2. Two-year survivals of present and previously reported series of patients treated surgically for tumors fixed to the spine

Authors	No.	En bloc resection	Vertebrectomy		Two-year survival (%)
			Partial	Total	
DeMeester and colleagues, 1989[8]	12	Yes	12	–	42
Gandhi and colleagues, 1999[14]	14	No	7	7	54
Present series	19	Yes	15	4	53

ered that one fourth of the bodies of the involved vertebrae could be removed with a flat osteotome without disturbing the spinal support. Bone involvement was subsequently clearly identified by Paulson[6] as an indicator of poor prognosis. Involvement of ribs or vertebrae was present in one half of the reported patients but in only 25% of the patients who survived for 5 years. Extensive invasion of vertebrae, as well as of the subclavian artery, was considered a contraindication to operation. Initial local tumor control was found to be a major prognostic factor in a number of publications on radiation therapy, whereas bony involvement worsened the prognosis in these series.[1,2] Komaki and colleagues,[2] in a report of patients with superior sulcus tumors treated at M.D. Anderson Cancer Center, noted in 1990 that patients undergoing resection did significantly better than others. Direct vertebral extension was considered a highly significant prognostic factor, with disease-free survivals at 2 years of 15% and 40% with and without vertebral invasion, respectively ($P < .0006$). The authors confirmed the significant role of local control, with 2-year survivals of 52% and 13% with and without local control, respectively ($P < .00001$). Consequently, incomplete surgical resections were associated with a 5-year survival of 9% compared with that of patients with complete resections (41%) in a series of patients treated at Memorial Sloan Kettering Cancer Center, as reported by Ginsberg and coworkers.[3]

En bloc resection of lung cancers fixed to the vertebral column remains a major challenge. Complete resection is theoretically the best means of local control. Neither the extended thoracic approach described by Shaw and colleagues[5] nor the vertebral osteotomy proposed by DeMeester and coworkers[8] enables a large vertebral body resection and spinal reconstruction. Gandhi and associates[14] reported their experience of successful resection in patients with T4 involvement of the vertebrae at the University of Texas M.D. Anderson Cancer Center in 1999. In our study we report the 8-year experience of the Departments of Thoracic Surgery and Orthopaedics at L'Institut Mutualiste Montsouris and the long-term results after vertebrectomy for non–small cell lung cancer invading the spine but not necessarily the superior sulcus. The technique of vertebrectomy through an enlarged posterior approach, as described by Roy-Camille and Mazel[11] in 1981, was used for lung resection in 19 patients since our first case report.[9] The majority of our patients, those with superior sulcus tumors, were treated through a combination of anterior cervicothoracic transmanubrial and posterior median spinal approaches. The anterior transmanubrial approach offers the advantage of enlarged access to the thoracic inlet compared with the transclavicular approach, described by Mathey and Cormier,[15] which is known as Dartevelle's approach. Furthermore, one avoids the functional and cosmetic inconveniences of both clavicle resection and division of the sternocleidomastoid muscle. In addition to secure control of the vascular elements, this approach allows performance of an upper lobectomy with a superior mediastinal lymph node dissection and division of the thoracic wall beyond the tumorous involvement. Moreover, the freeing of the anterior vertebral body plane from the posterior mediastinal elements can be done easily. Thus, the blind step of the posterior approach is rendered far safer. An esophageal fistula occurred in historical patient 2. This patient had been operated on at the beginning of the experience through a lateral thoracotomy. The prevertebral plane has likely not been adequately prepared without the anterior approach.

In opposition to the procedure used by Gandhi and colleagues,[14] our technique attempts an en bloc extratumorous resection (Table 2). At M.D. Anderson, the technique differs by dissecting the vertebral body through normal-appearing bone and removing the remaining portion of grossly normal vertebral body with a high-speed burr resection.[16] The authors believed that this procedure carried less morbidity than the classic en bloc vertebrectomy and provided good local-regional control when "negative margins are achieved even though tumor is transversed." The main purpose of our technique is to avoid violation of the tumor block, respecting oncologic principles. A 33% local recurrence rate was observed in patients with safe histologic margins, whereas 100% of the patients with positive margins had early local recurrences. A high rate of postoperative complications was observed in our series (53%), as in that of the M.D. Anderson authors (42%). This morbidity reflects the length and complexity of this operation. In our experience the

mean duration of the operation was 9.5 hours. A postoperative stay of 1 month could be considered as relatively long but includes in-hospital rehabilitation.

Six of the patients in our series had T3 tumors. In these patients a partial vertebrectomy was chosen as an extended resection to obtain free margins for tumors intimately adherent to the vertebral column. Interestingly, all of these patients had free margins at the pathologic examination of the surgical specimen. The only patient who relapsed on the site of the primary tumor was found to have an N3 tumor at operation and thus was classified as having stage IIIB disease.

Survivals observed in our short series do not allow firm conclusions. Two of our patients are alive and free of disease 38 and 45 months, respectively, after resection of 3 levels for invaded T4 vertebrae. Our 43% local control rate at 2 years in patients with IIIB disease compares far better with overall results of nonsurgical standard treatment of stage IIIB non–small cell lung cancer. For example, Arriagada and colleagues[17] found a 17% local control at 1 year in a randomized study comparing radiotherapy alone with chemoradiotherapy in this category of patients with nonresectable disease. The high rate of local-regional and distant recurrences demonstrates the necessity of an aggressive multimodal approach. Several reported studies demonstrate the feasibility of surgical resection after induction chemoradiotherapy in patients with stage IIIB non–small cell lung cancer.[18,19] In addition, another of our studies on induction chemoradiotherapy for stage IIIB lung cancer suggests that with surgical intervention, when feasible, one can achieve an encouraging 28% long-term survival for patients with stage IIIB disease in whom chemoradiotherapy alone failed to control disease.[20] In the TNM International Staging System T4 tumors are currently classified as "unresectable locally advanced" stage IIIB. Nevertheless, the fact that surgical intervention makes it possible to achieve complete remission and to spare patients with residual disease after chemoradiotherapy argues for changes in the TNM classification. A subclassification of T4 tumors as "potentially resectable" T4-1 and "definitively nonresectable" T4-2 was recently proposed. This proposed "colored" classification subdivides patients into 3 categories, according to their therapeutic options: green, surgical; red, induction; and black, nonsurgical.[21]

Results of this short series suggests that en bloc vertebrectomy for non–small cell lung cancers attached to the spine may be performed despite significant morbidity. The local control rate obtained with this technically demanding operation is encouraging compared with that obtained with standard radiation therapy. Long-term disease-free survival can be achieved, even with T4 invasion of the vertebral body. Extension of surgical resection of T3 Pancoast tumors to include the vertebral body is feasible and guarantees safe histologic margins. Further investigation, including multidisciplinary treatment, is required to improve final results for local and distant control.

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Discussion

Dr Garrett L. Walsh *(Houston, Tex).* I congratulate Dr Grunenwald and his colleagues for an interesting presentation on their innovative surgical techniques for upper lobe bronchogenic carcinomas, which, by means of clinical staging, were believed to invade the vertebral column.

I would strongly echo Dr Grunenwald's sentiments that the only hope for long-term disease-free survival in this patient population is an aggressive surgical approach to the vertebral body component of this tumor. In 1993, we established an interdisciplinary spinal surgical program at The University of Texas M.D. Anderson Cancer Center. Since this time, we have performed 1427 spinal operations; 44 of these have been for superior sulcus tumors with direct extension into the spinal column. We reported our experience in our first 17 patients 2 years ago at the annual meeting of The Society of Thoracic Surgeons. The overall actuarial 2-year survival was 54%. The ability to obtain negative margins was of paramount importance because none of our 6 patients with positive margins were alive after 2 years compared with the 80% 2-year survival of the 11 patients who had complete resections. Presently, we have a median follow-up of 43 months, with one third of our patients still alive without evidence of disease. The survival data of the 2 studies are not fully comparable because the final pathologic findings of Dr Grunenwald's study demonstrates 6 of the 19 patients to have T3 rather than T4 disease, and some of the tumors, as we saw in the last patient, are clearly not superior sulcus tumors. I see that the title of the article has been changed from the abstract to more accurately describe the tumor locations. Although our spinal surgeons strive for complete tumor extirpation, the resection and reconstruction techniques vary between our 2 centers and, I am sure, reflect philosophic differences between orthopedic surgeons and neurosurgeons. I work predominantly with neurosurgeons, who generally have no qualms about endolesional resections with initial disarticulation of the main specimen away from the vertebral body with direct resection with high-speed diamond drills and CUSA dissectors. The combined anterior and posterior approach permits a more rapid resection of the specimen, standard lobectomy, and chest wall resection under optimal exposure and reconstruction of the anterior column of the vertebral body with our standard methyl methacrylate and chest tube strut. Our patients are ambulatory immediately after the operation compared with a required 3- to 6-month period of immobilization by a plastic jacket, as you described in your article.

The technique that you describe is far more elegant from an oncologic perspective. However, despite a meticulous en bloc, no-touch resectional attempt, tumor recurrence was observed in 79% of your patients, 47% locally in the surgical bed. Despite avoiding a lateral thoracotomy, the hospital stay was nearly triple that of our series at a 30-day hospital length of stay.

I have several questions. Because nearly one third of your patients on final pathologic review had T3 rather than T4 lesions, do you believe that the anterior approach limited your ability to fully assess the degree of spinal involvement and perhaps subjected these 6 patients to a more extensive operation than would have normally been required? Would a lateral thoracotomy have helped in these patients?

On reflecting on our own local recurrence data, I am starting to believe that once a tumor has breached the outer cortex of the vertebral body, a total vertebrectomy may be the only true option for an R0 resection. When do you decide to proceed to a partial or complete vertebrectomy, and what are your thoughts on this issue?

To rotate the vertebrectomy site requires contralateral laminectomies, division of ribs, and ligation of the spinal nerve roots. Do you believe that this division of otherwise normal supporting structures may have contributed to the spinal instability that was seen in your patients?

Because you performed mostly anatomic pulmonary resections, for larger tumors, did you have any difficulty in rotating them out of the thoracic cavity, and if you did, what maneuvers did you use to compensate for this?

Finally, because your center is obviously a tertiary referral center for these more complex tumors, are you examining the role of neoadjuvant and adjuvant treatment protocols for the management of these patients?

I very much enjoyed your presentation and applaud your pioneering work in this technically challenging subset of patients with locally advanced lung cancer.

Dr Grunenwald. Thank you very much for your comments, Dr Walsh.

As you said, this is teamwork in which other specialties are involved. Our patients were operated on with Dr Mazel, who is an orthopedic surgeon, and this explains the philosophic difference you mentioned. From an oncologic point of view, our no-touch en bloc technique permitted 66% local control in patients undergoing complete resection because only 5 among 15 patients had local relapses in this group of patients with complete resection.

In answer to your questions, first, 6 of our patients had T3 lesions attached to the spine but without bony extensions. In these patients a partial vertebrectomy was chosen as an extended resection to obtain free margins for tumors intimately adherent to the vertebral column. Using this technique, we achieved more accurate margins than those obtained by only extrapleural resection. We do not regret this strategy because all of these patients had free margins at pathologic examination, and the only one who had a relapse on site had been found to have an N3 lesion at the time of the operation. We do not think lateral thoracotomy had helped in these patients.

With regard to the second question, I completely agree with Dr Walsh on his belief that the only option for an R0 resection would be total vertebrectomy, and taking into account these preliminary results, we will probably be more aggressive in the future. Up to now, we decided to proceed to a total vertebrectomy when more than 20% of the transverse diameter of the vertebral body was involved at magnetic resonance imaging.

With regard to the third question, spinal instability actually occurred in 2 patients at the beginning of our experience. It was caused by inadequate length of stabilization material, which was modified without further difficulties.

Fourth, occasionally we had to reopen the anterior incision to remove a large specimen. In the case of a very modest tumor in the upper lobe, we prefer to remove the major part of the pulmonary

lobe after stapled transection to reduce the volume of the specimen before closure of the anterior incision, but the tumor is left attached to the column, and we never use obstetrical forceps to extract the specimen.

Finally, as far as the role of neoadjuvant treatment protocol is concerned, at the present time our patients are treated preoperatively with 2 cycles of chemotherapy with vinorelbine tartrate (Navelbine) and cisplatinum. Only patients with positive margins receive postoperative radiotherapy.

Dr Robert J. Ginsberg *(Toronto, Ontario, Canada).* Of the patients you presented, you performed 4 total vertebrectomies. Could you tell us how they did? I know one was skiing in the Alps the next year or two later. There were 4 total vertebrectomies, is that correct?

Dr Grunenwald. Yes.

Dr Ginsberg. What was the outcome of those 4 total vertebrectomies?

Dr Grunenwald. Three patients were alive more than 30 months after total vertebrectomy.

Dr Ginsberg. And what is the follow-up?

Dr Grunenwald. The patient I have shown to you is alive after 47 months. Others died at 5, 34, and 44 months, respectively.

Dr Ginsberg. Could you once again tell us the reasons for using a transmanubrial approach on those patients in whom hemivertebrectomy is required? I can see the rationale of this approach for the total vertebrectomy, and I think it is an excellent approach when you have patients who do require a total resection, but I still do not know the rationale of doing a transmanubrial approach for hemivertebrectomies.

Dr Grunenwald. The main problem we encountered in vertebrectomies was the attachment of the vertebral column to the posterior mediastinum and the posterior organs in the cervical area. Our orthopedic surgeon is very happy when I can completely dissect the anterior vertebral plane at the lower part of the cervical region and the upper part of the mediastinum. It is only possible by an anterior approach to completely free the larynx, the esophagus, the great vessels, et cetera. An anterior approach is very useful to have a direct view of the tumor because from the anterior part of the patient, you are directly in front of a posterior tumor.

Dr Ginsberg. How many C8 vertebrae were removed?

Dr Grunenwald. I suppose you are talking about C7 vertebrae, Bob. In 1 case we performed hemivertebrectomy on 4 levels, from C7 to T3.

Dr Ginsberg. There is T1 and down, T1 and lower? All were T1 and lower?

Dr Grunenwald. Yes.

Dr Ginsberg. What does the larynx have to do with that?

Dr Grunenwald. The problem is to put the posterior material for spine stabilization.

Dr Ginsberg. I see.

Dr Grunenwald. The orthopedic surgeon has to be sure that he will not put the screw in the esophagus or in the organs in front of the vertebral bodies.

Dr Ginsberg. I see.