Combined chest wall resection with vertebrectomy and spinal reconstruction for the treatment of Pancoast tumors

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Object. Traditionally, superior sulcus tumors of the lung that involve the chest wall and spinal column have been considered to be unresectable, and historically, patients harboring these tumors have been treated with local radiation therapy with, at best, modest results. The value of gross-total resection remains unclear in this patient population; however, with the recent advances in surgical technique and spinal instrumentation, procedures involving more radical removal of such tumors are now possible. At The University of Texas M. D. Anderson Cancer Center, the authors have developed a new technique for resecting superior sulcus tumors that invade the chest wall and spinal column. They present a technical description of this procedure and results in nine patients in whom stage IIIb superior sulcus tumors extensively invaded the vertebral column.

Methods. These patients underwent gross-total tumor resection via a combined approach that included posterolateral thoracotomy, apical lobectomy, chest wall resection, laminectomy, vertebrectomy, anterior spinal column reconstruction with methylmethacrylate, and placement of spinal instrumentation. There were six men and three women, with a mean age of 55 years (range 36–72 years). Histological examination revealed squamous cell carcinoma (three patients), adenocarcinoma (four patients), and large cell carcinoma (two patients). The mean postoperative follow-up period was 16 months. All patients are currently ambulatory or remained ambulatory until they died. Pain related to tumor invasion improved in four patients and remained unchanged in five. In three patients instrumentation failed and required revision. There was one case of cerebrospinal fluid leakage that was treated with lumbar drainage and one case of wound breakdown that required revision. Two patients experienced local tumor recurrence, and one patient developed a second primary lung tumor.

Conclusions. The authors conclude that in selected patients, combined radical resection of superior sulcus tumors of the lung that involve the chest wall and spinal column may represent an acceptable treatment modality that can offer a potential cure while preserving neurological function and providing pain control.

Key Words • superior sulcus tumor • Pancoast tumor • chest wall resection • vertebrectomy • spinal reconstruction

In 1924, Pancoast\textsuperscript{14} described a series of apical chest tumors that were characterized by pain, Horner’s syndrome, bone destruction, and atrophy of the hand muscles. These superior sulcus or Pancoast tumors are bronchogenic carcinomas that can invade the lower roots of the brachial plexus, sympathetic chain, mediastinal structures, spinal column, and adjacent ribs and chest wall. Numerous authors have observed that when these tumors advance to the point where they involve the great vessels, trachea, esophagus, and vertebral bodies (stage IIIb: vertebral body or mediastinal organ involvement; no lymph nodes with mediastinal nodes positive contralateral to the tumor or supraclavicular nodes positive; and distant metastasis present), patients have a very poor prognosis.\textsuperscript{6,8,12–14,20} More specifically, it has been noted that vertebral body invasion is clearly a negative prognostic factor. In a report by Ginsberg, et al.,\textsuperscript{6} the authors found only two 5-year survivors of 22 patients in whom the tumor involved the vertebral body and who had undergone resection. Komaki, et al.,\textsuperscript{12} found similar results in 18 patients, although some of these patients may have undergone retreatment with radiotherapy alone. Neither Wright and colleagues\textsuperscript{20} nor Maggi and associates\textsuperscript{13} reported any patients who survived longer than 5 years.

The treatment of patients who harbor locally advanced Pancoast tumors remains controversial. Although the results of multiple studies have proved the utility of performing gross-total resection in patients with less extensive disease, many surgeons believe that complete resection is either not warranted or not feasible in patients who harbor stage IIib tumors.\textsuperscript{1,8,12,13,15,16,19,20} Indeed, the value of gross-total resection remains unclear in this patient population; however, with recent advances in surgical technique and spinal instrumentation, more radical removal of such tumors is now possible. The historical con-
traindications to surgical resection, which included invasion of the brachial plexus, subclavian artery, and vertebral bodies, no longer apply.2,3,17,18

At The University of Texas M. D. Anderson Cancer Center, we have developed a technique for resecting superior sulcus tumors that invade the chest wall and spinal column. We present a technical description of this procedure and our results in nine patients with stage IIIb superior sulcus tumors who all had extensive invasion of the vertebral column, which necessitated vertebral body resection, anterior column reconstruction, and posterior instrumentation as well as apical lobectomy and chest wall resection.

Surgical Technique

The surgical procedure is illustrated in Figs. 1 and 2. After induction of general anesthesia and intubation of the patient with a double lumen endotracheal tube, correct positioning is verified bronchoscopically. Fiber optic bronchoscopy also allows visualization of subsegmental levels to assess endobronchial disease. (Preoperatively, a bougie is placed in the esophagus to identify the esophagus during tumor resection. Direct aortic wall involvement is rare in these tumors, and most often the aorta can be easily dissected free of the mass; however, preoperative imaging studies should be assessed to determine if aortic wall involvement is present.) The patient is then placed in a lateral decubitus position with the head secured in a Mayfield head holder. An extended standard posterolateral thoracotomy is performed to gain access to the chest cavity, whereas posterior midline exposure is needed for the laminectomy and dorsal instrumentation and fusion. The primary illustration depicts the surgical field after the tumor (along with the invaded chest wall) has been completely mobilized from the surrounding structures and reflected inferiorly. Complete laminectomy and partial vertebral resection at the T1–3 levels are visualized through the defect. The first through fifth ribs have been transected laterally and disarticulated medially from the spinal column. The C-8 and T-1 nerve roots are preserved, whereas the T-2 and T-3 nerve roots are sectioned proximal to the dorsal root ganglia. At the apex of the surgical cavity, brachial plexus, subclavian, and vertebral arteries are visualized. The azygos vein is observed crossing the surgical field at the inferior half of the surgical defect, and the esophagus and trachea are seen anterior to the thoracic spinal column.

FIG. 1. Artist’s illustration. Inset: The drawing demonstrates the surgical incisions: a standard posterolateral thoracotomy is performed to gain access to the chest cavity, whereas posterior midline exposure is needed for the laminectomy and dorsal instrumentation and fusion.
staging. If the patient’s respiratory reserve allows, a lobectomy is performed. In patients in poor respiratory condition, a segmental resection is performed. If the tumor is close to the hilum, the pulmonary artery and vein are anatomically dissected, individually ligated, and transected. Otherwise, the GIA stapler provides adequate hemostatic control. At this point, all of the segmental vessels are identified, doubly ligated, and transected. In addition, the parietal pleura is bluntly dissected along the anterior border of the spinal column. The tumor (with the involved chest wall) has remained attached to the inferior trunk of the brachial plexus. An attempt is made to spare the T-1 nerve root as it crosses beneath the angle of the first rib to join the C-8 nerve root.

At this point, the specimen is completely excised from the surrounding structures and removed from the operative field. Vertebrectomies are then completed by using the high-speed drill (Fig. 1). Reconstruction of the anterior spinal column is achieved with methylmethacrylate by using the chest tube technique.² The placement of anterior cervical locking plate and screws is followed by placement of posterior instrumentation in which hooks and rods, cervical lateral mass plates, and/or Wisconsin spinous process wires are used (Fig. 2). After decortication of the laminae and transverse processes, allograft bone and Grafton are packed dorsally to promote fusion. All patients underwent postoperative placement of two chest tubes to drain the chest cavity.
Illustrative Case

Case 5

History. This 38-year-old, right-handed woman was referred for evaluation of a left apical lung tumor. She initially presented to another institution 4 months previously with pain radiating to the left arm and numbness in the medial aspect of the arm, forearm, and medial three fingers of the hand. Imaging studies demonstrated a left apical mass. Using computerized tomography guidance, a needle biopsy sample of the lesion was obtained, which proved to be non–small cell lung carcinoma. Subsequently, the patient underwent a posterior operation in which laminectomy, further sampling of the tumor, and decompression of the neural elements were performed. Postoperatively she underwent radiotherapy (30 Gy) and chemotherapy (cisplatin and vinblastin). Her pain improved in the axilla; however, she experienced residual weakness involving the hand intrinsics. More recently, she experienced pain in the intrascapular region and was then transferred to our institution for further care.

Examination. A computerized tomography scan revealed a tumor that involved the apex of the lung on the left side with invasion of the chest wall and extension of the tumor into the T1–2 vertebral bodies and lateral spinal elements extending into the spinal canal. These ribs were divided, and an apical segmentectomy was performed.

A midline posterior incision was made, which was connected to the thoracotomy incision. The tumor extended into the paraspinal musculature in the upper thoracic region. Wide T-1, T-2, and T-3 laminectomies were performed, which allowed identification of the epidural mass. The C-8 and T1–3 nerve roots were identified. Because the T-1 nerve root was grossly involved with the tumor, it was transected. More rostrally, the C-8 nerve root was preserved completely. The ribs were then disarticulated, and the chest wall tumor was removed. Because the tumor extended into the T-1 and T-2 vertebral bodies, we performed a two-level vertebrectomy. Reconstruction of the spinal column was performed as described previously. The patient underwent placement of a methylmethacrylate construct and a cervical plate anteriorly; this was followed by posterior segmental instrumentation that included lateral mass plates and screws in C5–7, hooks in T4–6, and rods (Fig. 4).

Postoperative Course. The patient remained hospitalized for 5 days postprocedure. She did well, with near-complete resolution of her interscapular pain, but continued to experience intrinsic weakness of the left hand, which improved with occupational therapy. The patient completed her course of postoperative radiation therapy. At the time of writing, it is approximately 14 months since her surgery, and there is no evidence of tumor recurrence.

Results

Overall characteristics, treatment, and outcome data for
Our patients are provided in Table 1. There were six men and three women, with a mean age of 55 years (range 36–72 years). The histological composition of the tumors included squamous cell carcinoma in three patients, adenocarcinoma in four patients, and other large cell carcinomas in two patients. The mean follow-up period was 16 months (range 4–36 months). Six patients are still alive at an average of 15 months postsurgery. All patients are currently ambulatory or remained ambulatory until they died. Pain related to tumor invasion improved in four patients, whereas it remained unchanged in five. In three patients (Cases 1, 3, and 8) the instrumentation failed and required revision. In all three of these cases, the spinous processes were found to have been fractured, and as a result, the wires had pulled out. These patients underwent occipitocervicothoracic fixation at the time of revision (Table 1).

There was one case of cerebrospinal fluid leakage that was treated with lumbar drainage and one case of wound breakdown that required surgical revision. Two patients experienced local tumor recurrence, and one patient developed a second primary lung tumor.

**Discussion**

We believe that in performing the surgical technique described in this study, gross-total resection of stage IIIb superior sulcus tumors is feasible in properly selected patients. Our results are preliminary and are based on our experience in treating a small group of patients. Until additional studies are conducted, the absolute utility of this technique will remain unclear. What is known is that, historically, patients with these tumors have undergone radio- and/or chemotherapy with, at best, modest results.12,18 In traditional management, pain control is generally poor and neurological decline is common.

Our results demonstrate that pain related to tumor invasion can be improved in some patients who undergo aggressive surgical management. Furthermore, no case of neurological decline was demonstrated in our patients, with the exception of the expected results following sacrifice of a nerve root. The most serious postoperative complication was hardware failure, and all three cases occurred in patients whose posterior fixation involved the use of spinous process wires. In the patient in Case 5, we did use lateral mass plates and screws alone to achieve cervicothoracic junction fixation in combination with hooks in the thoracic region, and this patient did well (hardware failure did not occur); however, we now prefer to combine lateral mass plates and screws with spinous process wire fixation at this junction to reduce the rate of pullout and hardware failure. We are currently achieving segmental stabilization by using these devices, and there have been no hardware complications associated with this type of instrumentation.

Although they did not occur in our study, other procedure–related complications include spinal cord infarction and flail chest. The removal of four or five segmental vessels to allow excision of the tumor and adjacent chest wall is of serious concern, as it may lead to spinal cord ischemia or infarction, particularly because the upper thoracic region is a vascular “watershed” area. Although we did not obtain routine preoperative angiograms to assess the vascular anatomy of this region in our patients, no patient appeared to have suffered any postoperative neurological dysfunction that was attributable to spinal cord vascular compromise. Because the segmental vessels were interrupted on only one side (ipsilateral to the tumor) it is conceivable that collateral circulation from the opposite side was enough to sustain adequate spinal cord perfusion. This is certainly a different situation, for instance, from that of ascending aortic aneurysm repair, during which

### Table 1: Characteristics in patients with Pancoast tumors who underwent the combined approach

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age  (yrs)</th>
<th>Histological Diagnosis</th>
<th>Stage‡</th>
<th>VBR</th>
<th>NRS</th>
<th>Ant Recon</th>
<th>Pos Inst</th>
<th>Preop XRT (Gy)</th>
<th>Chemo</th>
<th>Postop XRT (Gy)</th>
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<td>AC</td>
<td>T4</td>
<td>T-2</td>
<td>T1–3</td>
<td>MMA</td>
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<td>—</td>
<td>59.4</td>
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<td>C1–T2</td>
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<td>—</td>
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<td>3</td>
<td>36</td>
<td>SCC, mod diff</td>
<td>T4</td>
<td>T-1 &amp; T-1&amp;</td>
<td>C8–T2</td>
<td>MMA</td>
<td>C3–T6</td>
<td>—</td>
<td>—</td>
<td>63</td>
<td>—</td>
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<td>4</td>
<td>61</td>
<td>AC</td>
<td>T4</td>
<td>T-1 &amp; T-1</td>
<td>T-1</td>
<td>MMA, ant plate C7–T3</td>
<td>C4–T6</td>
<td>64</td>
<td>cisplatin, VP-16</td>
<td></td>
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<tr>
<td>5</td>
<td>38</td>
<td>AC, poor diff</td>
<td>T4</td>
<td>T-1 &amp; T-1</td>
<td>T-1</td>
<td>MMA, ant plate C7–T3</td>
<td>C5–T6</td>
<td>—</td>
<td>—</td>
<td>?</td>
<td>—</td>
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<tr>
<td>6</td>
<td>68</td>
<td>SCC, mod diff</td>
<td>T4</td>
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<td>T-2</td>
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<td>7</td>
<td>72</td>
<td>SCC</td>
<td>T4</td>
<td>T-2 &amp; T-3</td>
<td>T-2</td>
<td>MMA</td>
<td>C3–T7</td>
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<td>T4</td>
<td>T2–4</td>
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<td>C2–T9</td>
<td>—</td>
<td>—</td>
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<td>carbolplatin, Taxol</td>
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Continued →

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Vertebrectomy and spinal reconstruction

Table 1 (Continued*)

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Neurological Exam</th>
<th>Perceived Pain/Analgesics</th>
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<th>Complications</th>
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<td>Preop</td>
<td>Postop</td>
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<tr>
<td>1</td>
<td>intact</td>
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<td>mild: Vicodin</td>
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<tr>
<td>2</td>
<td>weak</td>
<td>intact</td>
<td>severe: Vicodin</td>
<td>mild: Lortab</td>
<td>36</td>
</tr>
<tr>
<td>3</td>
<td>intrinsics</td>
<td>weaker</td>
<td>severe: MS Contin</td>
<td>severe: MS contin</td>
<td>7</td>
</tr>
<tr>
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<td>intact</td>
<td>weak</td>
<td>severe: Lortab</td>
<td>severe: Ultram</td>
<td>18</td>
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<tr>
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<td>weak</td>
<td>intrinsics</td>
<td>mild: Tramadol</td>
<td>mild: Tramadol</td>
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<tr>
<td>6</td>
<td>intrinsics</td>
<td>decreased</td>
<td>mild: none</td>
<td>mild: MS contin</td>
<td>9</td>
</tr>
<tr>
<td>7</td>
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<td>slightly</td>
<td>severe: MS contin</td>
<td>severe: MS contin</td>
<td>20</td>
</tr>
<tr>
<td>8</td>
<td>weak</td>
<td>intrinsics</td>
<td>severe: duragesic patch</td>
<td>mod: MS contin</td>
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</tr>
<tr>
<td>9</td>
<td>intrinsics</td>
<td>weak</td>
<td>mod: MS contin</td>
<td>mod: MS contin</td>
<td>4</td>
</tr>
</tbody>
</table>

* AC = adenocarcinoma; ant = anterior; chemo = chemotherapy; CSF = cerebrospinal fluid; FU = follow up; inst = instrumentation; LCC = large cell carcinoma; MMA = methylmethacrylate; mod = moderate; MS contin = long lasting morphine; NRS = nerve root sectioning; Oc = occiput; pos = posterior; recon = reconstruction; SCC = squamous cell carcinoma; UE = upper extremity; VBR = vertebral body resection; XRT = radiation therapy.
† Revised posterior instrumentation procedure was performed after hardware failure occurred.
‡ T4 = vertebral body or mediastinal organ involvement; NO = no lymph nodes; N2 = mediastinal nodes positive ipsilateral to the tumor; N3 = mediastinal nodes positive contralateral to the tumor; MO = distant metastasis present.

Blood flow is interrupted bilaterally and spinal cord infarction can occur. The occurrence of flail chest after resection of a Pancoast tumor is usually not a significant problem because in this part of the thoracic rib cage it is frequently possible to close the chest wall defect by using scapula and surrounding musculature. However, entrapment of the scapula should be avoided by resecting its tip so that it will not intrude into the defect.

In the present study, vertebral body reconstruction was performed using methylmethacrylate and the chest tube technique. Allograft bone was used dorsally in conjunction with posterior instrumentation. Because we did not use an external orthosis, we believed that methylmethacrylate with a locking plate was needed to obtain immediate stability anteriorly, whereas posterior arthrodesis would provide the required long-term durability of the construct. The use of a cage with bone graft would probably have accomplished the same goal, although this might have required an external orthosis until fusion was achieved. We also avoided using this method because all of our patients had either already undergone radiotherapy or would need it postoperatively, and this could delay fusion.

In a review of the literature on the surgical resection of advanced Pancoast tumors we found several small series. DeMeester, et al., have described a technique for resecting tumors that were adherent to the spine. Through an extended posterolateral thoracotomy, they performed a tangential osteotomy at the junction of the pedicle and the costal facet. The entire tumor, including the involved portions of chest wall, lung, and vertebral body, was then removed en bloc. We believe that a partial vertebrectomy provides suboptimum results in patients who have vertebral body invasion if gross-total excision is the goal.

In two reports, Grunenwald and associates have described an innovative technique in which vertebrectomy is performed for en bloc resection of superior sulcus tumors that invade the vertebral column. They initially performed a three-step procedure: an anterior cervical approach, a posterolateral thoracotomy, and finally, a posterior approach. During the third stage, the spinal column was transected using a Gigli saw to cut the vertebral endplates, thus allowing the tumor to be removed en bloc. The vertebral column was reconstructed anteriorly with autologous clavicle graft and with the placement of plates and screws posteriorly. More recently, Grunenwald and associates have described a two-stage procedure, consisting of anterior cervicothoracic and median posterior approaches, that achieves the same goal. The original report by these authors included results on two patients who underwent total vertebrectomy for en bloc resection of Pancoast tumors. One patient experienced a local recurrence at 18 months, and the other patient died 5 months after surgery. An updated report included 12 patients in whom surgery was performed for Pancoast tumors, although it is unclear how many patients required total vertebrectomy.

The technique described by Grunenwald and associates may represent a superior method of resection because it respects the basic principles of oncological surgery. We agree that en bloc resection is preferable and should be performed whenever feasible; however, we have chosen to perform a gross-total resection by using the high-speed drill to complete the vertebrectomies because we believe this to be a safer technique. The distinction between en bloc and gross-total resection may not be critical in the patient population of this study because of the extent of their disease. In many of our patients there was extensive tumor invasion...
near the brachial plexus that required meticulous dissection to peel the tumor away from the nerve structures. In these patients, en bloc resection would probably necessitate sacrificing a portion of the brachial plexus. We consider the gross-total resection of tumor in these patients to be an appropriate goal, whereas en bloc resection may be feasible in patients in whom tumor involvement is less extensive.

Conclusions

Although the treatment of Pancoast tumors that extensively invade the vertebral column remains controversial, we believe that with the advances in surgical technique and spinal reconstruction, complete resection is possible in a greater proportion of these patients than was previously thought. In our series postoperative complications were not insignificant; therefore, a comprehensive evaluation and careful patient selection is required prior to any surgical intervention. A multidisciplinary approach and comprehensive preoperative evaluation are required to achieve successful resection.

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References