Resection of the First Rib With Preservation of the T1 Nerve Root in Pancoast Tumors of the Lung
Andreas K. Filis, MD, Lary A. Robinson, MD, and Frank D. Vrionis, MD, PhD

Background: Surgical outcomes for Pancoast (superior sulcus) tumors of the lung have significantly changed during the last few decades and have improved with use of curative-intent surgery by utilizing en bloc complete resections.

Methods: A retrospective analysis was conducted of 11 selected patients treated at Moffitt Cancer Center from 2007 to 2016. Data from patient records were collected and analyzed.

Results: All 11 patients with a Pancoast tumor involving the first rib had their T1 root preserved at surgery. In 10 patients (90.9%), the tumor was removed en bloc. Clear margins of resection were documented in 4 cases (36.0%). No patient developed postoperative band weakness, but 3 patients (27.3%) had minor postoperative complications, including air leak, chylothorax, and pericardial effusion. One iatrogenic injury to the subclavian artery was reported during surgery; the injury was subsequently repaired. No operative mortality was reported.

Conclusions: Radical resection of Pancoast tumors is considered to be safe, and preserving the T1 nerve root provides more favorable, functional outcomes.

Introduction
Pancoast tumor of the lung, also known as superior sulcus tumor, constitutes a special variant of lung carcinoma localized at the apex of either lung. These carcinomas comprise 3% to 5% of all cases of non–small-cell lung cancer cases, most commonly squamous cell carcinoma.1 Up to 5% of Pancoast tumors are small cell carcinomas.2 Originally described by Pancoast3 in the early 20th century, these tumors were considered to have a uniformly fatal prognosis. By employing combined triple-modality treatment using chemoradiotherapy with surgical resection, as described by the Southwest Oncology Group (SWOG),4 outcomes have changed and 5-year survival rates have been markedly improved (≤ 55% with complete resection).5

Although radical resection is often considered the key element to increased survival following induction chemotherapy or chemoradiotherapy, it may be associated with some degree of functional compromise.1 Although the T1 nerve root is not the main contributor of hand muscle function (by contrast to the C8 nerve root), its involvement and consequent sacrifice by virtue of involvement of the first rib contributes to some degree of functional impairment from paresis of the ipsilateral hand.

In this study, we report our experience with en bloc resection of the tumor along with the first rib, with concomitant preservation of the T1 nerve root.

Methods
Study Protocol and Patient Population
A retrospective cohort analysis was performed of patients undergoing surgical resection for Pancoast tumors with concomitant preservation of T1 nerve root between 2007 and 2014 at the H. Lee Moffitt Cancer Center & Research Institute (Tampa, Florida).

Data Collection
Eleven patients with Pancoast tumors who underwent surgical treatment and T1 nerve root preservation were included in the study. Electronic medical records for these patients were reviewed. Demographical information, preoperative clinical characteristics, postoperative assessments, and long-term follow-up data (if available) were extracted.

Primary End Point
The primary purpose of this study was to assess the oncological and functional outcomes of patients undergoing surgical resection for Pancoast tumors with T1 nerve root preservation.

Presurgical Evaluation
All patients were initially evaluated by a thoracic onco-
logical surgeon and subsequently by a neurosurgeon. Pretreatment computed tomography (CT)–guided needle biopsy was performed to confirm the diagnosis in all cases. For operative planning, patients were evaluated with contrast-enhanced CT of the chest and magnetic resonance imaging (MRI) of the brachial plexus. Positron emission tomography (PET) was obtained for staging to rule out any local or systemic metastases. MRI of the brain for staging was also routinely obtained prior to treatment. Fig 1 shows the MRI results of a patient with a Pancoast tumor.

At the time of the neurosurgical consultation, based on imaging and clinical findings, spinal instrumentation was made available during surgery. The SWOG protocol for preoperative chemotherapy, consisting of 2 cycles of cisplatin and etoposide, with concurrent radiotherapy (45 Gy) was used in the earlier cases, and preoperative chemotherapy alone was given in the most recent 5 cases. If the pathology specimen margins were microscopically positive for the tumor, an additional radiation dose of 20 Gy was postoperatively administered. Alternatively, patients who did not receive preoperative radiotherapy were given a dose of 60 Gy in cases of R1 resection (microscopi-
cally positive margins) or 70 Gy in cases of R2 resection (grossly positive margins); radiotherapy was always postoperatively administered to the tumor bed.

A unique multidisciplinary approach for Pancoast tumors has been put into place at Moffitt Cancer Center. Fig 2 illustrates the algorithm of the steps to be followed, starting with the diagnosis and going through the selected treatment plan for Pancoast tumors. In our more than 20 years of experience, no patient has had R2 resection or N2 (ipsilateral mediastinal) positive nodes.

**Statistical Analysis**
A descriptive analysis was performed; qualitative variables were reported as frequencies and proportions, whereas quantitative variables were reported as mean plus or minus standard deviation. Differences across the mean preoperative and postoperative subjective pain scores were obtained by an independent sample t test. A type 1 error at 5% was set as being statistically significant. All analyses were 2-tailed and performed using SPSS version 22.0 (IBM, Armonk, New York).

**Surgical Technique**
At Moffitt Cancer Center, the surgical resection is jointly performed by a thoracic oncological surgeon and a neurosurgeon. The operative plan consists of posterolateral thoracotomy with upper lobectomy or segmental resection of the tumor by the thoracic oncological surgeon, with the neurosurgeon performing en bloc resection of the tumor along the posteromedial, superior chest wall, the brachial plexus, and spine (if involved).

The patient is placed in the lateral decubitus position with the lung deflated using a double-lumen endotracheal tube. The initial thoracotomy incision is posteriorly and superiorly extended, parallel to the medial border of the scapula. The trapezius muscle is inferiorly transected along the incision and the medial attachment of the trapezius and rhomboid muscles to the spine are detached, allowing mobilization of
the scapula and exposure of the upper chest wall. Initially, the lateral chest wall cuts are made to the first and typically the second and third ribs, as required. A window of approximately 1 cm in the chest wall allows visualization of the upper chest cavity during the surgery. Caution should be exercised while resecting the anterior segment of the first rib to avoid injuries to the overlying subclavian vessels by periosteal dissection and bone removal. The underlying intercostal nerves and vessels are distally cut, together with the ribs. Subsequently, ipsilateral paraspinal muscles are partially dissected off the transverse processes, exposing the lateral aspect of the facet joints and pars as well as the transverse processes. Using a small osteotome, the transverse processes are removed. The costovertebral ligaments are cut and a Cobb elevator is placed between the head of the rib and the lateral aspect of the vertebral body. By elevating the proximal rib, the exiting nerve roof is stretched, clipped, and cut (for T2 and below).

For the T1 nerve root, special attention is given, both at the foramen and distally at the plexus, superior to the first rib. The attachments of the scalenus muscles to the first rib must be carefully dissected until the inferior part of the brachial plexus is exposed. The C8 nerve root above the first rib and the junction of the T1 nerve root with the former superiorly and laterally to the first rib is visualized. The T1 nerve root is subsequently traced proximally along its course posterior to the proximal segment of the first rib. If the surgeon has difficulty in identifying the proximal T1 nerve root, then removal of the lateral aspect of the pars-facet complex may be required at the T1 to T2 level. Fig 3 shows key anatomical landmarks and their relation to the Pancoast tumor during surgical dissection.

Following identification of the T1 nerve proximally and distally, mobilization of the tumor is initiated. The portion of chest wall for resection is inferiorly pushed to identify the subclavian artery and the stellate ganglion. Tumor extension to involve the latter structure requires cutting the ganglion as low as possible to avoid Horner syndrome. The proximal first rib must be carefully rotated between the C8 and T1 nerve roots and inferiorly pushed together with the rest of the specimen, which is then marked for orientation, and the entire specimen with the en bloc attached tumor and lung tissue is sent to pathology.

This description of the resection is applicable to the majority of Pancoast tumors involving the chest wall. In the event that the tumor invades the lateral aspect of the vertebral body, the paraspinal muscle is severed and retracted, following which unilateral laminectomy is performed. Following the clipping of the involved nerve roots proximal to the ganglion, osteotomy medial to the pedicle is performed. Pedicle screw instrumentation or single-rod vertebral body screw placement is then used, if necessary (Fig 4).

Intraoperative somatosensory-evoked potential monitoring is used with all surgical procedures directly involving vertebrae. If concerns exist about close soft-tissue surgical margins, then an intraoperative frozen section evaluation of the surgical specimen is performed.

Follow-Up Care

At Moffitt Cancer Center, the initial inpatient postoperative care is primarily handled by the thoracic oncological surgeon in conjunction with the neurosurgeon; this is because any potential complications or problems are likely to be related to the lung resection. Patients are then evaluated in the outpatient clinic 2 to 3 weeks following surgery by the thoracic oncological surgeon and the radiation oncologist. The neurosurgical evaluation occurs within 8 to 12 weeks following surgery, after which most of the neurological outcome is apparent. At 6 weeks, adjuvant radiotherapy at a dose of 65 Gy is delivered to the tumor bed in patients who only received preoperative induction chemotherapy. Long-term follow-up care is usually coordinated by the medical oncologist and radiation oncologist.

Results

The mean age of the 11 patients who underwent surgical management for Pancoast tumors was
and 82% (n = 9) were men. Their mean height, weight, and body mass index were 172.1 ± 7.3 cm, 69.4 ± 10.7 kg, and 23.5 ± 3.9 kg/m², respectively. Their mean subjective preoperative pain score was 4.4 ± 2.9; this score improved early on following surgery to 4.1 ± 2.2, although this was not statistically significant (P = .598).

All patients presented with radicular thoracic pain, and none had any evidence of metastasis on pretreatment evaluation. All patients were evaluated by the same thoracic and neurosurgical team. The SWOG regimen4 was followed in most patients, except in the most recent 5 patients (45%); these patients received preoperative chemotherapy alone. In 2 patients (18%), chemoradiotherapy or radiotherapy did not precede resection; rather, full-dose radiotherapy was postoperatively administered. Subclavian artery involvement was seen in 2 patients (18%), 1 of whom had an iatrogenic injury that was intraoperatively repaired. Two patients (18%) required intraoperative spinal instrumentation. The rate of mean blood loss was 436 ± 408 mL. Four patients (36%) had margins free of disease based on the results of the final pathological evaluation. In all cases, postoperative function of the hand was normal. Although preservation of the T1 nerve root in its continuity could be achieved for all 11 patients, 1 patient (9%) developed hypothenar atrophy with altered sensation along the C8 and T1 distribution but without significant hand weakness.

Three patients (27.3%) developed postoperative complications, including late pericardial effusion 1 month after surgery, persistent air leak, and chylothorax (n = 2) that required repair with re-entry thoracotomy at 1 week. No operative mortality was reported. Of the 11 patients, 5 died within a mean of 21.9 months following surgery. Causes of death included distant metastasis to the brain (n = 1) and adrenal metastases (n = 1); these patients developed metastases 14 and 15 months after lung surgery, respectively. Three additional patients died a mean of 15 months after surgery, but the causes of these deaths were unknown because the patients were lost to follow-up.

**Discussion**

The management of Pancoast tumors has significantly changed during the last few decades. Locally advanced disease with invasion into the vertebral bodies was historically considered a relative contraindication for surgery. Komaki et al6 reported a significantly improved survival rate in these patients who underwent surgical resection compared with those who did not. Gandhi et al7 reported outcomes in patients with Pancoast tumors with vertebral involvement who were preoperatively treated with radiotherapy, and they reported an increase in the 2-year survival rate among those treated with combined modality therapy compared with those given monotherapy. SWOG researchers4 reported a 5-year survival rate of 54% in patients with T3–4N0 disease who underwent complete R0 surgical resection following preoperative, concurrent chemotheraphy and radiotherapy. Concurrent induction chemoradiotherapy has been the standard of care since 2001, which is when the Intergroup Pancoast tumor trial results were published.4 However, in this study population (performance status 0–1), the induction chemoradiation regimen was so toxic that a treatment-related mortality rate
of 2.7% was observed, and only 76.0% of all study patients underwent potentially curative surgery.8

Despite improving options for chemotherapy and radiotherapy, gross complete surgical resection remains fundamentally important for better rates of survival, although some neurological compromise may be seen. Such compromise is generally related to the anatomical nature of tumor involvement in the neurovascular structures, including the subclavian artery and vein and the lower brachial plexus trunks. In 2007, Davis et al8 described how Paulson routinely dissected the lower plexus to obtain radical resection. In 1975 Paulson3 reported a 5-year survival rate of 34% with preoperative radiotherapy and surgical resection. According to Davis et al,8 Shahian et al10 were the first to report on postoperative functional outcomes with radical nerve root resection. In other published series, the T1 nerve root was either resected or not reported.11-13

The report by Davis et al8 was the initial series that reported on T1 preservation as a key element of surgical treatment in this patient population. Although it was a small series (n = 7), complete tumor resection with sparing of the T1 nerve root was achieved in 5 patients (71%).8 Preoperative chemoradiotherapy was performed and the resection was jointly carried out by a thoracic surgeon and a neurosurgeon, which is similar to our patient cohort. Following this paradigm, the group achieved a 2-year survival rate of 80% and normal hand function.8

In our series of 11 patients for whom the T1 nerve root was preserved during surgery, 5 patients (45%) received preoperative chemotherapy, 4 (36%) received preoperative chemoradiotherapy, and 2 patients (18%) received postoperative radiotherapy alone. The long-term survival rate with these varying approaches is still pending evaluation.

During the last 5 years, we have adopted an approach of 3 cycles of preoperative chemotherapy alone followed by surgical resection at 3 to 5 weeks, then followed by full-dose radiotherapy (65 Gy) at the tumor bed. After induction chemotherapy alone, typically a clear dissection plane can be seen for surgery; this is critical for radical resection and helps to minimize intraoperative complications. This chemotherapy-alone approach has lower rates of morbidity and helps to facilitate surgical resection; full-dose radiotherapy postoperatively is also possible, which is especially important for local control if close or microscopically positive margins are present.

In an unpublished series, nearly 100% of study patients completed therapy, including surgery, and toxicity related to the induction regimen was not a limiting factor (compared with concurrent chemoradiotherapy; Lary A. Robinson, MD, personal communication, June 8, 2016). The long-term results of this modified, preoperative chemotherapy-alone approach compared with standard preoperative chemoradiotherapy are being analyzed in a large series at Moffitt Cancer Center (LAR, June 8, 2016).

Similar to a prior series,14 a relative high rate of cerebral metastasis (27%; n = 3) and local recurrence (9%; n = 11) was observed in our series after long-term follow-up. Based on our experience, free surgical margins and maximal multimodality therapy did not preclude the occurrence of late cerebral metastases. MRI of the brain is not a routine part of the treatment plan for long-term follow-up, and it is only preoperatively performed.

The results of T1 nerve root functional preservation in our series are similar to those of Davis et al,8 with approximately 91% of patients having good functional, postoperative outcomes. One patient (9%) had ipsilateral hypothenar atrophy and altered sensation along the distribution of the C8 and T1 nerve roots, thereby correlating with the anatomical preservation of T1 nerve root intraoperatively. Preoperative chemotherapy alone facilitated the optimal dissection, owing to tumor shrinkage, maintenance of more visible dissection planes, and satisfactory clinical outcomes.

Limitations
The primary limitations of this study are those related to its retrospective nature, including inherent selection bias and a smaller sample size. This study focused on describing the functional outcomes of a select group of patients with Pancoast tumor who underwent T1 nerve root preservation. Inferential statistics were not feasible to explore other clinical parameters.

Conclusions
With technical advancements, surgical resection for Pancoast tumors appears to be a feasible therapeutic option that should be pursued using a multidisciplinary team approach. Induction chemoradiotherapy or chemotherapy alone preceding surgical resection provides overall improvements in resectability and survival rates. Meticulous intraoperative dissection with complete resection by a multidisciplinary surgical team will generally lead to improved functional outcomes by preserving the T1 nerve root and without sacrificing oncological principles.

References


