Management of Pancoast tumours

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Non-small-cell lung carcinomas of the superior sulcus, frequently termed Pancoast tumours, are some of the most challenging thoracic malignant diseases to treat because of their proximity to vital structures at the thoracic inlet. Originally deemed universally fatal, Pancoast tumours are now amenable to curative treatment because of improvements in combined modality therapy and development of new techniques for resection. This review includes discussion of anatomical considerations, initial assessment, multimodality treatment, and surgical approaches for these cancers.

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Introduction

Non-small-cell lung carcinomas (NSCLC) of the superior sulcus, frequently termed Pancoast tumours, are some of the most challenging thoracic malignant diseases to treat because they generally invade adjacent vital structures, including the brachial plexus, subclavian vessels, and spine (figure 1).[1] Originally described by a radiologist, Henry Pancoast, in 1932,[2] superior sulcus NSCLC were deemed universally fatal until the 1950s, when the strategy of induction radiotherapy and en-bloc resection was shown to be potentially curative.[3,4] During the next 40 years, this approach remained standard care, with advances restricted to development of surgical techniques for T4 tumours infiltrating the subclavian vessels and spine.[5–7] However, complete resection was usually achieved in only 60% of patients, and overall survival at 5 years generally did not exceed 30%, indicating a clear need for innovative treatments.[8] During the 1990s, concurrent cisplatin-based chemotherapy and radiotherapy followed by resection was shown to be safe and effective for some stage III NSCLC.[9] Findings of small studies[10] suggested that this treatment strategy was appropriate for Pancoast tumours, which led to a large North American trial of induction chemoradiotherapy followed by resection, establishing this treatment as standard care. In this review, I discuss initial assessment and multimodality management of Pancoast tumours and the technical aspects of resection.

Anatomical definition

The original description by Pancoast of a superior pulmonary sulcus tumour was that of a carcinoma (of uncertain origin) arising in the extreme apex of the chest, associated with shoulder and arm pain, atrophy of the hand muscles, and Horner's syndrome. Anatomically, the pulmonary sulcus is synonymous with the costovertebral gutter, which extends from the first rib to the diaphragm. The superior pulmonary sulcus describes the uppermost extent of this recess.[11,12] Unknown to Pancoast, the most accurate definition of these tumours was given in 1931 by Tobías, who characterised the anatomical and clinical aspects of the lesion and recognised it as a peripheral lung cancer.[13] This original description has been expanded to include patients who do not have evidence of brachial plexus or stellate ganglion involvement. Infiltration of the chest wall at the level of the second rib or lower, or of the visceral pleura only, should not be judged to meet the criteria for a Pancoast tumour. Chest-wall involvement might be restricted to invasion of the parietal pleura or could extend deeper to infiltrate the upper ribs, vertebral bodies, subclavian vessels, nerve roots of the brachial plexus, or the stellate ganglion.[14]

The thoracic inlet can be divided into three compartments on the basis of insertion of the anterior and middle scalene muscles on the first rib and the posterior scalene muscle on the second rib (figure 2).[15] The anterior compartment, located in front of the anterior scalene muscle, contains the subclavian and internal jugular veins and the sternocleidomastoid and omohyoid muscles. The middle compartment, located between the anterior and middle scalene muscles, includes the subclavian artery, the trunks of the brachial plexus, and the phrenic nerve. The posterior

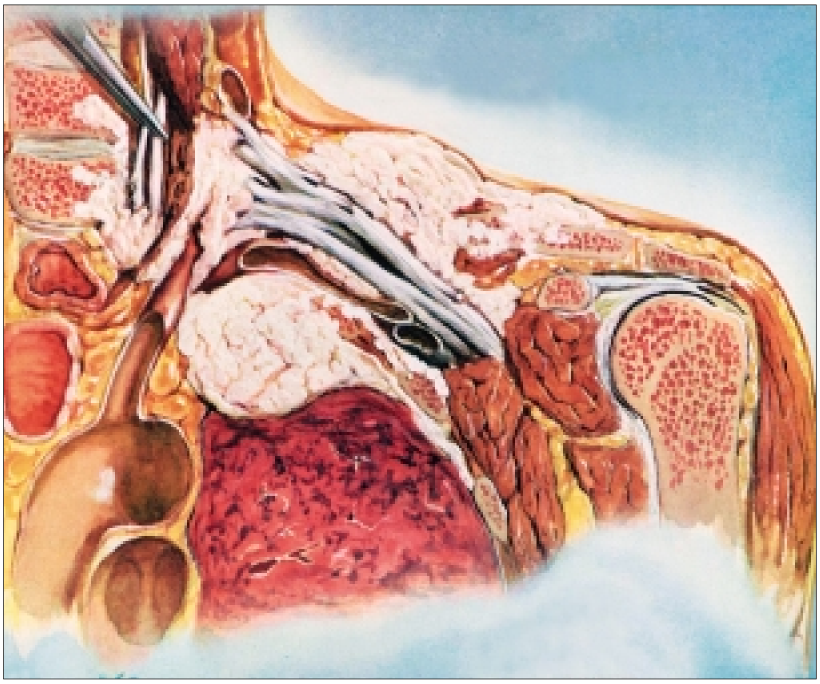

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Figure 1: **Superior sulcus lung carcinoma (Pancoast tumour)**
Cancer is shown invading structures of the thoracic inlet, including brachial plexus, subclavian vessels, and ribs. Reproduced with permission from ref 1.

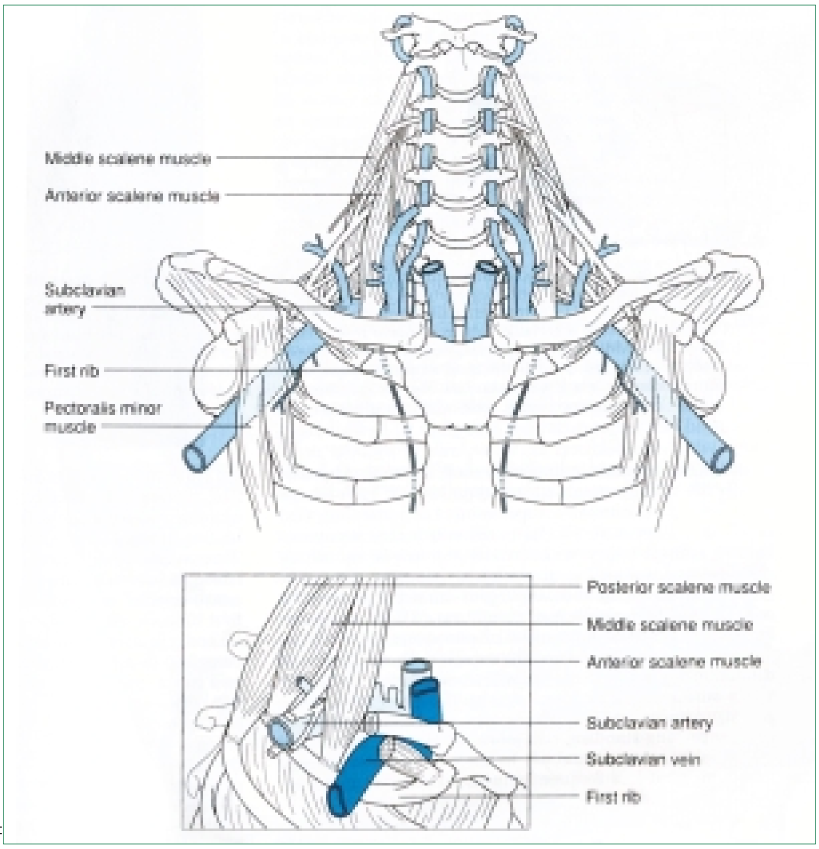

Figure 2: **Anatomy of the thoracic inlet**
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compartment contains the nerve roots of the brachial plexus, the stellate ganglion, and the vertebral column.

An understanding of the posterior location of neural structures and somewhat anterior location of vascular structures is important for adequate operative planning. Originally, Pancoast tumours were thought to be posterior in location and early attempts at resection were approached solely from the back. However, these lesions might also be located at the front, with vascular rather than neurological or vertebral involvement. Surgeons treating these cancers should be adept at both anterior and posterior approaches, since a combined procedure might be needed to obtain a complete resection.

Initial assessment

The clinical diagnosis of a Pancoast tumour does not invariably mean that the lesion is NSCLC. Patients with other diagnoses such as lymphoma, tuberculosis, or primary chest-wall tumours can present with an apical mass and chest-wall involvement. Lesions in this location are readily accessible for biopsy procedures via transthoracic fine-needle aspiration, and this technique should be done to confirm NSCLC.

Thorough preoperative assessment is needed before embarking on treatment that could lead to substantial morbidity. Superior sulcus NSCLC are, by definition, cancers of stage IIB or greater, and the extent of disease should be appraised fully before resection, with methods including CT of the chest and upper abdomen, whole-body PET, and brain MRI to investigate the primary tumour and mediastinal lymph nodes and to exclude sites of extrathoracic disease. The role of PET and brain MRI has not been studied specifically in Pancoast tumours, but implementation of these studies is logical in view of the locally advanced nature of these tumours. Because Pancoast lesions with mediastinal nodal metastases (N2 or N3 disease) have a poor prognosis, mediastinoscopy has been mandated in clinical trials and should be strongly considered for definitive pretreatment.

MRI is the modality of choice for imaging structures of the thoracic inlet, including the brachial plexus, subclavian vessels, spine, and neural foramina (figure 3).[6,16,17] Contrast-enhanced MRI of this area shows local extent of disease and is important for preoperative planning. Furthermore, the amount of nerve-root involvement must be assessed. Resection of the T1

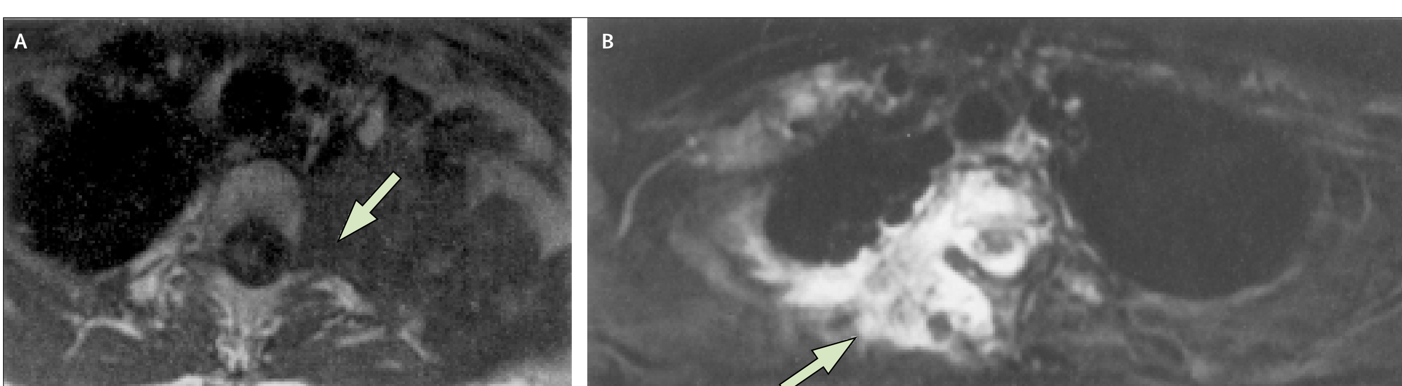

Figure 3: **Axial MRI scans of tumours of left (A) and right (B) superior sulci**
(A) Tumour extends to left neuroforamen (arrow), without epidural or vertebral body infiltration. (B) Tumour involves vertebral body and posterior element (arrow), without extension to epidural space. Reproduced with permission from ref 6.

nerve root is usually well tolerated, but removal of the C8 root or lower trunk of the brachial plexus leads to loss of hand and arm function. Careful neurological investigation is also very informative.[18] Pain extending along the ulnar aspect of the forearm and hand is consistent with T1 involvement; intrinsic hand muscle weakness suggests the C8 root or lower trunk is affected. At Memorial Sloan-Kettering Cancer Center, New York, (NY, USA), resections of Pancoast tumours are planned jointly with a spine neurosurgeon and a thoracic surgeon. Shared assessment and treatment allows accurate selection of patients and offers the best chance of complete resection.

Patients should also be assessed to establish whether they can tolerate combined procedures. Their performance status and renal and neurological function must be adequate for platinum-based chemotherapy. Pulmonary function tests and, when necessary, cardiac-stress testing are done to measure a patient’s ability to undergo pulmonary resection. These issues are especially important in elderly patients who are sometimes less able to withstand intensive combined procedures.

Evolution of multimodality management

Developments in the management of NSCLC of the superior sulcus during the past 70 years can be classified into four eras. At the onset of the first era, Pancoast described these tumours as “a peculiar neoplastic entity found in the upper portion of the pulmonary sulcus of the thorax...evidently epithelial in its histopathology, but its exact origin is uncertain”.[2] During the ensuing 20 years, these tumours became recognised as primary lung carcinomas but were thought to be inoperable and incurable. Treatment with radiotherapy was also unsuccessful. In 1956, Chardack and MacCallum[3] reported a case of a poorly differentiated squamous-cell carcinoma managed by en-bloc resection of the right upper lobe, affected chest wall, and nerve roots and by adjuvant radiotherapy (65·28 Gy over 54 days). The treated individual was alive and disease-free 5 years later. In 1956, Shaw referred a patient who presented with typical Pancoast’s syndrome for palliative radiotherapy. After 30 Gy of radiotherapy, their pain resolved and the tumour decreased in size, thus Shaw undertook a radical resection similar to that reported by Chardack and MacCallum. Complete resection and long-term survival achieved in this case prompted Shaw and Paulson[19] to test this treatment strategy further. In 1961, they reported 18 patients who received 30–35 Gy of radiotherapy over 2 weeks followed, a month later, by complete en-bloc resection of the affected lobe, chest wall, and nerve roots,[4] with excellent local control and longer than anticipated survival.

As a result of the report by Shaw and Paulson, induction radiotherapy (30 Gy over 2 weeks) and en-bloc resection via an extended posterolateral thoracotomy became standard care for superior sulcus NSCLC. For 30 years (the second era of the management of Pancoast tumours), the basic therapeutic strategy for these cancers remained unchanged. Findings of several series (table)[8,11,20–25] confirmed the original results of Shaw and Paulson, but also defined adverse prognostic factors, including the presence of mediastinal nodal metastases (N2 disease), spine or subclavian-vessel involvement (T4 disease), and limited resection (R1 or R2).[26–31] In the largest series published to date,[8,24] from Memorial Sloan-Kettering Cancer Center, which included 225 patients treated between 1974 and 1988, the results of the smaller series were corroborated, thus confirming the importance of these prognostic factors. Although operative mortality was low (4%), complete resection was achieved in only 64% of tumour stage (T) 3 and nodal stage (N) 0 and 39% of T4N0 tumours and locoregional recurrence was common.[8] Lobectomy was associated with better overall survival than was incomplete pulmonary resection, and addition of intraoperative brachytherapy to resection did not seem to enhance survival.[24] Overall survival at 5 years after surgery was 46% for T3N0, 13% for T4N0, and 0% for lesions with N2 disease.[8] These results emphasised the need for new treatment strategies to increase both local control and overall survival.

During the late 1980s and the 1990s, in what can be regarded as the third era in the management of superior sulcus carcinomas, several thoracic surgical groups developed new approaches for resection of tumours affecting the spine and subclavian vessels. Dartevelle and colleagues[5] developed an anterior transcervical method for cancers infiltrating the subclavian vessels, which was associated with 5-year survival of 31%. This work led to widespread acceptance of the anterior strategy, with subclavian-artery resection and graft reconstruction for T4 tumours. Modifications to the procedure included the transmanubrial osteomuscular sparing approach (rather than clavicular resection or disarticulation), addition of posterior or anterolateral

Preoperative treatment	n	Complete resection	Local recurrence	5-year survival	Ref
Radiotherapy, radiotherapy and chemotherapy	225	56%	40%	29%	8
Radiotherapy	61	NS	NS	26%	11
Radiotherapy	60	60%	15%	17%	20
Radiotherapy	34	NS	20%	33%	21
Radiotherapy, radiotherapy and chemotherapy	62	53%	NS	38%	22
None, radiotherapy	139	81%	31%	35%	23
Radiotherapy	124	56%	72%	26%	24
Radiotherapy	73	48%	NS	NS	25

NS=not shown. Modified with permission from ref 26.

***Table:* Results of major series of induction treatment (mainly radiotherapy) and resection for superior sulcus NSCLC**

thoracotomy to facilitate exposure to the lung and spine, and use of hemiclamshell thoracotomy (anterior thoracotomy and partial median sternotomy).[32–35] For superior sulcus carcinomas affecting the spine, groups from Memorial Sloan-Kettering Cancer Center, MD Anderson Cancer Center, Houston (TX, USA), and from France developed techniques for multilevel vertebrectomy and spine reconstruction done in conjunction with pulmonary resection. Such techniques were facilitated by improvements in materials available for spine stabilisation.[6,7,36–38] Development of approaches for complete resection of these technically challenging groups of T4 tumours was an important advance in surgical management of superior sulcus carcinomas. However, overall survival at 5 years remained about 30%, even in highly selected patients.

During this same period, researchers on several studies[25,39–41] reported results of treatment with radiotherapy only. These data are difficult to interpret because they are retrospective and include small numbers of patients who were only clinically staged and were treated in many different ways. Survival at 5 years ranged from 0 to 40% depending on T stage, total radiation dose, and other prognostic factors such as weight loss. All things considered, local control and survival seem lower than that reported in surgical series, but this finding is attributable partly to the population and the administration of treatment in a highly variable manner. However, brain metastases were uniformly reported to be a frequent site of disease progression.[41]

The success of combined modality treatment for stage IIIa (N2) NSCLC during the 1980s and 1990s led directly to the development of a large, prospective, multicentre, phase II trial (Southwest Oncology Group 9416, INT 0160),[42] which started the fourth era in management of these lesions. Induction chemoradiotherapy followed by resection is a logical treatment strategy for a group of cancers that are a formidable challenge for local control. The induction regimen used in the trial had been tested extensively in previous studies and was known to be feasible and effective in the multi-institutional setting.[9] 110 eligible patients were enrolled with mediastinoscopy negative, clinical T3–4 N0–1 tumours of the superior sulcus. Induction treatment was two cycles of etoposide and cisplatin with 45 Gy of concurrent radiotherapy. Patients with stable disease or tumour regression underwent thoracotomy and anatomical pulmonary resection followed by two additional cycles of chemotherapy. Initial results were reported in 2001.[42] Of the 110 patients enrolled, 83 (75%) ultimately underwent thoracotomy. The induction regimen was well tolerated and only five participants had grade 3 or higher toxic effects. Induction chemoradiotherapy could sterilise the primary lesion. A third of patients had a complete pathological response (n=28) and another third (n=26) had minimum residual microscopic disease in the resected specimen. Accordingly, a substantial number of participants had complete (R0) resection: 91% of T3 tumours and 87% of patients with T4 disease.

Three additional observations from this initial report are noteworthy. First, the number of postoperative complications was not greatly increased after induction chemoradiotherapy compared with historical experience with radiotherapy. Two patients (2·4%) died after surgery, and major complications—such as empyema and myocardial infarction—were infrequent. Second, postinduction imaging by CT overstaged many patients. For example, 55% of participants who had stable disease on CT had either a complete pathological response or only residual microscopic disease. Finally, as has been the experience with NSCLC in general, only a few patients (42%) could successfully complete the course of postoperative chemotherapy.

Updated results of this phase II trial were reported in 2003.[43] 5-year survival was 41% for all patients and 53% for those who had complete resection. Pathological response—but not tumour stage—predicted overall survival. Relative to previous experience with induction radiotherapy, the patterns of relapse changed mainly to that of distant failure rather than local recurrence. Of 55 patients who relapsed, only ten recurred locally, a rate of 12% compared with the historical rate of 40%.[23] Long-term results of SWOG INT 0160 are due to be published shortly.[44] The good results obtained from this trial with respect to response to induction treatment, low operative mortality, R0 resection and local control, and long-term overall survival effectively establish the treatment regimen used as a new standard of care, for both T3 and T4 tumours. In small single-institution studies, similar results have been reported.[10,45]

Future directions for multimodality treatment

Accrual to the phase II trial described above was completed successfully within the planned time frame, but needed the efforts of 76 surgeons from all North American cooperative groups to enrol 110 eligible patients. Thus, in future, randomised phase III trials that include resection are unlikely to complete accrual within an acceptable length of time for this uncommon NSCLC subset. However, the results highlight several issues that could be investigated in future trials of either single-group or randomised phase II design.

First, other induction regimens of contemporary chemotherapy drugs might lead to more pathological complete responses and longer survival. Alternatively, addition of targeted treatments (eg, bevacizumab) to cisplatin-based chemotherapy might be appropriate. Whichever current drugs are used though, they will have to be not only more effective but also no more toxic than platinum-based regimens when combined with radiotherapy and surgery. The induction schedule could be intensified by adding a third cycle of chemotherapy or by increasing the dose of radiation. Since the phase II trial was completed, two studies have reported use of a median radiation dose of 59·4 Gy in combination with platinum-based chemotherapy for induction treatment, with a resulting pathological complete response of 46% and a 5-year overall survival of 49% in 23 patients.[46,47] From this research, the conclusion that a higher radiation dose enhances survival is not clear. Whether similar results to these can be obtained safely in a multi-institutional setting remain to be seen.

Second, the outcome of the phase II trial shows the difficulty of delivering cisplatin-based treatment postoperatively to this group of patients. Based on findings of other studies in individuals with locally advanced NSCLC, docetaxel is being tested as single-agent adjuvant therapy in a phase II intergroup trial (SWOG 0220). In future, other drugs or targeted treatments might prove to be less toxic and more effective as adjuvant therapy than cisplatin-based strategies.

Finally, the high risk of brain relapse seen in the phase II trial is similar to that reported in other combined modality trials for individuals with locally advanced NSCLC and raises the issue of whether patients should be considered for prophylactic cranial radiotherapy. Hopefully, the results of an ongoing US and Canadian intergroup randomised trial testing the use of this radiotherapy technique in patients with locally advanced NSCLC will answer this question. At the current time, the combined modality regimen used in the phase II trial offers patients with Pancoast tumours substantially better treatment results than previously.

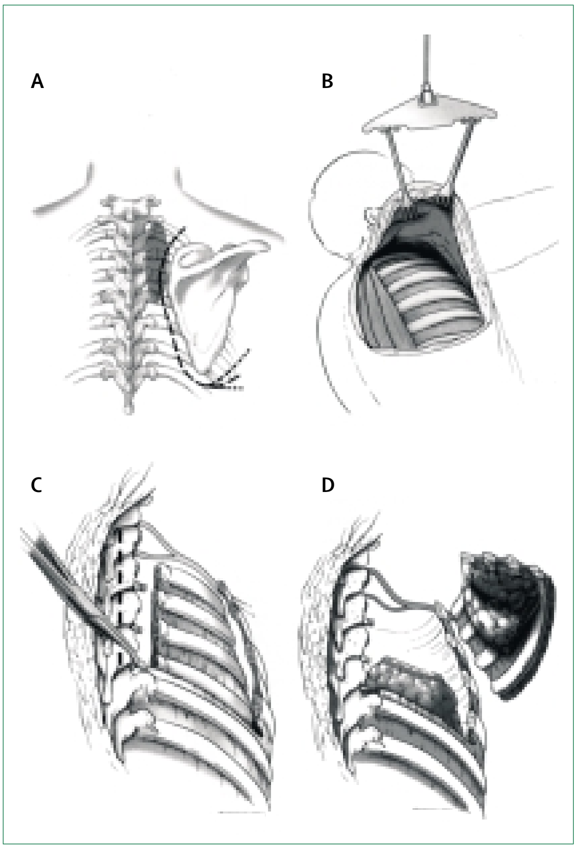

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Figure 4: **Approaches for resection of Pancoast tumours**
(A) Incision for posterolateral thoracotomy. (B) Scapula is elevated from chest wall. (C) Transverse processes resected from posterior spinal elements to facilitate resection of chest wall at level of neuroforamen and to achieve negative proximal margins. (D) En-bloc resection of tumour chest wall and left upper lobe. Reproduced with permission from ref 6.

Surgical techniques

Posterior approach

Figure 4 shows a patient positioned in the lateral decubitus position, rotated slightly anteriorly. With a posterior surgical approach, the chest is entered at the estimated level of chest-wall involvement via a posterolateral thoracotomy. The pleural cavity is examined to ascertain resectability, then an incision is made superiorly midway between the scapula and the spinous processes to the seventh cervical vertebra, dividing the trapezius and rhomboid muscles. This technique allows the scapula to be moved completely from the chest wall. Exposure is achieved either by placing the upper blade of the rib-spreading retractor under the scapula and the lower blade on the chest wall (figure 4B) or by raising the scapula with an internal mammary retractor. From the intrapleural incision, the relation of the Pancoast tumour to important structures in the thoracic inlet is established. Scalene muscles are detached from the first and second rib, the surface of the first rib is exposed, and the lesion is assessed to ascertain whether the subclavian artery and brachial plexus have been infiltrated.

If the cancer does not affect neurovascular structures in the thoracic inlet, chest-wall resection can be undertaken. The anterior border of the ribs is divided, allowing for a 4 cm margin from the tumour. Removal of the posterior chest wall is then started. The erector spinae muscle is retracted away from the thoracic spine, exposing the costovertebral gutter, and the ribs are disarticulated from the transverse process of the vertebral bodies. Alternatively, the transverse process is resected flush with the vertebral body if this area is invaded by cancer. To prevent a cerebrospinal fluid leak, which could result in meningitis or tension pneumocephalus, the intercostal nerves must be identified and closed with vascular clips (figure 4C). An incision is made at the posterior margin superiorly until the first rib is reached, and the T1 nerve root is ligated and divided if it is encased in tumour. Resection of the T1 root could result in diffuse weakness of the intrinsic muscles of the hand, although the hand remains functional. Removal of either the C8 nerve root or the lower trunk of the brachial plexus, or both, results in permanent paralysis of the hand's intrinsic muscles.

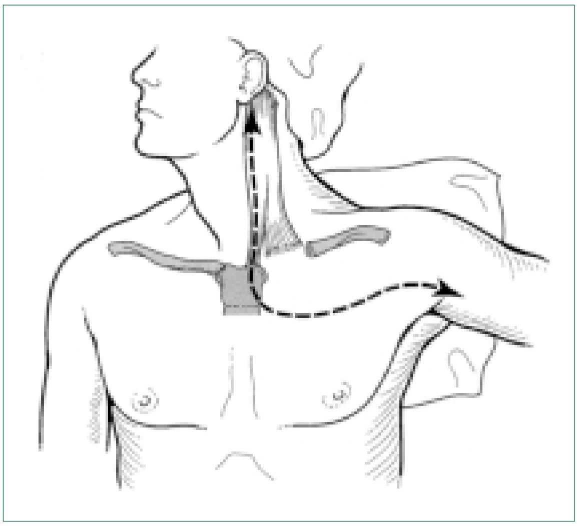

Figure 5: **Transclavicular approach**
Outline of incision, with resection of the medial half of the clavicle shown. A left L-shaped incision cervicotomy is made, which includes a vertical presternocleidomastoid cut extended horizontally below the clavicle up to the deltopectoral groove. To increase the exposure and perform the entire resection through this incision only, the interception between the vertical and horizontal branches of the L-shaped incision is lowered to the level of the second or third intercostal space, depending on the extent of the tumour. Reproduced with permission from ref 55.

After induction treatment, biopsy samples of soft tissue attached to nerve roots or the brachial plexus can show scar formation without residual carcinoma, resulting from induction therapy rather than viable tumour. In these cases, the nerves are spared.

Once chest-wall resection is complete, the specimen is allowed to drop into the chest cavity and lobectomy is undertaken (figure 4D). Standard mediastinal lymph-node dissection completes the operation. The chest wall might not need to be reconstructed if the chest wall defect is small and restricted to the upper three ribs. However, if a large defect is present, the inferior angle of the scapula will herniate under the chest wall. In this situation, the chest wall is reconstructed with a GoreTex patch (WL Gore, Flagstaff, AZ, USA) of 2 mm thickness. The thoracotomy incision is then closed.

Vertebral body and epidural tumour

With combined modality treatment, T4 disease with vertebral body and epidural tumour can be cured with resection. The extent of resection and reconstruction depends on the amount of involvement of the vertebral body, posterior element (spinous process, laminae, and pedicles), and epidural tumour. For lesions that infiltrate the vertebral body only, posterolateral thoracotomy with en-bloc chest-wall resection is done. Vertebral bodies are removed with a high-speed drill and by curettage of lytic soft-tissue tumour. The posterior longitudinal ligament is resected to provide a margin on the anterior dura, and adjacent disc spaces are exenterated to facilitate spinal fixation. For resections of one to two level vertebral bodies, anterior reconstruction alone is sufficient to provide mechanical support. Anterior structural support includes autologous iliac crest or local non-diseased rib, allograft fibula, and polymethyl-methacrylate and Steinman pins. Bone grafts should be supplemented with an anterior plate or screw-rod system to provide forward compression. In view of the size constraints of the vertebral bodies in the lower cervical and upper thoracic spine, individual screw-rod systems—such as Horizon (Johnson and Johnson, Depuy Spine, Raynham, MA, USA)—that are designed for paediatric scoliosis correction provide adequate fixation.

Tumours that infiltrate the vertebral body and posterior elements and extensive epidural lesions are resected via a posterior approach, with rearward cervicothoracic spinal fixation followed by anterior resection and reconstruction. For this procedure, patients are positioned prone and a midline incision is made. Posterolateral resection—including the spinous process, laminae, bilateral pedicles, and adjacent facet joints—is undertaken with a high-speed drill. Epidural tumour is dissected from the dura and multilevel rhizotomy of involved roots is done; the chest wall is then disarticulated from the vertebral bodies. Posterior segmental fixation is a challenge at the cervicothoracic junction. Many strategies have been used, but the basic principle is to maintain sagittal and coronal balance and add fixation points at least two levels cranial and caudal to the vertebral bodies resected. If T1 is affected, the fixing should be extended into the cervical spine with lateral mass screws. After posterior resection and reconstruction, posterolateral thoracotomy and anterior resection are undertaken, as previously described.

Anterior approaches

Several anterior approaches have been described for management of superior sulcus carcinomas, but Dartevelle and colleagues[5] are credited with solving the enigma of surgical accessibility to this complex anatomical region. Masaoka and colleagues[48] described management of the structures of the thoracic inlet via an anterior approach. They placed their patient in the supine position and did a partial median sternotomy, which was extended into the anterior fourth intercostal space and into a transverse incision at the base of the neck. The surgical team divided the neck strap muscles, retracted the anterior chest wall, and then opened the pleural cavity to expose vascular and nerve structures of the thoracic inlet. The scalene muscles were divided and lung and chest-wall resections undertaken.

Subsequently, Niwa and Masaoka[49] reported a modification of the posterior method for Pancoast tumours, the so-called hook approach, because removal of transverse processes and the head of the ribs was difficult with his anterior technique. In this revised strategy, a long, curved periscapular skin incision is made from the level of the seventh cervical vertebra to roughly the midclavicular line anteriorly above the nipple. By tilting the operating table and moving the arm, the entire thoracic inlet is exposed, and the subclavian vessels can be resected and reconstructed.

Dartevelle and colleagues described a transclavicular approach to the thoracic inlet. The patient is placed in the supine position with their neck hyperextended and head turned away from the affected side. An incision along the anterior border of the sternocleidomastoid muscle is extended horizontally below, parallel to the clavicle at the level of the second intercostal space up to the deltopectoral groove (figure 5);[5,50] the pectoralis major muscle is dissected away from the clavicle and a myocutaneous flap is folded back to expose the thoracic inlet. The scalene fat pad is excised. The extent of infiltration of the primary tumour into the thoracic inlet is assessed by opening the intercostal space below the cancer. The medial half of the clavicle is removed if the lesion is deemed resectable. The distal part of the internal, external, and anterior jugular veins is divided to expose the subclavian and innominate veins. If the subclavian vein is affected then it is resected.

The next part of the procedure entails division of the scalenus anterior muscle, at its insertion on the first rib. The phrenic nerve then is identified and preserved, but the subclavian artery is moved, dividing most of its branches. Resection of the vertebral artery is done only if the vessel is affected and no substantial extracranial occlusive disease can be detected on preoperative doppler ultrasound. If the subclavian artery has been invaded by tumour, it is resected and reconstructed, usually with a 6 mm or 8 mm polytetrafluoroethylene vascular graft. The middle scalenus muscle is divided above its insertion on the first rib, and the C8 and T1 nerve roots are identified and dissected from outside inwards up to the confluence of the lower trunk of the brachial plexus. Ipsilateral prevertebral muscles are resected together with the paravertebral sympathetic chain and stellate ganglion from the anterior surface of the vertebral bodies of C7 and T1. The T1 nerve root is usually divided, just lateral to the intervertebral foramen.

After these parts of the procedure have been done, the chest wall can be resected. The anterolateral arch of the first rib is divided at the costochondral junction, and the second rib is split at its midpoint: the dissection is continued along the superior border of the third rib to the costovertebral angle and the ribs are disarticulated from the transverse processes. Through this cavity, an upper lobectomy is done and the cervical incision is closed. With increasing experience, additional posterior thoracotomy becomes superfluous. If a vertebral resection is planned, the anterior approach also includes preservation of the medial half of the clavicle as a bone autograft, blunt dissection along the anterior longitudinal ligament of the spine, and implementation of a midline incision through the prevertebral planes to facilitate division of the affected vertebral bodies. The patient is then placed in the prone position and en-bloc tumour resection is done via a posterior thoracotomy.

The transclavicular approach, which includes removal of the medial half of the clavicle, has been the subject of concerns about functional and aesthetic outcomes. Nazari[51] proposed sparing the clavicle by disarticulating the medial end from the sternum, pulling it downward, and rotating it out of the operative field. At the end of the operation, the clavicle is fixed to the sternum with wires. However, this method sometimes fails to provide a stable sternoclavicular joint. Another alternative, proposed by Marshall and Kaiser,[52] uses an oblique osteotomy through the largest part of the clavicular head to raise the clavicle and dissect the thoracic and outlet structures. The two ends of the clavicle are rewired at the end of the procedure.

Grunenwald has described a transmanubrial osteomuscular sparing approach, which avoids division or disarticulation of the clavicle.[25] An L-shaped cervicotomy is made, similar to Dartevelle's approach.[5] The sternocleidomastoid muscle is dissected along its anterior border down to the internal jugular vein; the pectoralis major muscle is spared and the manubrium is exposed. The internal thoracic artery is ligated after division of the superior part of the manubrium (2×2 cm) via an L-shaped incision, thus leaving the sternoclavicular articulation intact. The first costal cartilage is removed, allowing mobilisation of an osteomuscular flap that is progressively raised by means of retraction of the manubrial edge. Inlet dissection and resection is then undertaken, as described by Dartevelle and co-workers.[5] The operation is completed by posterolateral thoracotomy.[53] Spaggiari and Pastorino[33] proposed adding a muscle-sparing anterolateral thoracotomy procedure to to this approach to complete the lobectomy, whereas Klima and colleagues[54] suggested extending the L-shaped section of the manubrium down to the first intercostal space, allowing the surgeon to lift the clavicle, subclavian muscle, and transected part of the manubrium without dividing the first costal cartilage and ligament.

Pancoast tumours invading the anterior structures of the thoracic inlet can now be resected completely because of the development of approaches that allow exposure to vital neurovascular structures. However, the number of anterior approaches has proliferated to such an extent that selection of the best technique can be confusing. Macchiarini has summarised nicely the disadvantages and advantages of all of them.[55]

Conclusion

Superior sulcus NSCLC pose a formidable therapeutic challenge because of their proximity to several vital

Search strategy and selection criteria

References for this review were identified by searches of MEDLINE and PubMed with the terms "Pancoast tumours", "superior sulcus tumours", "adjuvant therapy", and "surgery", and by looking through reference lists from relevant articles. Reports published between 1996 and 2006 were included, as well as historical material.

structures in the body. During the past 40 years, the development of effective combined modality treatments and of new surgical approaches has greatly increased local control and overall survival for patients with these tumours. Future studies are needed to address the continuing difficulties of systemic relapse after surgery, especially in the brain.

Conflicts of interest

I declare no conflicts of interest.

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