Review Article

Pancoast tumors

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Abstract: Pancoast tumors, situated at the lung's apex, pose a unique challenge due to their proximity to critical structures. The evolution in surgical techniques, particularly video-assisted thoracic surgery (VATS), offers innovative methodologies for the effective treatment of these tumors. This article provides an in-depth exploration of the advancements and applications of VATS techniques, catering specifically to Pancoast tumors. The history of VATS is traced, dissecting the divergence between conventional VATS (c-VATS) and advanced VATS (a-VATS). We spotlight how technological progressions have bolstered the prominence of these techniques. Contemporary evidence points towards a growing inclination for VATS, which is attributable to its tangible benefits. Patients undergoing VATS typically experience attenuated post-operative discomfort and an expedited return to normal mobility. An emerging subset of VATS, the uniportal VATS, marks a significant stride in minimally invasive thoracic surgery. The inception, development, and benefits of this revolutionary technique are meticulously detailed, offering readers a clear understanding of its potential. Navigating complex surgical situations, especially when the tumor impinges on the vertebrae, the article sheds light on the hybrid approach. This approach amalgamates the strengths of various techniques, furnishing surgeons with a robust framework to operate effectively. In summation, the manifold advantages of VATS, from patient recovery to pain mitigation, underscore its significance in thoracic oncology. However, for its potential to be fully harnessed, strict adherence to oncological guidelines and superior surgical acumen are imperative. This article serves as a comprehensive guide, bridging the knowledge gap and accentuating the pivotal role of VATS in the contemporary surgical landscape.

Keywords: Pancoast tumors; video-assisted thoracic surgery approach for Pancoast (VATS approach for Pancoast); thoracoscopy for superior sulcus tumors

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Introduction

Tumors originating from the superior pleuro-pulmonary margin above the first rib that impact adjacent thoracic inlet structures can lead to a clinical presentation termed Pancoast syndrome (1). This condition manifests with pain dispersing to areas like the neck, axilla, anterior thoracic wall, the inner side of the scapula, and the same side's inner arm and forearm extending to the wrist. It may also

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show intrinsic hand muscle weakness and atrophy, Claude Bernard Horner manifestation, and swelling of the upper arm (2). These manifestations arise from the involvement of multiple structures: the parietal pleura, endothoracic fascia, apical bone structure, and nerves including the brachial plexus, sympathetic chain, and stellate ganglion (3-6). Tumors located in the superior sulcus region possess the potential to and notably infiltrate the subclavian vessels. The involvement of subclavian vessels can have significant clinical implications due to their pivotal role in blood flow to the upper extremity. Furthermore, the inferior segment of the brachial plexus and the superior terminus of the thoracic autonomic chain, encompassing the stellate ganglion, can also be affected. The manifestation of neurologic indications and symptoms stemming from the invasion of the brachial plexus is recognized as Pancoast syndrome. Concurrently, tumoral destruction of the stellate ganglion culminates in the clinical presentation termed Horner syndrome (4-6).

Most Pancoast tumors are non-small cell pulmonary carcinomas, making up 3% to 5% of pulmonary carcinoma instances. The predominant histological variant is adenocarcinoma, transitioning from the earlier predominant squamous cell carcinoma (7). This carcinoma variant is predominantly observed in industrialized nations and could be associated with filtered cigarette consumption. Pancoast syndrome can also result from other cancers and even non-malignant tumors in the superior pulmonary sulcus (8,9). On rare occasions, other tumors like paravertebral thoracic schwannomas and myxofibrosarcomas can lead to analogous clinical observations (10-12).

The aim of this article is to delineate the key diagnostic and therapeutic considerations for patients presenting with Pancoast syndrome, highlighting the importance of comprehensive evaluation, staging, and the role of the video-assisted thoracic surgery (VATS) approach in management.

Evaluation

In the context of diagnosing Pancoast tumors, it's crucial to evaluate various imaging tools and diagnostic methodologies at our disposal. Simple thoracic radiography might not identify the tumor during its initial phase. As the pathology advances, one might observe lung apex disparities or enhanced pleural thickness. Computed tomography (CT) can reveal encroachments into bones, spine, mediastinum, or the brachial plexus. Conversely, magnetic resonance imaging (MRI) offers a detailed evaluation of the tumor's local progression (13-16).

Over the recent decade, the utilization of positron emission tomography (PET) has seen a marked escalation as an integral component of the preoperative evaluation for lung cancer. Within the context of Pancoast tumors, its relevance manifests in dual capacities. Primarily, it facilitates the preoperative staging of lymph nodes (17) and aids in the detection of occult metastases in patients with non-small cell lung cancer (NSCLC) (2). Secondly, PET is instrumental in re-stratifying tumors subsequent to neoadjuvant therapy (18). However, its limitations include an inability to offer precise topographical details regarding the initial lesion, except in the presence of coincident atelectasis. Lymph nodes that display positivity on a PET scan necessitate verification via mediastinoscopy or endoscopic endobronchial ultrasound (EBUS). Moreover, a negative PET-CT scan does not conclusively negate nodal engagement, hence, invasive staging remains indispensable. For cases presenting with intrinsic hand muscle atrophy, a rigorous neurological assessment is mandated to discern nerve root compromise.

Utilizing a flexible fiberoptic bronchoscope for bronchoscopy may help identify any invasion into tracheal or bronchial spaces, but acquiring a tissue sample is crucial for histological validation, gauging surgical feasibility, and strategizing treatment (19).

When seeking tissue diagnosis, percutaneous transthoracic needle biopsy emerges as the premier method, boasting a diagnostic efficacy of 95% (19). In situations where the common and less invasive methods render ambiguous results, VATS might be employed for tissue sampling. Additionally, employing EBUS, mediastinoscopy—particularly on the right side—and/or anterior mediastinotomy could be pivotal in delineating the nodal status and disease's spread. EBUS allows access to most mediastinal, hilar, interlobar, and selected intralobar lymph nodes because the lymph nodes are anatomically closely associated with the airways. This explains why EBUS-transbronchial needle aspiration (TBNA) was more accurate than mediastinoscopy for staging NSCLC in certain studies (20).

It's imperative to procure histological evidence when there's an apparent enlargement of mediastinal lymph nodes from radiographic or CT evaluations (21-23).

It's worth emphasizing that while certain diagnostic tools may exhibit exceptional sensitivity and specificity, their collective use ensures a thorough understanding of the pathology.

The initiation of preoperative physiological evaluation encompasses a comprehensive cardiovascular examination followed by spirometric assessment to ascertain the forced expiratory volume in 1 second (FEV1) and the diffusing capacity of the lung for carbon monoxide (DLCO). It is imperative to compute the anticipated postoperative pulmonary functions (PPO). When both % PPO FEV1 and % PPO DLCO exceed 60%, the individual is deemed to be at negligible risk for anatomical lung resection, obviating the need for supplementary assessments (23).

Should the % PPO FEV1 or % PPO DLCO fall within the range of 60% to 30% of the projected values, it becomes requisite to employ a low-technology exercise assessment for more intricate evaluation. Demonstrable proficiency on this rudimentary exercise assessment, evidenced by ascending stairs beyond 22 m or achieving a shuttle walk distance exceeding 400 m, categorizes the risk associated with anatomical resection as insubstantial (23).

In instances where PPO FEV1 or PPO DLCO (or both) are below the 30% threshold or if results from the stair-climbing or shuttle walk test are deemed unsatisfactory, a cardiopulmonary exercise test becomes paramount. A peak oxygen consumption (O_2peak) falling below 10 mL/kg/min or 35% signifies a pronounced risk of mortality and prolonged debilitation subsequent to major anatomical resection. Conversely, an anticipated O_2peak surpassing 20 mL/kg/min or 75% is indicative of minimal risk (21,23). In addition, the patient's performance status and renal and neurologic function must be adequate for platinum-containing chemotherapy (21).

Staging

The classification of Pancoast tumors, based on their T status, is determined as a minimum of T3 due to the invasion into the chest wall. Should there be further intrusion into the vertebral structure or subclavian vessels, it escalates to T4. Research data indicates a bleak 5-year survival prognosis, less than 10%, for patients with vertebral infiltration, while subclavian vessel compromise also indicates poor outcomes (24,25). A study by Dartevelle and colleagues documented a 30% 5-year survival for T4 cases, however, they highlighted the detrimental effect of subclavian vessel compromise (22).

Preoperative identification of pN2 or pN3 node engagement is paramount, given their association with suboptimal 5-year survival outcomes. Pancoast tumors present with mediastinal N2 lymph node positivity in roughly 20% of cases, underscoring the pivotal role of mediastinoscopy for preoperative assessment as asserted by earlier research (22). The integration of chemoradiotherapy and extensive surgical removal advocates for an intensified extrathoracic assessment, even in cases devoid of distant metastatic signs (26).

In an expansive evaluation of superior sulcus tumors conducted at Memorial Sloan-Kettering Cancer Center, the cohort subjected to bimodal intervention (initial radiotherapy succeeded by comprehensive removal) manifested a 5-year survival of 46% for stage IIB, none for stage IIIA, and 13% for stage IIIB malignancies. Factors like T and N classifications and the thoroughness of tumor removal influenced survival rates. Comprehensive staging played a cardinal role in survival outcomes. Yet, complete histological tumor removal was realized in just 64% of T3 N0 and a mere 39% of T4 N0 malignancies (27).

Rusch *et al.* [2000] have undertaken pivotal research to understand the factors that influence the outcomes post-surgical resection of T3 and T4 lung cancers of the superior sulcus. Their comprehensive study reveals pertinent findings that add depth to our understanding of the surgical management of such cancers (24).

In a subsequent study conducted by Rusch *et al.* in 2007, an analysis of superior sulcus NSCLCs was carried out. The results shed light on the effects of induction chemoradiation followed by surgical resection on the long-term outcomes of these patients (28).

Furthermore, the Intergroup Trial 0160 (SWOG 9416) from 2001 focused on evaluating patients at stage T3–4N0–1. These patients underwent two cycles of cisplatin-etoposide in conjunction with a concurrent radiotherapy dosage of 45 Gy. The results were promising: complete resections were observed in 91% of T3 patients and 87% of T4 patients. The post-surgical mortality rate was an impressive low of 2.3%. Upon a detailed pathological examination, a third of the cases exhibited complete remissions, while another third showed microscopic residual disease. The remaining third presented with macroscopic viable tumor. Importantly, the pathologic complete response emerged as the primary prognostic determinant for survival (29).

Treatment

Surgical intervention for Pancoast tumors is intricate, attributed to the tumor's encroachment into nearby structures like the brachial plexus, subclavian vessels, and vertebral column. Multiple surgical protocols exist, with the

prevalent method being the comprehensive removal of the tumor alongside the chest wall, generally undertaken 3 to 5 weeks post-chemo-radiotherapy (post-CT/RT). The extent of removal is influenced by the tumor's dimensions and positioning, with the posterior and anterior trans-cervical strategies being frequently employed.

Primary method involves complete removal of the tumor and part of the chest wall, typically 3–5 weeks after CT/RT.

Procedure type is dictated by the tumor's size and location. Common methods include the posterior and anterior trans-cervical approaches.

If the tumor affects the brachial plexus or vertebral column, a combined thoracic and neurosurgical approach is required.

Advancements in spinal equipment now allow for improved removal from the vertebral structure.

Certain structures' involvements may pose surgical challenges, but not always contraindications.

Engagements of specific structures like the vertebral elements, subclavian conduit, and metastasis to same-sided supraclavicular lymph nodes might be deemed as potential, though not definite, surgical restrictions by certain experts (17,22,30-34).

Post-surgery complications can include chylothorax, ulnar nerve issues, Horner's syndrome, cerebrospinal fluid-related problems such as leaks and meningitis.

Typically, the removal of T1 and T2 neural roots doesn't cause significant clinical issues. Reported surgical mortality rates range from 4% to 10% (35).

For cases where the tumor is regionally progressive, surgically unfeasible, or if surgery poses medical risks, CT/RT or sole radiotherapy stands as a feasible therapeutic alternative.

Synchronous CT/RT is recommended for stage III non-Pancoast NSCLC.

Follow-up immunotherapy is advised for a year after definitive CT/RT.

Primary radiotherapy is suitable for patients with deteriorated health or metastatic tumors. It can provide pain relief for approximately 90% of patients (36-38).

Intense radiotherapy can lead to 5-year survival rates up to 40% for localized superior sulcus tumors. Dosages between 60 and 66 Gy for infeasible tumors and reduced dosages for symptom relief in metastatic patients (36-38).

Traditionally, sole radiation therapy (RT) before tumor resection resulted in higher incomplete resections, increased local recurrence, and suboptimal survival rates.

Induction CT/RT has shown to significantly reduce both local and distant recurrences and improve survival rates for stage III lung cancer.

The strategy of induction CT/RT followed by resection is more effective than relying solely on induction RT (30).

For a comprehensive treatment guideline for patients with bronchogenic carcinoma, including a detailed treatment scheme for Pancoast tumors, readers are referred to the National Comprehensive Cancer Network guidelines (39).

Uniportal VATS for Pancoast tumor

Various methodologies are adopted for VATS, including the standard VATS lobectomy, necessitating access incisions measuring between 1.5 and 2 cm for 2 to 4 thoracoscopic portals and 2–6 cm anterior utility incision. The portal count relies on the surgeon's proficiency. This modality is minimally invasive as rib spreading in intercostal spaces is not mandated. Literature differentiates between conventional VATS (c-VATS) and advanced VATS (a-VATS), with the initial technique operating under camera supervision and the latter through video-assisted mini-thoracotomy (40). Technological strides have fostered the evolution of these methodologies, escalating the ubiquity of VATS lobectomy clinically. STS data indicates a rise in VATS lobectomy preference from 10% in 2002 to 29% in 2007 compared to traditional surgical techniques (41).

In the VIOLET study undertaken by the academic department of thoracic surgery at the Royal Brompton Hospital, London, in 2022 (42), it was elucidated that patients undergoing VATS lobectomy for lung cancer exhibited a superior recovery in physical function within the 5-week post-randomization period in comparison to those subjected to open surgery.

In Pancoast procedures, which entail expansive incisions, VATS diminishes pain and complications (43). The minimized invasiveness from VATS facilitates patients in undergoing robust physical therapy and enhanced mobility (41-43). For Pancoast tumor excisions, VATS must be performed only when maintaining the oncological principles as in open surgery. Nonetheless, its suboptimal application may yield inferior outcomes, and it should be reserved for adept thoracic surgeons. Conventional thoracotomy remains advisable when a surgeon's VATS experience is minimal or in the face of perilous perioperative challenges. Complication rates post-VATS lobectomy range from 6% to 34.2% as opposed to a ceiling of 58% in standard thoracotomy (44-49).

Figure 1 Upper thoracic vertebrae freeing from the tumor via posterior midline vertical incision.

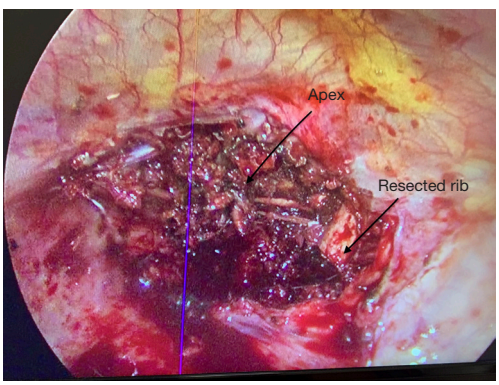
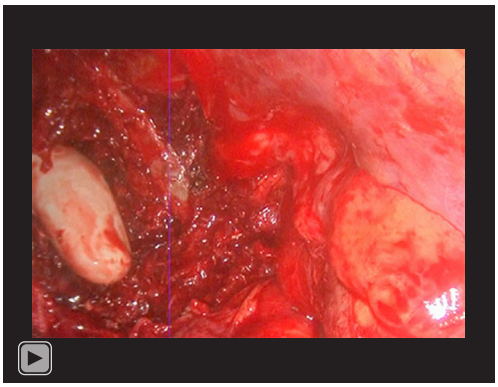


Figure 2 The bed of an apical tumor after resection showing a resected rib and the Surrounding structures.

Uniportal VATS has emerged as a novel, proven, and feasible strategy since the early 1990s, with the latest progression being its uniportal form. The VATS technique for lobectomy isn't rigid, typically comprising 3 to 4 incisions but also achievable through a solitary incision. This uniportal strategy was pioneered by Rocco and team for select thoracic procedures (46). The creation of flexible instruments has paved the way for major pulmonary excisions via a singular incision. Rocco and associates first introduced single-incision pulmonary excisions in 2004. By 2011, Gonzalez and his team from Coruña University Hospital presented the initial



Video 1 Digital palpation of the tumor through the posterior incision, ensuring no residual suspect tissues.

uniportal VATS lobectomy (47). The incision magnitude aligns with that typically reserved for dual or triple portal access (50-53). Instrumentation is facilitated by high-caliber 30° thoracoscopes, offering an unobstructed target view. For Pancoast tumors, a hybrid strategy is employed, which merges uniportal pulmonary removal with direct vision chest wall excision (53).

In instances of vertebral involvement, surgical initiation involves positioning the patient prone (*Figure 1*). Following the tumor's disengagement from the spine and potential mesh placement for spinal cord protection, the tethered pulmonary lobe is disengaged and relocated into the pleural cavity. Subsequently, the patient is repositioned into the decubitus stance. The lobectomy proceeds as customary with the uniportal modality. Post-surgery, the excised region undergoes internal exploration (*Figure 2*). Occasionally, posterior incision digital palpation aids in tumor localization, ensuring no residual suspect tissues (*Video 1*). Concluding the operation, the chest drain is positioned through the same incision, with layered wound closure (*Figure 3*).

Strengths and limitations

Strengths

The article provides an analysis of VATS in treating Pancoast tumors, offering valuable insights into its history, variations, and technological advancements.

It presents a comprehensive view of the clinical implications, including patient recovery and pain mitigation, and discusses the significance of VATS in thoracic oncology.

The exploration of the uniportal VATS and hybrid

Figure 3 Early and late image for postoperative incision. (A) The position of the chest drain through the surgical incision with additional micro drain for irrigations and drainage of basal fluid secretions. (B) Postoperative incisional scars 2 weeks after the operation.

approaches contributes to understanding the range of options available for complex surgical scenarios.

Limitations

The article may not sufficiently address the specific challenges and potential complications associated with each technique, particularly in varied clinical settings. While it emphasizes the need for surgical expertise, it may not provide detailed guidance on the learning curve or training requirements for these advanced techniques. The focus on VATS might limit the discussion of alternative treatments or approaches that could be relevant in certain patient scenarios.

Conclusions

Pancoast tumors persist as a formidable surgical challenge. Leveraging VATS techniques can expedite recovery, curtail post-surgical pain, and minimize complications, contingent on preserving oncological principles and its execution by skilled surgeons.

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