Surgical Staging of Lung Cancer

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The staging of lung cancer defines the extent of disease. Accurate staging is important to define operability, select treatment regimens, and predict survival. Nonsurgical and surgical techniques are used to stage patients. The

ABSTRACT: The staging of lung cancer defines the extent of disease. Accurate staging is important to define operability, select treatment regimens, and predict survival. Nonsurgical and surgical techniques are used to stage patients. The most important nonsurgical techniques used currently are the chest x-ray and computed tomographic (CT) scan of the chest and upper abdomen. In the future, positron emission tomography (PET) may become the single most important nonsurgical investigation. Surgical staging involves histologic assessment of the primary tumor and potential sites of metastases. At present, the standard for surgical staging is cervical mediastinotomy. Other minimally invasive surgical procedures used to stage patients with lung cancer are scalene lymph node biopsy, bronchoscopy with transbronchial biopsy, anterior mediastinoscopy, and video-assisted thoracoscopy. The different surgical staging options and their indications will be discussed in depth. [ONCOLOGY 13(5):679-685, 1999]

Introduction

The staging of lung cancer defines the extent of the disease. Accurate staging is crucial for defining operability, selecting treatment regimens, and predicting survival. Lung cancer staging is based on the American joint Committee for Cancer (AJCC) TNM (tumor, node, and metastases) system, which describes the greatest anatomic extent of disease (Table 1).[1] TABLE 1

<table>
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<th>TNM Staging of Lung Cancer</th>
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<td>Nonsurgical and surgical techniques are used to stage patients. All preoperative techniques are clinical. Operative and postoperative information provides the pathologic stage. A proper history and physical examination are mandatory.</td>
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Noninvasive Imaging Techniques

Chest x-ray and computed tomographic (CT) scan of the chest wall and upper abdomen are the most frequent imaging investigations used prior to diagnosis. The chest x-ray provides information pertaining to the size and location of the tumor, secondary effects to the remaining lung, hilar
adenopathy, and metastatic disease involving the skeletal structures. Computed tomography defines more accurately the size, location, and characteristics of the tumor, local extension into contiguous structures, lymphadenopathy, and metastatic disease to the liver and adrenal glands. Although the CT scan is very helpful as an initial screen, it is relatively insensitive in detecting invasion, as compared with surgical staging. Several studies have demonstrated that CT scans have a sensitivity of 79% for identifying positive mediastinal adenopathy. The specificity of CT for detecting metastatic lung cancer is even lower (65%) when compared to surgical staging. Computed tomography is approximately 85% accurate in predicting malignant lymph nodes when these nodes are greater than 1.5 cm in size. The data suggest that the CT scan should be used as an initial investigation in clinical staging. Its findings can then be confirmed with selective minimally invasive staging procedures.

**Surgical Staging**

Surgical staging involves histologic assessment of the primary tumor and potential sites of metastases. T1 and T2 lesions are based on size and lobar atelectasis or pneumonia. Lesions found within 2 cm of the carina but not involving the carina are considered T3 lesions. T3 lesions also include those tumors that involve structures amenable to resection; these include the parietal pleura, chest wall, diaphragm, mediastinal pleura, mediastinal fat, pericardium, phrenic nerve, and sympathetic chain. Lesions that cause obstructive pneumonia or atelectasis of the entire lung are also considered T3 tumors. T4 lesions are those that invade structures not amenable to resection, including the heart, great vessels, esophagus, vertebral body, carina, and trachea, as well as tumors that are associated with a malignant pleural effusion. Determinants of T3 and T4 lesions can be identified via minimally invasive surgical procedures. The most common metastatic sites are the regional lymph nodes. N1 disease includes the ipsilateral segmental and peribronchial lymph nodes. These nodes are resected with an anatomic lung resection. N2 nodes are located in the ipsilateral mediastinum or subcarina. Extension of disease to the contralateral mediastinal, scalene, or supraclavicular lymph nodes is considered to be N3 disease. **FIGURE 1**

![Regional Nodal Stations for Lung Cancer Staging](image)

A lymph node map developed by the American Thoracic Society provides a numbering system to identify the lymph node groups in the lung and mediastinum (Figure 1). This map can be used to record and classify the extent of lymph node metastases assessed radiographically, surgically, and pathologically. Surgical procedures used in the staging of lung cancer are scalene node biopsy, bronchoscopy, cervical mediastinoscopy, anterior mediastinotomy, and thoracoscopy. These different options and their indications will be discussed in depth.

**Scalene Lymph Node Biopsy**

Daniels was the first to describe scalene lymph node biopsy in 1949. This technique was used to define extrathoracic disease in patients with lung cancer, and biopsies were commonly performed without palpable lymphadenopathy. Scalene lymph node biopsy was widely used prior to the advent
of cervical mediastinoscopy in patients suspected of having inoperable bronchogenic carcinoma. A palpable scalene lymph node should be subjected to a fine-needle aspiration biopsy. Controversy remains concerning nonpalpable, blind lymph node biopsy. This procedure is seldom done routinely but may be appropriate in selected situations.

Lee and Ginsberg suggest that ipsilateral scalene lymph node biopsy should accompany cervical mediastinoscopy in patients who are being considered for combined-modality therapy that includes surgery.[7] Their approach involves scalene lymph node biopsy (prescalene fat pad) through the same suprasternal notch incision used for mediastinoscopy. In patients determined to have N2 disease by mediastinoscopy, the scalene node biopsy harbored occult nonclinical involvement in 15.4% of cases; 68.4% of patients with N3 were found to have occult involvement of the scalene lymph nodes. There may be a selected role for scalene node biopsy in patients with N2 disease who are being considered for combined-modality therapy and in patients with superior sulcus tumors.

**The Technique**—Scalene node biopsy can be performed under local or general anesthesia. The incision is made over the palpable lymph node or, if the nodes are nonpalpable, over the ipsilateral side of the lung lesion. A 2-cm incision is made 2 cm above the clavicle over the lateral border of the sternocleidomastoid muscle. The omohyoid muscle is retracted superiorly and laterally. The borders of the dissection are the jugular vein medially, the omohyoid muscle superiorly and laterally, and the subclavian vein inferiorly, which is usually not clearly identified. The entire fat pad is excised.[7] Often, the transcervical artery requires division, and the phrenic nerve should be avoided. The thoracic duct must be ligated if injured.

When scalene lymph node biopsy is combined with cervical mediastinoscopy, the same incision is used (ie, a 2- to 3-cm incision 1 cm superior to the suprasternal notch). After the cervical mediastinoscopy has been performed, the mediastinoscope is directed posterolaterally and superiorly behind the carotid sheath into the supraclavicular fossa. Using careful blunt dissection of the medial aspect of the fat pad, biopsies are performed.

**Complications**—Rare complications that may be associated with this procedure are pneumothorax, arteriovenous fistula, and damage to the phrenic nerve.

**Bronchoscopy**

Flexible fiberoptic bronchoscopy is a reliable, safe technique for the evaluation and staging of lung cancer. This procedure can be performed as an outpatient procedure while the patient is under local anesthesia. Bronchoscopy provides a visual assessment of an endobronchial tumor and may identify an unexpected primary tumor or a second primary lesion.

As mentioned previously, tumors that involve the trachea or carina are staged as T4. Tumors within 2 cm of the carina are defined as T3. Tumors involving the origin of the right upper lobe bronchus can be assessed with respect to performing a sleeve right upper lobectomy or right pneumonectomy.[8] These procedures involve the removal of a sleeve of the right main bronchus with the right upper lobectomy and an end-to-end anastomosis; or the removal of a sleeve of the distal trachea with the right pneumonectomy and an end-to-end anastomosis between the trachea and the left main bronchus. The bronchoscope may be used to perform bronchoalveolar lavage and brushings for cytology, as well as transbronchial biopsies under imaging guidance. Bronchoscopy has a limited role in the assessment of mediastinal lymph nodes. Enlarged peribronchial lymph nodes may cause extrinsic airway compression and are easily biopsied transbrachonially. A widened carina suggests subcarinal lymphadenopathy, which can be biopsied in a similar fashion.

**The Technique**—Bronchoscopy is performed with local anesthesia and intravenous sedation. A thorough examination is essential. First, the larynx and vocal cords are visualized. Immobility of a vocal cord may indicate involvement of a recurrent nerve with tumor, which is a sign of inoperability (T4).

The trachea and the carina are also assessed initially. Extrinsic compression or involvement of the trachea can be identified, and widening of the carina is highly suggestive of involved subcarinal lymph nodes. The carina is biopsied if it is thickened or there is a suggestion of submucosal extension of the tumor.

**Complications**—The complication rate for flexible fiberoptic bronchoscopy is 0.08%, and mortality is 0.01%.[9] Premedication and topical anesthesia are responsible for a large portion of the complications, including respiratory depression. Massive bleeding may occur in patients with bleeding dyscrasias, which should be identified.
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preoperatively and corrected. A biopsy should not be done unless the prothrombin time is over 40% of normal and the platelet count is greater than 50,000/mm³. All anticoagulants should be discontinued at least 7 days prior to the performance of bronchoscopy.

Transbronchial Biopsy

Wang popularized the use of transbronchial needle biopsy to diagnose mediastinal masses or involvement of mediastinal lymph nodes.[10] In some cases, a transbronchial biopsy may eliminate the need for mediastinoscopy. A CT scan is essential prior to a transbronchial biopsy because it provides an accurate road map to the mediastinum. Enlarged lymph nodes on the CT scan increase the yield of positive cytology from a transbronchial biopsy. The subcarinal lymph nodes are divided into anterior and posterior compartments. To avoid puncturing the azygoesophageal recess and causing pneumothorax, biopsy of the posterior carinal lymph nodes should be performed only when CT scanning demonstrates enlarged lymph nodes in that location.[10]

Right and left paratracheal lymph nodes are easily aspirated when enlarged. The aortopulmonary lymph nodes are technically more difficult to aspirate because of their proximity to the aorta and pulmonary artery. However, aspiration at this site does not carry any additional risk.[11] Para-aortic lymph nodes, and the inferior pulmonary ligament lymph nodes are not accessible. If the patient has severe obstructive lung disease, biopsy under fluoroscopic guidance is advised to decrease the risk of complications, especially pneumothorax.

The Technique—The transbronchial biopsy needles are usually 21 gauge, 1.5 cm in length, and contain a small, spring-loaded guidewire to permit extraction of a tissue.[11] The needle is passed down the bronchoscope within a protective outer sheath. Once the sheath is beyond the end of the scope, the needle is advanced out of the sheath and directed forcibly through the wall of the trachea or bronchus into the suspicious mediastinal mass or lymph node. The needle is reinserted multiple times in the same region, while gentle suction is applied. The needle is then withdrawn from the bronchoscope and flushed with saline. Collected material is sent for cytology.

Complications of transbronchial needle biopsy are the same as those for bronchoscopy with biopsy. In addition, mediastinal bleeding may occur if there is injury to the mediastinal vessels, which may require aggressive treatment. This rare complication may be minimized by performing transbronchial biopsy under fluoroscopic guidance.

Cervical Mediastinoscopy

Cervical mediastinoscopy was initially described by Harkens et al[12] in 1954 but was popularized by Carlens[13] in 1959. Cervical mediastinoscopy has become an integral part of the evaluation and staging of patients with lung cancer and is the most commonly used staging procedure. The sensitivity of cervical mediastinoscopy is 89% but its specificity is 100%.[14] There are patients who are considered “mediastinoscopy negative” but are found to have N2 disease at thoracotomy. Survival of these patients is better than that of patients who are mediastinoscopy positive and who undergo thoracotomy.[15]

Patients who are primary candidates for cervical mediastinoscopy are those with enlarged mediastinal nodes on the CT scan. The major advantage of mediastinoscopy is that it allows for bilateral exploration of the superior mediastinum. Mediastinoscopy provides access to the pretracheal space, extraluminal trachea, mainstem bronchi, and mediastinal lymph nodes. Accessible lymph nodes are the left and right paratracheal nodes and the subcarinal lymph nodes. Access to lymph nodes in the aortopulmonary window is limited with this approach. These nodes are important in left upper lobe cancers because they represent the first area of advancement in many cases.

The Technique—Cervical mediastinoscopy is performed under general anesthesia. The patient's head is hyperextended to decrease the space between the sternum and trachea. A 2- to 3-cm transverse incision is made approximately 1 cm superior to the suprasternal notch. The strap muscles are divided at the midline and retracted laterally, and the thyroid isthmus is retracted superiorly. The pretracheal fascia is incised, and a tunnel is created immediately anterior to the trachea by blunt finger dissection. The mediastinoscope is then inserted into this pretracheal space. Using blunt dissection, the lymph nodes are identified and exposed. Biopsies of the lymph nodes are taken carefully. Paratracheal nodes and anterior subcarinal nodes are explored and biopsied.
As mentioned above, the lymph nodes present in the aortopulmonary window are not accessible by traditional cervical mediastinoscopy. An extended mediastinoscopy that provides access to these nodes has been described by Ginsberg et al.\[16\] This procedure is performed through a typical cervical mediastinoscopy incision.

In extended mediastinoscopy, the mediastinoscope is advanced over the aorta between the innominate and carotid arteries. The mediastinoscope is directed toward the preaortic lymph nodes (level 6). Access to the subaortic (level 5) lymph nodes can be attained with downward traction on the aorta.

Because extended mediastinoscopy requires manipulation of the aorta, it is contraindicated in patients with atherosclerosis of the aorta. This procedure requires experience and is difficult to perform.

An anterior mediastinotomy is a more common approach to accessing lymph nodes in the aortopulmonary window.

**Complications**—Morbidity of mediastinoscopy is minimal. Hoarseness may occur after dissection of nodes in the left paratracheal area or the use of electrocautery near the left recurrent nerve. Left vocal-cord paresis is almost always transient.[8]

Bleeding is usually not a problem if the dissection is performed carefully. The azygous vein may be injured and require an anterior thoracotomy for repair. Pneumothorax may occur after cervical or anterior mediastinoscopy but can be treated by aspirating the air prior to closing the incision.

**Anterior Mediastinotomy**

Anterior, or parasternal, mediastinotomy is similar to the procedure initially described by McNeill and Chamberlain in 1966.[17] As mentioned previously, this procedure permits excellent exposure to the anterior mediastinum and the aortopulmonary lymph nodes.

**The Technique**—An incision is made parasternally in the second intercostal space. The pectoralis major muscle is divided, and the thorax is entered through the medial second intercostal space. Both the mediastinum and pleural space can be explored conveniently with either a mediastinoscope or a thoracoscope. Para-aortic lymphadenopathy can be palpated and biopsied under direct vision. Subaortic adenopathy is palpated adjacent to the left pulmonary artery and the phrenic and vagus nerves. This approach does not allow access to the posterior mediastinal lymph nodes in the area of the distal main stem bronchus.[8]

Anterior mediastinotomy is routinely done on the left side but, in selected circumstances, can be performed on the right side as well. Depending on disease location, the incision can also be performed in the third intercostal space if appropriate.

**Thoracoscopy**

Initially, thoracoscopy was used primarily for the management of pleural effusions and empyema and the lysis of tuberculosis adhesions.[18] It has regained popularity with the addition of video-optics and thorascopic instrumentation.

The main advantage of thoracoscopy is that it requires small incisions, which may result in decreased postoperative pain, shortened hospital stay, and reduced time to return to work. A disadvantage of this procedure is that it requires single lung ventilation and general anesthesia. Thoracoscopy allows a panoramic view of the entire pleural cavity, including the hilum, mediastinum, lung, visceral pleura, chest wall, and parietal pleura. Peripheral nodules can often be resected for intraoperative diagnosis. Thoracoscopy can also help evaluate the primary tumor by determining whether there is local extension into, or invasion of, the pleura. It may determine the presence of pleural implants or invasion of the pericardium, phrenic nerve, or recurrent laryngeal nerve. Thoracoscopy maybe useful in staging the ipsilateral hilum and paratracheal lymph nodes. In the right hemithorax, the paratracheal lymph nodes superior to the azygous vein (levels 2R and 4R) can be visualized just beneath the mediastinal pleura.

In the left hemithorax, thoracoscopy can visualize the preaortic lymph nodes (level 6) and the subaortic nodes (level 5), neither of which can be seen with routine cervical mediastinoscopy. Posterior mediastinal lymph nodes are also accessible with this technique, as are inferior pulmonary ligament nodes (level 9) and paraesophageal nodes (level 8). These lymph nodes cannot be accessed with any of the other surgical methods.[19]

**The Technique**—In the operating room, the patient is intubated with a double-lumen endotracheal tube and is positioned in the lateral decubitus position. The first incision is made in the sixth intercostal space at the posterior axillary line and a trocar is inserted. This port is for the
camera.

Two additional incisions are made in the fifth intercostal space at the anterior axillary line and in the seventh or eighth intercostal space at the anterior axillary line. Trocars are placed in these incisions under direct visualization. The instruments are placed in these trocars.

A complete exploration is performed. Anteriorly, the pericardium, phrenic nerve, and internal mammary vessels are identified. Superiorly, the subclavian vessels and the cupula of the pleura are examined. Posteriorly, the aorta, vagus, esophagus, and periaortic lymph nodes are inspected. Inferiorly, the chest cavity is examined, specifically, the diaphragm and inferior pulmonary ligament.[20] All enlarged lymph nodes and suspicious lesions found on the chest wall or diaphragm are biopsied.

The anterior mediastinum is still best assessed by cervical mediastinoscopy. Thoracoscopy should not be used routinely to assess lung carcinoma, but rather, should be utilized only when other surgical staging procedures fail to define the status of locoregional involvement.

**Complications**—Modern thoracoscopy is an extremely safe procedure. A review of the literature suggests a mortality rate of less than 0.1%. Complications can be avoided by skillful execution of the procedures and by strict observance of simple safety rules. Complications are seldom encountered during therapeutic thoracoscopy; greater risks are encountered with surgical thoracoscopy procedures, which are more invasive, require general anesthesia, and involve higher-risk patients. Major complications include mediastinal emphysema, air embolism, acute re-expansion pulmonary edema, and hemorrhage due to vessel perforation during biopsy of the parietal pleura or section of a pleuroplumonary adhesion. Various minor complications include local subcutaneous emphysema, residual pneumothorax, transient fever, respiratory disturbances, empyema, cardiac arrhythmia, pulmonary fistula, chest wall infection, and malignant seeding of the thoracoscopy pathway, particularly in patients with mesothelioma. The overall incidence of all implications is less than 3%.

**Conclusions and Future Directions**

Intrathoracic surgical staging of lung cancer includes information obtained from bronchoscopy, mediastinoscopy, and thoracoscopy. Cervical mediastinoscopy remains the gold standard for patients with non-small-cell lung carcinoma with suspected N2 and N3 disease. Anterior mediastinotomy, extended mediastinoscopy, and video-assisted thoracoscopy are useful for biopsying lymph nodes that are not accessible by standard cervical mediastinoscopy. Thoracoscopy may also help determine unresectability by identifying invasion of the mediastinal structures. Currently, determination of the pathologic status of the mediastinal lymph nodes is required to permit accurate staging, select appropriate treatment, and predict prognosis. It is particularly useful in defining the stage of disease histologically prior to preoperative induction therapy.

In the near future, pathologic diagnosis may not be required. Continued advances in imaging technology have improved the ability of positron emission tomography (PET) to evaluate lung cancer. Studies have demonstrated that PET provides accurate, noninvasive detection of malignancy that is useful in the staging of lung cancer.[21] Positron emission tomographic imaging will likely become an increasingly important part of the evaluation of patients with lung cancer.[22] Currently, national trials are being organized to establish conclusively the value of the PET scan in the pretreatment staging of lung cancer.

**References:**


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