# Table of Contents

**General Considerations** ........................................................................................................... 1
  Developmental Anatomy of The Lungs ...................................................................................... 1
  Pulmonary Physiology .............................................................................................................. 2
  Pulmonary Diagnostic Procedures .......................................................................................... 5
  Pulmonary Resections ............................................................................................................ 12

**Cardio-Thoracic Trauma** ......................................................................................................... 15
  Blunt Thoracic Trauma ........................................................................................................... 15
  Penetrating Thoracic Trauma .................................................................................................. 17

**Chest Wall Anomalies and Tumors** ....................................................................................... 19
  Congenital Deformities Of Chest Wall ................................................................................... 19
  Chest Wall Tumors .................................................................................................................. 21
  Thoracic Outlet Compression Syndrome ................................................................................. 23

**The Diaphragm** ..................................................................................................................... 29
  Congenital Diaphragmatic Hernias .......................................................................................... 29
  Tumors of the Diaphragm ......................................................................................................... 30
  Traumatic Perforation ............................................................................................................. 30
  Pacing ...................................................................................................................................... 31

**The Pleura** .............................................................................................................................. 33
  Pleural Effusions & Chylothorax .............................................................................................. 33
  Tumors of The Pleura ............................................................................................................... 35
  Infections of The Pleura .......................................................................................................... 38
  Malignant pleural effusions ..................................................................................................... 40

**Tracheal Diseases** .................................................................................................................. 43
  Congenital Tracheal Anomalies .............................................................................................. 43
  Tracheal Neoplasms ................................................................................................................ 44
  Infection and Inflammation ..................................................................................................... 45
  Trauma ................................................................................................................................... 45
  Postintubation Injuries ............................................................................................................. 45

**The lungs** .................................................................................................................................. 49
  Congenital Lesions .................................................................................................................. 50
  Bullous & Bleb Diseases .......................................................................................................... 56
  Infections of the Lung .............................................................................................................. 67
  Lung Cancer ............................................................................................................................ 77
  Lung Cancer Staging ............................................................................................................... 95
  Oncogenes in Lung Cancer .................................................................................................... 99
  Sugery for Lung Cancer .......................................................................................................... 101
  Supeior Sulcus Tumors .......................................................................................................... 105
  Pulmonary Metastases .......................................................................................................... 109
  Benign Respiratory Tract Tumors ......................................................................................... 112

**Esophageal Diseases** ............................................................................................................. 125
  Esophageal Diagnostic Procedures ......................................................................................... 125
  Congenital Esophageal Disease ............................................................................................. 129
<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Esophageal Injuries</td>
<td>130</td>
</tr>
<tr>
<td>Esophageal Motility Disorders</td>
<td>137</td>
</tr>
<tr>
<td>Hiatus Hernias</td>
<td>150</td>
</tr>
<tr>
<td>Benign Esophageal Disease: Benign Strictures, Tumors, Cysts &amp; Duplication</td>
<td>151</td>
</tr>
<tr>
<td>Malignant Tumors</td>
<td>156</td>
</tr>
<tr>
<td>Esophageal Cancer Palliation</td>
<td>156</td>
</tr>
<tr>
<td>Molecular Biology of Lung and Esophageal Cancer</td>
<td>160</td>
</tr>
<tr>
<td><strong>The Mediastinum</strong></td>
<td><strong>163</strong></td>
</tr>
<tr>
<td>Mediastinal Tumors</td>
<td>164</td>
</tr>
<tr>
<td>Superior Vena Cava Syndrome</td>
<td>172</td>
</tr>
</tbody>
</table>
**General Considerations**

**Developmental Anatomy of The Lungs**

A. **Intrauterine stage**
   - Four periods of development: embryonic, pseudoglandular, canalicular, and terminal sac
   - Embryonic period begins at 26 days with ventral protrusion of the foregut and ends at 32 days with appearance of 5 lobar bronchi
   - Pseudoglandular period lasts from 5th to 16th weeks and is characterized by rapid branching and formation of all conducting airways
   - Canalicular period lasts from 16th to 25th weeks and is characterized by capillary ingrowth and appearance of saccules
   - Terminal sac or alveolar period begins at 25 weeks, and alveolar development begins between the 30th and 36th weeks
   - Type I and II epithelial differentiation typically occurs at 28 weeks

B. **Neonatal stage**
   - Precursors of typical acinar unit are present at birth: bronchioles, transitional ducts, and terminal saccule
   - Alveolar development continues after birth with remodeling and multiplication
   - The total adult number of alveoli are not reached until at least age 8
   - Alveolar enlargement continues until adulthood, although no new alveoli are added

C. **Histology**
   - The mature lung is characterized by closely packed alveoli divided by thin septa, occupied by capillaries
   - Capillary endothelium is typically a single cell layer with few organelles and thin cytoplasmic matrix
   - Over 95% of alveolar epithelium is type I cells, which are also very thin with few organelles
   - Type II alveolar cells are cuboidal and secrete surfactant
   - Surfactant synthesis peaks at term and decreases to adult levels shortly thereafter
   - An increase in the lecithin-sphingomyelin ratio to more than 2:1 occurs just before birth
   - Type II cells can be stimulated to produce this pattern of phospholipid by steroids, thyroxine, estrogens, beta-agonists, and increases in ventilation or tidal volume
   - Surfactant stabilizes the alveoli, lowers surface tension to keep alveoli open at low volumes, prevents alveolar wall adhesion, and helps maintain pulmonary compliance

**Anatomic Variants with Normal Parenchyma**
   - Superior segment of lower lobe delineated by separate fissure
   - Medial accessory left lower lobe
   - Azygous lobe - mesentery of azygous vein forms double fold of visceral pleura that isolates part of right upper lobe
   - Bilateral bilobation or trilobation
Situs inversus thoracis or totalis - totalis form associated with Kartagener's syndrome (situs inversus, bronchiectasis, pansinusitis - immotile cilia syndrome).

**Pulmonary Physiology**

Preoperative evaluation and perioperative care of a patient includes
1. tissue diagnosis of primary disease and decision if an operative procedure is indicated
2. assessment of patient’s general condition
3. preoperative preparation and postoperative care

The Evaluation of pulmonary function includes assessment of cardiac function, the oxygen carrying red cells, the lungs, chest wall and ventilatory muscular function

**Lung physiology**
1. well suited for efficient exchange of O2 and CO2 with a large surface area and low perfusion pressure (300 million alveoli)
2. gas exchange controlled by two pumps- the right ventricle and the chest cage-diaphragm
3. elastic recoil of lungs ejects gas and fibrous skeleton maintains airway patency
4. Clinical evaluation of pulmonary function

a. history and physical- exercise tolerance
b. CXR, ABG
c. simple spirometry
d. vital capacity (FVC)- total exhaled volume

FEV1- forced expiratory volume at one second- indication of flow
FEV1 1000-2000 ml adequate for surgery
FEV1 800 ml or less preclude surgical resection

Restrictive disease- vital capacity, inspiratory and expiratory reserves are diminished- can result from diseases of the lung, pleura, chest cage and muscles -kyphoscoliosis, ARDS, pleural effusions or fibrosis

Functional residual volume is decreased
limited capacity to expand lungs but no difficulty emptying lungs

Obstructive Disease- lung elastic recoil decreases, compromising the force of exhalation - most common form in clinical practice
usually due to smoking, damaged alveoli can lead to pulmonary HTN unsupported airways leads to airway trapping and atelectasis

**Ventilatory Pump and Work of Breathing**
1. Ventilatory pump consist of the thoracic cage and ventilatory muscles
2. the ventilatory pump is a suction pump which expands the chest cage to pull air into the lungs
3. dyspnea signals that the work required of the ventilatory muscles has reached a level that exceeds the comfortable capacity of the patient
4. thoracotomy creates a region of non-contractile muscles which lowers tidal
volume and increases respiratory rate
5. several disease processes can cause ventilatory pump failure

e. central depression
f. muscle paralysis
g. fatigue
h. mechanical defects in the thoracic cage-trauma, post-surgical
1. failure of ventilatory pump leads to atelectasis and decreased lung compliance
2. functional residual volume decreases with loss of functional alveoli
3. post-operative pain control- epidural can help prevent splinting and therefore atelectasis
9. work capacity of ventilatory muscles are trainable- sedentary patients will poor muscle function as compared to active patients

**Fluid Exchange and Lung Water**

blood circulating through normal lung capillaries at normal rates and pressure causes a net fluid movement from the capillaries into the lung interstitium.
The filtered fluid is picked up by the lymphatics and returned to the circulation
Management of fluid therapy is critical in post-operative pulmonary resection patients since this fluid balance is disrupted
1. increased filtration post-operatively
2. decreased capillary bed and lymphatic mass
3. increased cardiac output
4. must carefully titrate fluid balance especially in pneumonectomy patients

**Ventilation -Perfusion Incoordination** effective gas transfer relies on the coordination of ventilation and perfusion
1. ventilation-perfusion mismatch occurs post-operatively
2. V/Q mismatch is the most common form of post-operative hypoxemia
3. usually secondary to the development of atelectasis

**Shunt Fraction**
Determines the fraction of blood ejected by the left ventricle that has no gas exchange in the lungs
1. patients with a shunt fraction > 0.15 to 0.20 are vulnerable to a low C.O.
2. tissue oxygen delivery falls
3. pulmonary artery catheter should be placed to optimize C.O.

**One Lung Anesthesia**
1. procedure of choice for pulmonary resection
2. videothoracoscopy has increased demand
3. unventilated lung is perfused and is a source of an intrapulmonary shunt that can lead to hypoxemia
4. usually ventilated on 100 % oxygen

**Pneumonectomy lung reduction surgery**
1. derived from the observation of chest wall adaptation in lung transplant patients
2. bilateral stapling of peripheral lung tissue to diminish lung volumes
3. reinforced with bovine pericardial strips to prevent leaks
4. improvement in symptoms and FEV1
5. improves diaphragmatic motion

**Summary of Evaluation of Gas Exchange Function** - background facts for assessing pulmonary function are as follows:
1. there is a large reserve in normal individuals
2. condition of the ventilatory muscles depends on the physical state of the patient
3. as lung volume falls, airways in dependent areas of the lung close
4. with aging and smoking, airways close at higher lung volumes
5. V/Q mismatch occurs with airway closure
6. V/Q mismatch requires increased alveolar ventilation to maintain the same amount of gas exchange
7. spirometry measures the volumes of lung and the ability to move air
8. PaCO2 is an indicator of adequacy of ventilation
9. PaO2 is an indicator of adequacy of oxygenation

**Pulmonary Assessing Pre-operative Function**
1. History and physical examination
2. CXR
3. laboratory data
4. Room air arterial blood gas
5. pulmonary function tests
   a. FEV1- 1000- 2000 ml acceptable
   b. MVV if > 50 L/min acceptable, if < 28 L/min severely decreased function
   c. split-lung function test predicts post-operative FEV1 based on ventilation scan on each lung if post-operative FEV1 > 800 ml then patient will tolerate pneumonectomy e.g. patient with left lower lung tumor, FEV1 1.72 Liters with split function of 62 % on right and 38 % on left would predict a post-operative FEV1 of 1.0 liters for left pneumonectomy if PCO2 45 then the patient is not a candidate for resection unless a medical regimen improves gas exchange
   a. cessation of smoking b. bronchodilators c. appropriate antibiotics for bronchitis d. exercise

**Selected Articles**

**Sources for further reading**
Pulmonary Diagnostic Procedures

Pulmonary Function Testing

100,000 thoracotomies are performed annually
Preoperative assessment of risk required

Resectability
The amount of lung tissue than can be safely removed without pulmonary insufficiency. Depends on pulmonary reserve.

Operability
Ability of the patient to survive the procedure and perioperative complications. Depends on Comorbid conditions

Pulmonary Function Testing

Pulmonary spirometric studies
Pulmonary hemodynamic response testing
Exercise testing

Spirometry

Modern spirometry is complex and sophisticated
Affected by height, age, weight, sex, race and posture
Blacks, Polynesians, Asians - lung volumes 10-12% less than similarly aged whites
Main stays of preoperative assessment are arterial oxygenation, spirometry, and diffusion capacity
Spirometry and arterial oxygen not predictive of postoperative complications

Diffusion Capacity

Is more sensitive as a predictor of postoperative complications
DLCO estimates pulmonary capillary surface area, hemoglobin content, alveolar micro architecture
DLCO is decreased in emphysema, pulmonary hypertension and interstitial lung disease
DLCO <60% was the best predictor of mortality
Ventilation/Perfusion Scans

Useful in determination of postoperative lung function
Perfusion scans (Tc99) are more predictable than ventilation scans (Xe133)
Spirometry and lung scans accurately predict postoperative lung function
A calculated postoperative FEV1 of less than 40% of predicted was associated with 50% mortality rate
Absolute minimum postoperative FEV1 should be > 800 cc

Pulmonary Hemodynamics Response Testing

Not popular in North America
Pulmonary artery pressure and resistance determine survival
Pulmonary arterial pressure > 35 mmHg results in decreased survival (10 fold)
Pulmonary hypertension is a contraindication to lung resection
PVR > 190 dynes associated with 90% mortality
Unfortunately pulmonary function tests do not identify patients with high pulmonary vascular resistance

Exercise Testing

Minimal achievement tests

Submaximal effort, not standardized

Maximum exercise tests

Arterial desaturation with exercise
Maximal oxygen consumption (MVO2)
Blood lactate level during exercise

Guidelines for Patient Selections

FVC < 50% of predicted
FEV1 < 50% of predicted
FEV1 < 2.0 Liters
DLCO < 60% of predicted
PAP > 35 mm/Hg
PVR > 190 dynes
MVV < 50% of predicted (with good patient cooperation)

Summary
Postoperative lung function (based on spirometry and V/Q scans) can be predicted. In pneumonectomy patients the best predictor of death was calculated postoperative FEV1. In all patients the best predictor of death was calculated postoperative DLCO. Best predictor of overall complications was DLCO and predicted postoperative DLCO.

EXTENDED OUTLINE

I. Pulmonary Lymphatic Drainage

RUL - lower paratracheal  higher paratracheal  neck  
RML - subcarinal  right paratracheal  
RLL - subcarinal  right paratracheal  
LUL - subaortic (Botallo’s node)  Anterior mediastinal or left paratracheal  
LLL - subcarinal

II. Clinical findings often do not correlate with anatomical predictions

III. Scalene Node Biopsy

A. Indicated with a palpable node  
B. Staging ie. nonpalpable is more controversial  
   1. SNB vs. Mediastinoscopy  
      a. M&M the same  
      b. Yield: SNB - 10% positive, Mediastinoscopy- 30% positive  
C. Technique  
   - anatomical bonderies include:  
     inferiorly: subclavian vein  
     medially: internal jugular  
     posteriorly: anterior scalene

IV. Mediastinoscopy

A. Positive node 30-35% of the time  
B. Controversy  
   1. Do patients with suspected cancer who are otherwise operable need this procedure  
   2. What to with a positive node (N2 Disease)  
C. Studies  
   1. Maassen  
      -1921 cases of Stage I & II  
      central masses - 23% positive nodes  
      peripheral masses - 19% positive  
D. CT Scan
Lecture Notes of Cardiovascular & Thoracic Surgery

Part IV: General Thoracic Surgery

1. Negative predictive rate 80-97%
2. Positive predictive rate 44-82%
3. Dales: meta-analysis
   - false negative 20%
   - false positive 21%
4. Kerr: 15% of positive restricted nodes are less than 10mm

E. N2 Disease carries a 5 yr survival of 3% (Mountain et al 28%)
   1. exceptions:
      a. limited aortopulmonary nodes and no anterior mediastinal nodes
      b. non-small cell with limited ipsilateral tracheobronchial intranodal involvement
F. Morbidity less than 0.1%
G. Technique

1. Definition
   Over 100,000 thoracotomies are performed annually in the United States alone, and preoperative assessment of risk is required. Two concepts are key to risk assessment: resectability, which is the amount of lung tissue than can be safely removed without pulmonary insufficiency, and operability, which is the ability of the patient to survive the procedure and any perioperative complications. Resectability depends on pulmonary reserve and operability depends on comorbid conditions. The main tests for preoperative assessment are arterial oxygenation, spirometry, and diffusion capacity.

2. Arterial Blood Gases
   - The gas partial pressure in liquid is equal to the barometric pressure times the fractional gas concentration
   - The solubility of oxygen and carbon dioxide in blood is affected by hemoglobin and buffers
   - Lower temperature, an increase in pH, and a fall in blood PCO2 will all shift the HbO2 dissociation curve to the left, increasing the affinity of hemoglobin for oxygen
   - Three points of the curve to remember:

<table>
<thead>
<tr>
<th>PaO2</th>
<th>Saturation</th>
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<tr>
<td>100 (arterial)</td>
<td>97%</td>
</tr>
<tr>
<td>50</td>
<td>84%</td>
</tr>
<tr>
<td>40 (venous)</td>
<td>75%</td>
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   - CO2 is usually transported as HCO3-, but can combine with hemoglobin and carbonic anhydrase
   - Venous PCO2 is about 46; arterial and alveolar PCO2 is about 40
   - Normal alveolar-arterial (A-a) PO2 gradient is 10 in young adults and up to 20 in older adults
Calculate A-a gradient as follows: PAO2 = 150 - PaCO2, then subtract the PaO2
Common causes of increased A-a gradient include hypoventilation, reduced
inspired oxygen, right-to-left shunting, and V/Q mismatch from atelectasis or airway obstruction
A PaCO2 greater than 45 indicates a higher risk of morbidity and mortality, but hypoxemia is unreliable as a predictor of poor outcome

3. Spirometry
Modern spirometry is complex, sophisticated, and is affected by height, age, weight, sex, race and posture
Important values include VT, FEV1, FVC, and FEV1/FVC
In restrictive disease, the total lung capacity, vital capacity, and FEV1 are all reduced, but the FEV1/FVC is normal
In obstructive diseases like emphysema, the total lung capacity and vital capacity are increased, and the FEV1 and FEV1/FVC are reduced
Blacks, Polynesians, and Asians have lung volumes 10-12% less than similarly aged whites
An FEV1 less than 2.0 liters indicates a higher risk of morbidity and mortality

4. Diffusion Capacity
Is more sensitive than spirometry as a predictor of postoperative complications
DLCO estimates pulmonary capillary surface area, hemoglobin content, and alveolar microarchitecture
The test is particularly useful in patients with dyspnea and relatively normal spirometry
DLCO is decreased in emphysema, pulmonary hypertension and interstitial lung disease; it is increased in mitral stenosis, left-sided failure, and polycythemia
A DLCO less than 60% is a good predictor of mortality

5. Ventilation/Perfusion Scans
Blood flow (perfusion) is absent in pulmonary vascular obstruction and ventilation is absent in atelectasis
The perfusion portion (Tc99) is more predictable than the ventilation portion (Xe133)
When used together with spirometry, lung scans can accurately predict postoperative lung function

6. Pulmonary Hemodynamics Response Testing
Pulmonary artery pressure and resistance are determinants of survival
- A pulmonary arterial pressure greater than 35 mmHg results in a 10-fold decreased survival
- Pulmonary hypertension is a contraindication to lung resection
- PVR greater than 190 dynes is associated with 90% mortality
- Unfortunately, pulmonary function tests do not identify patients with high pulmonary vascular resistance

7. Exercise Testing
- Maximal oxygen consumption (MVO2) may be useful in evaluating marginal patients
- Elevated blood lactate level during exercise may help predict mortality, but is not useful for postoperative complications

8. Guidelines for Patient Selections
- FVC Less than 50% of predicted
- FEV1 Less than 50% of predicted
- DLCO Less than 60% of predicted
- MVV Less than 50% of predicted (with good patient cooperation)

9. Bronchoscopy
A. Indications
- A wide range of diseases are indications for either diagnostic or therapeutic bronchoscopy, most commonly carcinoma, pulmonary infections, and interstitial lung disease
- The surgeon must perform bronchoscopy prior to thoracotomy on any patient who may undergo pulmonary resection
- Specific indications for the procedure include chronic, persistent cough; hemoptysis; localized wheezing; and bronchial obstruction

B. Diagnostic Bronchoscopy
- An 8 x 40mm rigid bronchoscope is suitable for most adults
- The flexible bronchoscope is useful for peripheral or upper lobe lesions, but is limited in the presence of thick secretions and excessive bleeding
- Either topical or general anesthesia may be used depending on patient status and age
- As the tip of the bronchoscope passes the larynx, the patient's head is lowered and extended
- Use ball-tip or cup forceps for tissue sampling, and always biopsy proximal to a gross tumor to define the upper limit of the tumor
- Flexible bronchoscopy allows for transbronchial needle biopsy, washings, and brushings
C. Therapeutic Bronchoscopy
· Most foreign bodies can be removed by bronchoscopy; grasping forceps or a Fogarty catheter are the most useful
· Heavy retained secretions can usually be drained using flexible bronchoscopy with a large side port
· Palliation resection of endobronchial obstructing tumors can be done with the Nd:YAG laser
· Other treatments include brachytherapy and phototherapy

D. Specific Conditions
· Bronchogenic carcinoma can present as an endobronchial mass, submucosal or peribronchial involvement, a peripheral mass, diffuse metastatic disease, or occult tumor
· Masses and metastatic disease should be directly biopsied, while submucosal involvement and peripheral masses requires transbronchial needle biopsy, washings and brushings
· Occult tumors are discovered from positive sputum cytology; a thorough bronchoscopic examination will find the majority of these lesions
· Bronchoscopy is also useful for tuberculosis, fungal infections, and opportunistic infections in the immunocompromised patient

Selected Articles

Sources for further reading

Textbook Chapters

Pulmonary Resections

A. Right upper lobectomy
   1. incise hilar pleura
   2. visualize pulmonary vein
   3. pulmonary artery lies superior and posterior to the vein
   4. dissection is carried out to the anterior-apical artery
   5. artery and vein are dissected circumferentially being careful of the takeoff of the middle lobe artery
   6. upper lobe bronchus is identified just inferior to the azygos

B. Right middle lobectomy
   1. identify the posterior branch to the RUL & superior segment branch to the RLL through the major fissure
   2. identify two arterial branches to the middle lobe
   3. middle lobe vein most commonly drains to the superior vein
   4. key is to divide the vein first, followed by the bronchus, and finally the artery

C. Right lower lobectomy
   1. dissection begun in the major fissure
   2. artery seen and dissected distally
   3. bronchus is visualized after division of the artery and then divided after identifying the middle lobe bronchus
   4. finally the vein is divided

D. Right pneumonectomy
   1. incise the hilar pleura
   2. dissect the pulmonary veins
   3. dissect the pulmonary artery (may need to open the pericardium)
   4. isolate mainstem bronchus
   5. cover the bronchial stump

E. Right sided lymph node dissection
   1. dissect the area bordered by:
      inferiorly - azygos vein
      superiorly - subclavian vein
posteriorly - trachea
anteriorly - superior vena cava

F. Left upper lobectomy
1. incise the hilar pleura
2. pulmonary artery is the most superior structure in the hilum
3. ligamentum arteriosum can be divided to obtain length
4. dissect the artery to the superior segment of the LLL
5. divide the fissure to expose the lingular arteries
6. divide the artery, then the vein, and finally the bronchus

G. Left lower lobectomy
1. begin in the fissure if complete, otherwise begin at the hilum
2. visualize the superior segment artery
3. divide the posterior aspect of the fissure
4. dissect the artery onto the basilar trunk
5. expose the inferior vein in the inferior pulmonary ligament
6. divide the artery, vein, and bronchus

H. Left pneumonectomy
1. identify the pulmonary artery, and vein
2. traction is needed to expose the proximal mainstem bronchus
3. Divide the artery, vein, and bronchus

I. Left lymph node dissection
1. dissect lateral to the ligamentum, between the aortic arch and the pulmonary artery
2. dissect superior to the arch
3. dissect the inferior pulmonary ligament

J. Pointers for the left side
1. aortopulmonary window may be difficult to dissect secondary to infiltration of disease, and a very friable, tethered artery
2. apical-anterior artery is tenuous
3. left mainstem is difficult to dissect
Selected Articles

Sources for further reading

Textbook Chapters
Cardio-Thoracic Trauma

Definition
Trauma to the chest is usually divided into blunt and penetrating injury. Proper emergency care and resuscitation are integral parts of the management of these patients, who may have airway obstruction, life-threatening hemorrhage, and severe associated injuries.

Blunt Thoracic Trauma

1. Chest Wall Injuries
- Rib fracture is the most common thoracic injury
- Significant intrathoracic injury may be present without rib fracture in children due to rib cage elasticity
- Narcotics and intercostal nerve blocks are sufficient for simple rib fractures
- Patients with flail chest should be supported with mechanical ventilation for several days to regain chest wall stability
- Consider tracheostomy for prolonged intubation to minimize laryngeal injury and facilitate pulmonary care
- First rib fracture indicates significant force, and aortography is indicated if the patient also has brachial plexus deficit, absent radial pulse, pulsating supraclavicular mass, or widened mediastinum

2. Pulmonary Injuries
- Pulmonary contusion probably occurs to a varying degree in all thoracic injuries and is a major component of flail chest
- Significant hypoventilation and shunting from contusion requires judicious fluid management and ventilatory support, if indicated
- Partial, complete, and tension pneumothorax should all be managed promptly with chest tube insertion
- Subcutaneous emphysema should prompt investigation for pneumothorax but is not in itself an indication for chest tube placement
- Hemothorax should be managed with early chest tube drainage to prevent clot formation and incomplete evacuation
- Surgical exploration is recommended if initial output is more than 1000 ml or chest tube drainage is more than 100 ml/hr for 4 hours
- A clotted hemothorax should be evacuated early by thoracotomy to improve pulmonary function and prevent late fibrothorax

3. Tracheal/Bronchial Injuries
- Most tracheal injuries are cervical and range from crush injuries to complete tracheal separation
· If endotracheal intubation is not possible, a surgical airway should be obtained
· Primary repair of tracheal lacerations or separation should be performed, if possible
· Blunt trauma typically causes a circumferential laceration of either main bronchus with complete separation
· Only 50% of patients will have a pneumothorax with this injury, and hemothorax is uncommon
· Only 1/3 of patients are diagnosed in the first 24 hours, and only 1/2 within the first month
· Early repair is the preferred treatment if the diagnosis is made, and requires thoracotomy with intubation of the uninjured bronchus
· Late strictures from incomplete tears or parenchymal isolation from complete tears can be repaired with bronchoplastic procedures, but may require pulmonary resection

4. Cardiac/Great Vessel Injuries
· Myocardial contusion is the most common injury and is suspected with EKG changes and serial enzyme elevations
· Coronary artery injury can result in thrombosis and myocardial infarction
· Atrial or ventricular rupture is usually fatal, although the pericardium may restrict bleeding enough to allow survival to the ER
· The patient should be monitored in the ICU and may require heparinization for coronary thrombosis and anti-arrhythmic therapy
· Echocardiography and angiography are indicated for tamponade and post-injury murmurs, which suggest valvular insufficiency or septal defect
· Aortic rupture is also usually fatal, but can result in formation of a false aneurysm, typically at the aortic isthmus
· Patients with a widened mediastinum on CXR should have prompt aortography, which will demonstrate an intimal tear
· Surgical repair should be done promptly, as fatal hemorrhage can occur at any time
· Techniques include LA-FA bypass, proximal aorta-distal aorta shunting, and cross-clamping without cardiopulmonary bypass

5. Diaphragm Rupture
· Most lacerations occur on the left hemidiaphragm and result from automobile accidents
· Usually, the stomach herniates and undergoes volvulus, massively dilates, and causes left lung collapse and mediastinal shift to the right
· Gastric distension can also result in perforation and should be prevented by NG tube placement
· Splenic and liver injury is also common in this setting
· The diaphragm can be repaired either through the chest or abdomen, and all tears should be closed in double-layer fashion
Penetrating Thoracic Trauma

Comment: Knowledge of the type of weapon in gunshot wounds is useful, as unbalanced or hollow-point ammunition can cause extensive internal destruction despite small entrance wounds. In addition, such missiles can fragment and embolize. It is important to remember that any penetrating injury to the fourth interspace or below may well have passed through the diaphragm, and attention given to possible intraabdominal injury.

1. Chest Wall Injuries
   · Laceration of intercostal or internal mammary arteries can be life-threatening and operative intervention based on chest tube output
   · The pulmonary vessels are rarely the source of major bleeding unless a hilar vessel is injured
   · High-velocity missiles and shotgun wounds can produce extensive open wounds requiring immediate occlusion and intubation, followed by operative repair

2. Pulmonary Injuries
   · Most penetrating wounds only require chest tube insertion and lung expansion
   · Parenchymal injuries requiring operation can usually be oversewn without difficulty
   · Bronchial or pulmonary artery injury can require resection
   · A large vascular clamp placed across the lung hilum facilitates exploration and vessel repair

3. Base of Neck Injuries
   · The close proximity of major structures make injury highly probable
   · This can be assessed by angiography, contrast swallow, endoscopy, or surgical exploration
   · The surgical approach will vary, but median sternotomy with lateral or superior extension provides the widest exposure
   · Avoid prosthetic grafts for vascular repair if the trachea or esophagus are also injured
   · Cardiopulmonary bypass may be required if the aorta must be cross-clamped

4. Cardiac/Great Vessel Injuries
   · The right ventricle is most commonly injured, followed by the left ventricle
   · Ventricular septal defect is the most commonly intracardiac injury
   · Most patients do not reach the hospital, as the injury to the pericardium leads to exsanguination instead of tamponade
   · Hypotension that does not respond to rapid volume replacement suggests significant injury
   · CXR, EKG, and echocardiography have little diagnostic value in these patients
   · Subxiphoid pericardiocentesis is useful for diagnosis; negative deflection of the QRS complex indicates contact with the epicardium and a drain should be left in place
   · Subxiphoid pericardial window is preferred for tamponade, however, and should be performed in the operating room, as the patient may rapidly exsanguinate
Emergency room thoracotomy is seldom indicated, being reserved for moribund patients or rapid deterioration without time to transfer to the OR
- Median sternotomy is the preferred approach
- Repair ventricular lacerations with pledgetted nonabsorbable horizontal mattress sutures
- Oversew atrial or aortic injuries
- Coronary artery division should be managed by ligation and bypass grafting on cardiopulmonary bypass
- Obvious septal defects or gross valvular insufficiency should be repaired; otherwise, the injury should be more adequately studied with postoperative catheterization

5. Tracheal/Bronchial Injuries
- Tracheal injury is suggested by pneumothorax, pneumomediastinum, subcutaneous emphysema, hemoptyisis, and airway obstruction
- Following intubation or a surgical airway, an anterior collar incision is the best approach
- Median sternotomy may be required for associated vascular injury or intrathoracic tracheal laceration
- Avoid tracheostomy if possible when a vascular repair is in proximity

ESOPHAGEAL INJURIES
- Blunt injury is rare; the most common cause is endoscopic perforation, followed by penetrating injuries
- Mediastinitis is a lethal complication and early surgical intervention is recommended
- Cervical esophageal injury should be approached through a lateral neck incision and thoracic injuries via thoracotomy
- If the tissue is not extensively damaged, primary repair with drainage is appropriate; otherwise, the wound is left open
- Postemetic rupture (Boerhaave's syndrome) presents with pain, fever, and shock; death can occur within 24-48 hours
- The diagnosis is suggested by cervical and mediastinal air, widened mediastinum, and pleural effusion
- The esophagus should be closed in two layers, the mediastinum widely opened, and the area drained into the pleural space via thoracotomy

COMPLICATIONS OF THORACIC TRAUMA
- ARDS follows many types of injuries, but is particularly common in thoracic trauma
- It typically begins a few hours after injury and progresses rapidly
- Ventilatory support with PEEP and high FIO2 is the standard of care
- Failure of ARDS to improve after 4-6 days is associated with a high incidence of death
- Arrhythmias are common in this patient population, particularly atrial fibrillation, which can be treated with standard measures
- Ventricular arrhythmias suggest myocardial injury or infarction and should be investigated
- Many patients require tracheostomy and attention should be given to proper care
- Other complications include atelectasis, thromboembolism, infection, and air embolism
Chest Wall Anomalies and Tumors

Congenital Deformities Of Chest Wall

1. Pectus Excavatum
   · Most common congenital sternal deformity, occurring in 1 in 400 children
   · Excessive growth of lower costal cartilage results in sternal depression
   · Usually causes a deeper depression on the right, pushing heart to the left
   · Congenital with progressive worsening over time
   · Rarely familial

2. Physiologic Manifestations
   · Usually asymptomatic
   · Subjective decrease in respiratory reserve with exercise
   · Scoliosis and mitral valve prolapse have been associated with pectus excavatum
   · Decreased maximal voluntary ventilation and a mild restrictive pattern on PFTs has been documented in some studies
   · Decreased SV and CO during upright exercise has also been demonstrated

3. Operative Indications
   · Cosmetic correction is the most common reason
   · Psycho-social factors, however, may be quite limiting, particularly in older children
   · Respiratory insufficiency and recurrent pulmonary infections
   · Best results are obtained in patients between the ages of 3 and 5

4. Operative Technique
   A. Ravitch repair
      · Midline or transverse inframammary incision
      · Pectoralis reflected bilaterally to expose costal cartilages
      · Subperichondrial resection of all deformed costal segments
      · Elevate sternum from underlying structures and separate from cartilage
      · Transverse sternal osteotomy and fixation with pin or cartilage support
   
   B. Sternal eversion
      · En bloc excision of sternum and associated deformed cartilages
      · Free graft everted and fixated
      · Alternatively, the graft can be mobilized on an internal mammary artery pedicle
      · New anterior surface of the sternum shaped to form proper contour

   C. Prosthetic implants
      · Silastic or other prosthetic molds generally give poor results

5. Results
   · Cosmetic results are good in 80-90%
   · Recurrence occurs in about 10-20% of patients
   · Return of normal respiratory function and improvement in exercise capacity is possible

6. Other Deformities
   A. Pectus Carinatum
· More common in males and is associated with scoliosis
· Usually presents as anterior sternal displacement with symmetric costal cartilage concavity
· Costal cartilage resection gives excellent results

B. Poland's syndrome
· Unilateral absence of pectoralis major with hypoplasia or aplasia of ipsilateral breast and ribs, and bradysyndactyly
· More common in males, usually occurs on the right side, and is most often sporadic
· Operative repair involves rib grafts and prosthetic patching of the chest wall

C. Sternal fissure
· Complete, upper, or distal varieties occur
· Narrow clefts can be closed primarily after mobilization by oblique chondrotomies
· Broader clefts may require a prosthesis to avoid compressing the heart

D. Cantrell's Pentalogy
· Characterized by a distal cleft, omphalocele, diaphragmatic cleft, pericardial defect, and congenital heart defect (usually VSD or TOF)
· One-stage repair is usually possible
Chest Wall Tumors

1. Incidence
   · Comprise 7-8% of all bony tumors
   · Most primary chest wall tumors are malignant
   · 85-90% occur in the ribs (50% malignant)
   · 10-15% occur in the sternum (95% malignant)
   · Male:female = 2:1

2. Clinical Presentation
   · Slowly enlarging mass eventually causes pain and presence of mass
   · Pain is more common in malignant tumors, but 20-25% are asymptomatic
   · Tumors occur at any age and are more likely to be malignant in older patients
   · CXR with rib detail films and CT scan are usually adequate and can evaluate associated pulmonary nodules
   · MRI distinguishes nerve and vascular invasion

3. Etiology

<table>
<thead>
<tr>
<th>Malignant</th>
<th>Benign</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chondrosarcoma</td>
<td>Fibrous dysplasia (40%)</td>
</tr>
<tr>
<td>Myeloma</td>
<td>Chondroma (30%)</td>
</tr>
<tr>
<td>Osteogenic sarcoma</td>
<td>Osteochondroma</td>
</tr>
<tr>
<td>Ewing's sarcoma</td>
<td>Desmoid</td>
</tr>
</tbody>
</table>

4. Principles of Treatment
   · Excisional rather than incisional biopsy should be performed if a primary chest wall tumor is suspected
   · Full thickness excision of the tumor with 1 rib margin is necessary; do not compromise resection to avoid large chest wall defect
   · Large tumors may warrant incisional biopsy
   · Needle biopsy is best for suspicious mets or myeloma
   · Sternal tumors should be treated by sternectomy

5. Principles of reconstruction
   · A defect less than 5 cm does not require reconstruction
   · Posterior defects do not require reconstruction due to scapula
   · Defects larger than 5 cm will require reconstruction
   · Skeletal stabilization can be accomplished with a mesh patch or methyl methacrylate
   · Soft tissue reconstruction can be done in a variety of ways, including myocutaneous flaps (latissimus dorsi, pectoralis major, rectus abdominus) and omental transposition

6. Results
   · Low operative mortality and good postoperative pulmonary function
   · Overall long term survival is about 50-70%, with best rates for chondrosarcoma and rhabdomyosarcoma, and worst rates for malignant fibrous histiocytoma
   · Survival is better with wide excision
   · Adjunctive therapy may improve survival

Selected Articles

A nice series of 252 patients where the authors primarily repaired pectus deformities with anterior wedge osteotomy and steel strut support. Low complications and excellent functional and cosmetic results were obtained.


As the title denotes, a very large series of patients with follow-up extending to 40 years. The authors recommend repair between the ages of 4 and 6 years and add a temporary support bar beneath the sternum.


The authors' data showed no improvement in ejection fraction or cardiac index at rest or with exercise. There was increase in both right and left ventricular volume after operation, suggesting that there is relief of some degree of cardiac compression.


A definitive article which covers both primary and metastatic neoplasms of the chest wall. The authors discuss how to select operative candidates and the reconstructive options.

Sources for further reading

Textbook Chapters
Thoracic Outlet Compression Syndrome

Definition
Compression of the subclavian vessels and brachial plexus at the superior aperture of the chest, most commonly against the first rib. Other terms for this syndrome include scalenus anticus syndrome, costoclavicular syndrome, hyperabduction syndrome, cervical rib syndrome, and first thoracic rib syndrome.

Anatomy
A. Surgical Anatomy
· The first rib divides the cervicoaxillary canal into a proximal space and a distal space (the axilla)
· Most neurovascular compression occurs in the proximal section, which consists of the costoclavicular space and the scale triangle
· Costoclavicular space boundaries: clavicle (superior), first rib (inferior), costoclavicular ligament (anteromedial), and scalenus medius/long thoracic nerve (posterolateral)
· Scalene triangle boundaries: scalenus anticus (anterior), scalenus medius (posterior), and first rib (inferior)
· The subclavian vein lies anteromedial to the scalenus anticus; the subclavian artery and brachial plexus run posterolateral to this muscle

B. Functional Anatomy
· Certain movements and position of the arm and shoulder girdle, as well as anatomic variations, can narrow the costoclavicular space or scalene triangle
· Arm abduction rotates the clavicle toward the first rib
· Arm hyperabduction pulls the neurovascular bundle around the coracoid process and head of the humerus
· Poor shoulder posture lessens the angle of the sternoclavicular joint as the distal end of the clavicle "droops"
· Severe emphysema or excessive muscular development causes abnormal lifting of the first rib
· Anatomic variations narrow either the superior angle or the base of the scalene triangle, producing upper and lower types of compression syndromes, respectively
Etiology
There are many factors which can cause neurovascular compression at the thoracic outlet. Bony abnormalities are present in about 30% of patients, and some of these may be visualized on plain chest x-ray.

<table>
<thead>
<tr>
<th>I. Anatomic Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>· Interscalene compression</td>
</tr>
<tr>
<td>· Costoclavicular compression</td>
</tr>
<tr>
<td>· Subcoracoid compression</td>
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</tbody>
</table>

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<tr>
<th>II. Congenital Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>· Cervical rib</td>
</tr>
<tr>
<td>· Rudimentary first rib</td>
</tr>
<tr>
<td>· Scalene muscle abnormalities</td>
</tr>
<tr>
<td>· Fibrous bands</td>
</tr>
<tr>
<td>· Bifid clavicle</td>
</tr>
<tr>
<td>· First rib exostosis</td>
</tr>
<tr>
<td>· Enlarged C7 transverse process</td>
</tr>
<tr>
<td>· Omohyoid muscle abnormalities</td>
</tr>
<tr>
<td>· Anomalous transverse cervical artery</td>
</tr>
<tr>
<td>· Postfixed brachial plexus</td>
</tr>
<tr>
<td>· Flat clavice</td>
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</tbody>
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<thead>
<tr>
<th>III. Traumatic Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>· Fractured clavice</td>
</tr>
<tr>
<td>· Humeral head dislocation</td>
</tr>
<tr>
<td>· Upper thorax crush injury</td>
</tr>
<tr>
<td>· Sudden effort of shoulder girdle muscles</td>
</tr>
<tr>
<td>· C-spine injuries/cervical spondylosis</td>
</tr>
</tbody>
</table>

| IV. Atherosclerosis                 |

*adapted from Kirklin and Barratt-Boyes

Clinical Presentation
The character and pattern of symptoms will vary depending on the degree to which nerves, blood vessels, or both are compressed

A. Neurogenic
· More frequent than vascular compression
· Pain and paresthesias present in 95% of patients
· True motor weakness with atrophy of hypothenar/interosseus muscles found in 10%
· Sensory fibers lie on the outside of the nerve bundles and are the first to be affected by compression
· Symptoms usually have ulnar nerve distribution (medial arm and hand, 4th and 5th fingers)
· Pain is insidious and involves neck, shoulder, arm and hand
· Strenuous physical exercise precipitates the symptoms, with arm in abduction and neck hyperextended
B. Vascular
· Pain is usually diffuse and associated with coldness, weakness, and easy fatiguability of the hand and arm
· Unilateral Raynaud's phenomenon in about 7.5% of patients, which can be precipitated by hyperabduction or carrying heavy objects
· There may be signs of distal embolization, poststenotic dilation or aneurysm of the subclavian artery, or true arterial occlusion
· Venous obstruction is much less common and is known as "effort thrombosis" or "Paget-Schroetter syndrome"
· The affected arm is edematous, discolored, and aches

Diagnosis
A. Clinical maneuvers
· Positive findings for all tests include a decrease or loss of the radial pulse, or reproduction of symptoms
· Adson/scalene test: patient holds a deep inspiration, fully extends neck, and turns head to the side
· Costoclavicular test: shoulders drawn inferiorly and posteriorly
· Hyperabduction test: arm is hyperabducted to 180 degrees

B. Radiologic tests
· CXR and C-spine films can detect cervical ribs and degenerative changes
· Cervical CT should be performed if osteophytic changes and intervertebral space narrowing are present
· Angiography is indicated for a pulsating paraclavicular mass, absent radial pulse, or paraclavicular bruit

C. Ulnar nerve conduction velocity
· Points of stimulation include the supraclavicular fossa, middle upper arm, below elbow, and wrist
· Normal value across the thoracic outlet is 72 m/sec; any value less than 70 m/sec indicates compression

<table>
<thead>
<tr>
<th>Grading of Compression</th>
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<tbody>
<tr>
<td>Velocity</td>
</tr>
<tr>
<td>66-69 m/sec</td>
</tr>
<tr>
<td>60-65 m/sec</td>
</tr>
<tr>
<td>55-59 m/sec</td>
</tr>
<tr>
<td>less than 54 m/sec</td>
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</tbody>
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Differential Diagnosis
· The differential diagnosis for thoracic outlet syndrome is quite broad and includes neurologic, vascular, pulmonary, cardiac, and esophageal disorders.
· Some of the more common conditions include herniated cervical disk, cervical spondylosis, and peripheral neuropathies
Treatment
- Physical therapy should be initiated in all patients
- Most patients with an UNCV above 60 m/sec will improve with conservative therapy
- Surgical intervention should be considered if symptoms persist after physical therapy and the UNCV shows minimal or no improvement

Operative Technique
- Always document preoperative neurologic findings
- Transaxillary first rib resection avoids division of major muscle groups, ensures complete removal of the first rib, and has the best cosmetic result
- Position the patient in the lateral position with the affected arm abducted 90 degrees and loosely suspended (straight up to the ceiling)
  - Transverse incision in the axilla between pectoralis major and latissimus dorsi
  - Dissect along the external thoracic fascia to the first rib
  - Divide the scalenus anticus at its insertion on the rib
  - Remove middle and anterior portion of first rib after periosteal elevation
  - Divide costoclavicular ligament and remove posterior portion of first rib
  - Always protect the brachial plexus and vessels
  - Remove the entire first rib, as any residual portion may cause recurrence

Results
- Almost all patients will have relief with conservative therapy, with about 5% requiring surgery
- Symptoms recur in about 10% of patients
- Less than 2% will require reoperation
- A recent study from the Annals of Thoracic Surgery of over 2200 patients showed excellent or good results after operation in over 90% of cases
Recurrent Thoracic Outlet Syndrome

- About 1-2% of patients will have persistent or progressively more severe symptoms after their operation
- Most have recurrence within 3 months of operation
- Symptoms, physical examination, and UNCV findings should be diagnostic before reoperation
- *Pseudorecurrence* occurs in patients in whom a cervical rib or the second rib was resected instead of the first rib, or the first rib was resected instead of the causative cervical rib
- *True recurrence* occurs in patients in whom the first rib was incompletely resected or there was excessive scar development around the brachial plexus
- The posterior thoracoplasty approach provides the best exposure
- Persistent or recurrent bony remnants should be excised
- Careful neurolysis of the nerve root and brachial plexus is performed along with dorsal sympathectomy
- One series of over 400 patients had improvement in symptoms in about 80% of patients; 7% required a second reoperation
**Selected Articles**


*This series of over 2200 patients treated with the transaxillary approach has impressive results - over 90% of patients had excellent or good relief of symptoms. Importantly, there was no significant difference in the results and relief of symptoms from upper or lower plexus compression.*


*This is the lead article in the second section of this issue dedicated to thoracic outlet syndrome and focuses on the careful clinical evaluation as the key to properly treating this difficult patient population.*


*The author discusses two techniques for using VATS: standard three-port and transaxillary first rib removal. Excellent relief has been obtained with the sympathectomy.*


*This article illustrates some of the challenges associated with reoperation for recurrent thoracic outlet syndrome and outcomes.*

**Sources for further reading**

**Textbook Chapters**


The Diaphragm

Anatomy
- Composed of a central tendinous portion and a peripheral muscular portion
- Muscular portion consists of sternal, costal, and lumbar components
- Three major openings: aortic (aorta, azygos vein, thoracic duct), esophageal (esophagus, vagus nerves), caval (IVC)
- Right and left phrenic arteries arise from the abdominal aorta
- Additional arterial supply from pericardiophrenic and musculophrenic arteries
- Venous drainage is via right and left phrenic veins to the IVC; some drainage to the left renal vein as well
- Right and left phrenic nerves supply both sensory and motor innervation

Congenital Diaphragmatic Hernias

A. Bochdalek's Hernia
- Occurs posterolateral in the area of the 10th and 11th ribs
- 90% occur on the left
- 2:1 male to female incidence
- Usually isolated and not associated with other congenital defects
- Typically manifests as acute respiratory distress
- CXR demonstrates intestine in the thorax and shift of mediastinal contents to the right
- Initial treatment includes NG decompression, positive-pressure ventilatory support, and surgical correction
- Approach left-sided defect through the abdomen in order to explore for malrotation and obstruction
- Right-sided defects are repaired through a thoracotomy
- Postoperative mortality can be as high as 50%, mostly attributed to increased pulmonary vascular resistance
- ECMO is useful to reduce pulmonary vascular resistance and help resolve persistant fetal circulation

B. Morgagni's Hernia
- Defect occurs in a subcostosternal location
- Uncommon (less than 3% of diaphragmatic hernias) and usually asymptomatic
- Well defined hernia sac becomes symptomatic typically after age 40, when obesity, pregnancy, or trauma increases intraabdominal pressure
- The transverse colon is the most common organ to herniate, and can present as an acute colonic obstruction
- Repair is usually performed through a upper midline incision

C. Esophageal Hiatal Hernia
- Congenital defects causing these hernias are uncommon in adults, but some neonates and infants may have reflux associated with an esophageal hiatal hernia
- Typical symptoms are vomiting, respiratory complications, anemia, and failure to
Tumors of the Diaphragm

A. Primary
- Rare tumors; cysts are more common than inflammatory masses, which are more common than neoplasms
- Equal male:female incidence; left-sided tumors are slightly more common than right-sided tumors
- Symptoms include pain, cough, dyspnea, and GI symptoms
- CXR and CT scan will localize the tumor
- The majority of neoplasms are benign (60%), which are usually cysts
- Up to 40% are malignant, usually sarcomas
- Treatment includes excision and closure of the diaphragmatic defect

B. Metastatic
- Most neoplastic involvement of the diaphragm occurs from contiguous extension of nearby tumors
- The most common lesions arise from lung, esophagus, stomach, liver, and the retroperitoneum
- Treatment is based on the primary tumor

Traumatic Perforation

- Penetrating perforation should be suspected with any thoracic injury below the level of the nipples (5th ICS)
- Most blunt hernias are caused by automobile accidents, and about 90% occur in the left hemidiaphragm
- Blunt trauma defects are large, usually about 10-15 cm, and typically located in the posterior left hemidiaphragm
- Stomach is the most commonly herniated organ, followed by spleen, colon, small bowel, and liver
- Respiratory insufficiency is common early, while intestinal obstruction predominates later
- CXR and CT scan will diagnose most; barium contrast is contraindicated, as it can produce a total obstruction in this setting
- Missed injury and delayed diagnosis commonly leads to bowel incarceration and obstruction
- Mortality is relatively high (15-40%) due to high incidence of associated injuries
- Repair should be undertaken promptly with full exploration for other injuries
- Left-sided perforation should be repaired through the abdomen to allow correction of associated injuries
- Right-sided perforations may require thoracotomy

thrive
- Diagnosis rests on esophagography, fluoroscopy, and pH monitoring
- Treatment is primarily medical; surgery is indicated for medical failure
Pacing

A. Indications
· Sarnoff (1940's) and Glenn (1950's) were the primary developers of diaphragmatic pacers
· Pacing is indicated in patients who have chronic ventilatory insufficiency with normal nerves, lungs and diaphragm
· This includes some quadriplegic patients and central alveolar hypoventilation
· Contraindications to pacing are lower motor neuron dysfunction, muscular dystrophy, and extensive lung disease

B. Mechanism
· There are four components to a diaphragmatic pacer:
  1) Transmitter: sets respiratory rate and length of inspiration
  2) Antennae: transfers signal across intact skin to the receiver
  3) Receiver: obtains signal and energy from external portion by inductive coupling
  4) Electrode: stimulates the phrenic nerve
· The electrode portion is usually implanted on the phrenic nerve through the 2nd ICS anteriorly
· The receiver is placed in a subcutaneous pocket

C. Central Alveolar Hypoventilation
· Features of CAH include: hypoxemia and hypercapnia increasing with sleep, hypoventilation or apnea during sleep, and clinical findings of cyanosis, polycythemia, and cor pulmonale
· These patients have near-normal ventilatory capacity tests, but have a reduced response to induced hypoxemia and hypercapnia
· Absence of upper airway obstruction or persistence after relief must also be demonstrated
· These patients should begin pacing within 3 weeks of operation

D. Quadriplegia
· Patients with high cervical lesions (C1 or C2) are suitable candidates; injury to C3-C5 may injure the motor component of the phrenic nerves, preventing adequate pacing
· Delay surgery for several months to allow for potential recovery after spinal cord injury
· Pacing should be gradually introduced to avoid diaphragmatic fatigue and permanent damage
· Patients should be selected who are good candidates for long-term rehabilitation
Selected Articles


Great review article on surgical intervention in CDH. As expected, proper preoperative resuscitation enhances outcomes.


Excellent review of nearly 1000 patients with traumatic herniation. Less than 50% were diagnosed preoperatively, emphasizing the need for high index of suspicion.


An older article that contains lots of radiographs, but is a good review of all varieties of tumors and cysts.


An even older article, which reviews the use of pacing in this syndrome. Indications and operative technique are discussed.

Sources for further reading

Textbook Chapters

The Pleura

Pleural Effusions & Chylothorax

1. Anatomy

Parietal and Visceral pleura
Potential space
Histology
Arterial supply

Parietal
Visceral

Lymphatic drainage
Innervation

Coronal View
Cross Section

2. Physiology

Mechanics

Negative pleural pressure

Fluid movements

Visceral
Parietal
Lymphatics

3. Video Assisted Thoracotomy

Indications - Diagnosis

Undiagnosed pleural effusion
Pleural based lesion
Tumor staging and diagnosis (biopsy)
Evaluation of thoracic injury

4. Indications - Therapeutic
Pneumonolysis
Foreign body extraction
Pleurodesis
Debridement of empyema cavity
Control of hemorrhage
Clot evacuation
Sealing of pneumothorax

5. Malignant Pleural Effusion

Diagnosis

Pathophysiology
Fluid characteristics

Appearance
Chemistry (exudate)

Protein > 3 g/dl; LDH > 200 u
pH < 7.3; glucose < 60 mg/dl
Amylase > 160 u

Cytology, Histology
V.A.T.S.

6. Malignant Pleural Effusion

Management

Repeated thoracentesis
Chest tube drainage with intrapleural sclerosis

Empty pleural space
Expandable lung
CT output < 150 - 200 cc/day

Pleurectomy
Miscellaneous

Shunts, XRT
Hormonal therapy, chemotherapy

7. Mesotheliomas

Benign Localized
Asbestos - no; asymptomatic
Extra-thoracic - 1/3
Resection

Malignant Localized

20% primary malignant pleural tumors
Localized, symptomatic
Wide en bloc excision

Diffuse Malignant

0.8-2.1/million/yr
50% - pure epithelial; 30% - mixed
Asbestos - yes; smoking – no

**Tumors of The Pleura**

8. **Diagnosis**

   Middle-aged men, symptomatic, asbestos
   CXR, CT scan
   Biopsy: Keratin (+), CEA (-), hyaluronic (+)

**Management**

   Supportive care
   Debulking with subtotal pleurectomy
   Radical surgery
   XRT, chemotherapy

**Prognosis**

   Median survival 6-14 months

9. **Chylothorax**

   Obstruction or injury of thoracic duct
   Anatomy of the duct - main and right
   Mechanics of lymph flow
   Chyle
1500 - 2400 cc/day
Triglyceride 0.4-0.6 g/dl
AG ratio 3:1
WBC 2,000-20,000 cells/ml (90% T)

Congenital, traumatic, non-traumatic

10. Diagnosis

R > L
Pleural effusion analysis
Pseudochyle

Management

Non-operative: Drainage, dietary management
Non-traumatic
Traumatic

Surgery if > 1,000 cc/day X 7 days or leak > 2 weeks
Esophageal resection or pneumonectomy
Lung trapped, nutritional complications
Direct ligation of fistula, duct ligation

EXTENDED OUTLINE

Usual causes:

- contamination of pleural space
- imbalance in the dynamic equilibrium with fluid accumulation
- mesothelioma

ANATOMY

-mesothelial cells
-parietal/visceral components

Blood supply

-parietal—systemic>>intercostal, bronchial, and subclavian arteries

-venous drainage into the peribronchial veins
Lecture Notes of Cardiovascular & Thoracic Surgery

Part IV: General Thoracic Surgery

- visceral—systemic and pulmonary circulations

- venous drainage into the pulmonary venous system

Lymphatic system—two systems

- visceral—pulmonary system (lower lobes)
- parietal—direct communications with the pleural space—stomata

PHYSIOLOGY

- pleural pressure is essentially negative during the breathing cycle—at FRC, pressure is –2 to –5 cm H2O; full inspiration –25 to –35 cm H2O
- more negative at the apex than the base

Fluid—200cc to 1L absorbed Q24 hours

- Composition

MANAGEMENT OF PLEURAL DISEASES

Spontaneous pneumothorax

- Peripheral lung bleb is the usual cause

- usually seen in tall thin individuals

- pathogenesis of lung blebs is unknown

  ? rapid lung growth relative to the pulmonary vasculature
  ? higher transpulmonary pressure at apex—increased alveolar pressure

- acute pleuritic chest pain common symptom
- physical exertion is unrelated to occurrence

Management

- observation if small—air resorbed at 50-75ml/day
- supplemental oxygen
- tube thorocostomy for

moderate sized or tension PTX disease in the contralateral lung
persisting symptoms
progression of size
Hemothorax quite uncommon—torn adhesion usual cause
Indications for surgery for first episode PTX:

Risk factors for recurrence:
-about 20% recur
    -75% recur on the same side within 2 years of the first episode
    -when a surgical procedure is required, two principals are important:

removal of the offending blebs
production of pleural symphysis

-axillary thoracotomy (3rd interspace) or VAT
-pleurodesis achieved via talc or doxycycline—do not use talc in young patients or those with CF because the adhesions formed preclude lung transplantation

Secondary spontaneous pneumothorax

-seen mostly in older people with documented lung disease
-predominant symptom is severe SOB—not chest pain
-initial tx—tube thoracostomy
-prolonged air leak common
-recurrence rate—50% after one episode; therefore people with a reasonable operative risk should have definitive treatment

Infections of The Pleura

Empyema

-purulent pleural effusion with (+) bacteriologic cultures

Post traumatic empyemas

-penetration of the chest wall—foreign material carried into the pleural space
-presence of a hemothorax—becomes secondarily infected from a chest tube

Stage I-parapneumonic effusion
Stage II-fibrinopurulent phase; (+) bacterial invasion
Stage III-chronic phase; ingrowth of fibroblasts and capillaries; thick peel
Complications most likely, e.g., empyema necessitatis-dissection of pus through the soft tissues of the chest wall and eroding through the skin

Diagnosis—fever, tenderness
- posterior and lateral—extend to the diaphragm
- CXR: inverted D-shaped density on the lateral chest film
- most common organisms: S. aureus, G(-) bacteria, and anaerobes;
  almost 50% are polymicrobial
- effusions with pH <7, glucose <50, LDH >1000, should be drained

Management

Complete drainage of the collection
Obliteration of the empyema space
Investigation and treatment of the underlying infection
Management of associated conditions

Decortication-goal is full lung expansion—via extensive debridement
- early aggressive approach—as soon as tube thorocostomy is ineffective

Eloesser Flap—long term drainage of empyema

Removal of chest tube tract and carrying the incision down to the ribs
Two ribs and the intervening intercostal muscles are removed
Skin sutured to the pleura—dependant drainage insured

Clagett procedure—open window thorocostomy
  excision of the sinus tract
  instillation of antibiotics in the pleural cavity,
  closure of the chest wall
  described for post-pneumonectomy empyema
  best results (25-60%) when no bronchopleural fistula present
Streptokinase
Persistence of empyema usually is secondary to
  inadequate drainage
  chronic pulmonary disease (TB, Fungus, Neoplasm)
  immune suppression
  foreign body
In summation for chronic empyema:
- Tube thorocostomy
- thoracoscopy/open decortication
- Eloesser flap
- Thoracoplasty/Muscle transposition

**Malignant pleural effusions**

-due to a disturbance in the equilibrium of production and absorption of fluid
- lymphatic obstruction esp. with paraneoplastic effusions

Management—palliation/relief of symptoms (usually dyspnea) is the goal—removal of effusion

-options—pleurectomy; mechanical pleurodesis; talc poudrage; pleuroperitoneal shunt; tube thorocostomy and sclerosis

Mesothelioma
Benign localized
unassociated with asbestos exposure
asymptomatic--detected on routine CXR
paraneoplastic syndromes common

well-encapsulated visceral pleural masses

Malignant localized
20%
symptomatic
wide enbloc excision
adjuvant therapy of little value

Malignant diffuse

asbestos exposure with latency period of 20 years
intensity of exposure more important than duration.
usual patient is middle aged male with pleuritic chest pain/SOB
CXR shows pleural calcifications

three main types—epithelial (confused with adenocarcinoma), mesenchymal, and mixed
median survival 6 to 14 months--most die of local complications
subtotal pleurectomy—1 year survival—60%
radical extrapleural pneumonectomy

adjuvant chemotherapy
Chylothorax—results from thoracic duct obstruction
Anatomy of thoracic duct--50% of the population
originates from the cisterna chyli—T12-L2

Right posterior mediastinum between azygous, esophagus, and aorta
Tracheal bifurcation, crosses to left chest

Neck-anterior to scalene muscle and enters venous system at jugular/subclavian junction
Physiology—upward flow secondary to pressure gradient, fat intake, contraction of the duct, and the presence of valves

-1.5-2.5 L/day
-odorless with high triglyceride count, total protein, WBC (T-Cell)

Etiology

Diagnosis—chylomicrons

Pseudochyle

Management--Non-operative (tube thoracostomy/thoracentesis) for non traumatic

Diet—medium chain triglycerides—reduce lymph flow
-Traumatic—operate if >1L/day for 7 days or leak > 2 weeks
children >100ml/day per year of age for 2-3 weeks
Operate if lung entrapped or nutritional complications

Technique-direct ligation of the fistula [heavy cream]

Subdiaphragmatic duct ligation—right thoracotomy; mass ligature of the tissue between the azygous and aorta

THORACOPLASTY

Thoracoplasty for TB-historic approaches attempted to copy nature’s intentions, i.e., resection of the chest wall to collapse the underlying diseased lung.
Most successful was 3 stage approach by Alexander
75% sputum conversion
multiple pulmonary complications
“frozen shoulder”
cosmetically unacceptable results

Schede
Plombage-introduced in the 1950’s

Various materials placed extrapleurally between the lung and ribs or extraperiostally
did not interfere with cough or chest wall movement
complicated by infection
60% conversion rate.

Osteoplastic thoracoplasty
posterior ends of the upper ribs are resected in increasing lengths back to the tip of the transverse processes which are left intact
ribs are reflected down
posterior ends are wired to the uppermost intact rib
chest wall stability.

Muscle transposition into chronic empyema cavity
Can also be done as a free flap
Tracheal Diseases

Anatomy
A. The trachea
- Average length is 11 cm (range 10-13 cm) and shortens with age
- 18-22 rings (about 2 rings per cm)
- The cricoid cartilage is the only complete ring
- Average diameter is 2.3 cm laterally and 1.8 cm anteroposteriorly
- In infants, the anteroposterior diameter is greater
- COPD will increase the AP diameter ("saber sheath")

B. Anatomic relationships:
- Anterior - thyroid isthmus, innominate artery, aortic arch
- Posterior - esophagus
- Lateral - azygous, pleura, recurrent laryngeal nerves
- Inferior - anterior and posterior subcarinal lymph nodes

C. Arterial supply:
- Three branches of the inferior thyroid artery on either side of the upper trachea
- Subclavian, supreme intercostal, internal thoracic, innominate, superior and middle bronchial arteries all contribute to varying degrees
- Lateral longitudinal vessel anastomoses feed transverse vessels, which penetrate between cartilage rings to supply submucosa
- Mobilize only 1-2 cm circumferentially to avoid ischemic necrosis
- Mobilize anteriorly and posteriorly to avoid significant vessels

Congenital Tracheal Anomalies

A. Agenesis or atresia
- Usually fatal at birth

B. Tracheoesophageal fistula
- Tracheal lesion easily closed, esophageal portion more difficult
- Rarely has associated stenosis

C. Congenital stenosis
- Webs and diaphragms most often occur at subcricoid level
- Three types of stenosis: generalized hypoplasia, funnel-like narrowing, and segmental stenosis
- Main bronchi most often normal with generalized hypoplasia, vary in size with funnel-like narrowing, and commonly have anomalies with segmental stenosis
- Associated with a wide range of anomalies throughout the body
- About 50% of pulmonary sling cases are associated with lower tracheal stenosis
D. Diagnosis of congenital stenosis
· Suspicion in infants with inspiratory and expiratory stridor or more severe respiratory distress
· Wheezing, retraction, poor feeding, failure to thrive may also be present

E. Management
· Operations in infants are high risk, as postoperative edema may obstruct small airways and mechanical ventilation may disrupt anastomoses
· A conservative approach is wise, as less than 1/3 of the trachea in a child can be resected
· Webs can be dilated or excised endoscopically
· Stenoses should not be dilated, as this can create longitudinal tears, resulting in recurrent scarring and stricture
· Tracheostomy for palliation is a suitable alternative to allow growth for surgical repair

**Tracheal Neoplasms**

A. Primary neoplasms of the trachea are rare

B. Squamous cell carcinoma
· Most common tracheal neoplasm
· Well localized exophytic or ulcerated lesion
· Multiple lesions or a superficially infiltrating variety also occur
· 1/3 of patients will present with mediastinal or pulmonary metastasis
· Spread is usually to regional tracheal lymph nodes and then directly into mediastinal structures

C. Adenoid cystic carcinoma (cylindroma)
· Grows slowly and displaces mediastinal structures rather than invading
· Submucosal and perineural spread may occur for quite long distances
· Best chance at cure is complete resection at first operation

D. Clinical Features
· Dyspnea on exertion
· Wheezing
· Stridor
· Excessive secretions
· Hemoptysis
· Pneumonia
· Cough

E. Secondary tracheal neoplasms
· Thyroid cancers are the most common indication for tracheal operations for secondary malignancy
· Laryngeal carcinoma involves the upper trachea by direct extension
· Bronchogenic carcinoma more commonly involves the carina or bronchial origin on the right
· Tracheoesophageal fistula can result from radiation therapy for or from invasion by esophageal cancer
· Other tumor include carcinoid, head and neck, breast, and lymphoma

**Infection and Inflammation**

· Tuberculosis may cause strictures of the lower trachea and bronchi
· Strictures are submucosal and the cartilage has a grossly normal caliber
· Fibrosing mediastinitis and histoplasmosis may be so extensive as to preclude reconstruction
· Idiopathic strictures most often occur in the upper trachea
· Other causes include Wegener's granulomatosis, amyloid, sarcoid, relapsing polychondritis, and tracheopathia osteoplastica

**Trauma**

A. Penetrating injuries
· Usually involve the cervical trachea
· Fresh injuries can be closed primarily

B. Blunt injuries
· Closed trauma may lacerate or sever the trachea
· A severed trachea should be re-approximated if possible
· The distal trachea should be intubated for security
· A tracheostomy tube should be inserted in the distal severed end for complex injuries and repair undertaken later
· A vertical split at carina is usually diagnosed by a pneumothorax that fails to resolve with closed suction
· Bronchoscopy, thoracotomy, and occasionally cardiopulmonary bypass are required to repair this lesion
· Traumatic TEF should be promptly repaired, as inflammation makes repair difficult when the diagnosis is delayed
· Always establish the function of the recurrent laryngeal nerves and larynx prior to surgery, if possible

**Postintubation Injuries**

· These are currently the most frequent cause of tracheal stenosis

A. Laryngeal level
· Sealing cuffs may irritate vocal cords, causing granulomas and fusion of the posterior commissure
- Mucosal erosion at the cricoid can cause subglottic stenosis
- Most lesions are reversible with time

B. Stomal level
- Principle factors include a stoma that is too large, loss of tissue from infection (rare), and pressure erosion from rigid connecting systems (most common)
- Avoid injuring the first cartilaginous ring during original tracheostomy to prevent subglottic stenosis
- Avoid low placement of the tracheostomy to prevent innominate artery erosion and supracarinal stenosis

C. Sealing cuff level
- Most common cause is direct pressure necrosis by high-pressure cuff
- This has essentially disappeared with use of low-pressure, high-volume cuffs
- Children may develop granuloma on anterior tracheal wall when ventilated without a cuff

D. Tracheomalacia
- Usually occurs in segment of trachea between stoma and the cuff
- Secretions pool here and inflammation leads to cartilage thinning

E. Tracheoesophageal fistula
- Manifested by sudden appearance of secretions in tracheobronchial tree
- Pneumonitis, pneumonia, abscess, and gastric dilation may develop
- Methylene blue in tube feedings will appear promptly in the trachea

F. Trachoinnominate fistula
- Manifested by sudden exsanguinating hemorrhage into the tracheobronchial tree
- Emergent tamponade with high-pressure cuff or digital pressure is necessary

**Diagnosis**
- CXR
- Fluoroscopy determines laryngeal function and presence of tracheomalacia
- CT to evaluate extramural extension of tumors
- Bronchoscopy and biopsy at the time of operation

**Resection and Reconstruction**
- All patients should be induced slowly and gently in the OR
- Extubation in the OR is desired in order to avoid intubation injury to the suture line

A. Upper half of trachea
- Collar incision with partial upper sternal split, if necessary, is used for benign and malignant lesions of the upper trachea
- Almost all stenoses above the carina can be reached through this approach as well
- Dissect anteriorly from the cricoid cartilage to the carina, staying close to the trachea
- The recurrent laryngeal nerves must be identified
- Divide the trachea and intubate distally
- About 4.5 cm can be removed without additional mobilization
- Laryngeal release is preferred, if needed, taking care to avoid injury to the superior laryngeal nerves
- Hilar release is more hazardous and is contraindicated in patients with poor pulmonary function
- Once the sutures have been placed, the distal tube is removed and the endotracheal tube is readvanced past the anastomosis
- All sutures are tied and the anastomosis tested under water for leakage

B. Lower half of trachea
- Posterolateral thoracotomy in 4th interspace provides optimal exposure and should be performed on the side contralateral to the aortic arch (usually right)
- About 4.5 to 5 cm can be resected without extreme maneuvers
- Release technique include hilar dissection, loosening of the carina, and cervical flexion
- Laryngeal release does not provide any additional mobilization
- A pleural or pericardial flap is constructed to protect the anastomosis

Tracheostomy
- Principal indications include upper airway obstruction, management of secretions, prolonged ventilation, and emergent airway
- Second and third rings are opened vertically
- Avoid high and low stoma placement to prevent subglottic stenosis and innominate artery erosion
- Persistent stoma 3 to 6 months after tracheostomy should be closed surgically

Results
- Small numbers of patients make accurate predictions of survival difficult
- Resection of benign tumors and low-grade malignant tumors appears to have high probability of cure
- Single-stage resection and reconstruction is probably the best approach for squamous cell and adenoid cystic carcinoma
- Adjunctive radiation is usually indicated for squamous cell and adenoid cystic tumors
- Selected patients can be treated effectively with resection and reconstruction for secondary tracheal tumors

Selected Articles


Sources for further reading

Textbook Chapters

The lungs

Developmental Anatomy of The Lungs

A. Intrauterine stage
· Four periods of development: embryonic, pseudoglandular, canalicular, and terminal sac
· Embryonic period begins at 26 days with ventral protrusion of the foregut and ends at 32 days with appearance of 5 lobar bronchi
· Pseudoglandular period lasts from 5th to 16th weeks and is characterized by rapid branching and formation of all conducting airways
· Canalicular period lasts from 16th to 25th weeks and is characterized by capillary ingrowth and appearance of saccules
· Terminal sac or alveolar period begins at 25 weeks, and alveolar development begins between the 30th and 36th weeks
· Type I and II epithelial differentiation typically occurs at 28 weeks

B. Neonatal stage
· Precursors of typical acinar unit are present at birth: bronchioles, transitional ducts, and terminal sacule
· Alveolar development continues after birth with remodeling and multiplication
· The total adult number of alveoli are not reached until at least age 8
· Alveolar enlargement continues until adulthood, although no new alveoli are added

C. Histology
· The mature lung is characterized by closely packed alveoli divided by thin septa, occupied by capillaries
· Capillary endothelium is typically a single cell layer with few organelles and thin cytoplasmic matrix
· Over 95% of alveolar epithelium is type I cells, which are also very thin with few organelles
· Type II alveolar cells are cuboidal and secrete surfactant
· Surfactant synthesis peaks at term and decreases to adult levels shortly thereafter
· An increase in the lecithin-sphingomyelin ratio to more than 2:1 occurs just before birth
· Type II cells can be stimulated to produce this pattern of phospholipid by steroids, thyroxine, estrogens, beta-agonists, and increases in ventilation or tidal volume
· Surfactant stabilizes the alveoli, lowers surface tension to keep alveoli open at low volumes, prevents alveolar wall adhesion, and helps maintain pulmonary compliance

Anatomic Variants with Normal Parenchyma
· Superior segment of lower lobe delineated by separate fissure
· Medial accessory left lower lobe
· Azygous lobe - mesentery of azygous vein forms double fold of visceral pleura that isolates part of right upper lobe
· Bilateral bilobation or trilobation
· Situs inversus thoracis or totalis - totalis form associated with Kartagener's syndrome (situs inversus, bronchiectasis, pansinusitis - immotile cilia syndrome)

**Congenital Lesions**

**Agenesis, Aplasia, and Hypoplasia**

**A. Agenesis and Aplasia**
- *Agenesis* = complete absence of carina, main bronchus, lung, and pulmonary vasculature
- *Aplasia* = development of carina and rudimentary main bronchus; absence of lung and pulmonary vessels
- Bilateral pulmonary agenesis extremely rare and uniformly fatal
- More than 50% of patients with unilateral agenesis have other associated anomalies
- Agenesis does not show a right or left predominance
- Lobar agenesis is less common than total lung agenesis

**B. Hypoplasia**
- Failure to obtain adequate size; all components are present, but incompletely developed
- Severity of hypoplasia determines the degree of respiratory compromise
- Major abnormality is a decrease in the number of airway generations and pulmonary artery branchings
- Two general causes: large diaphragmatic hernia or primary embryologic defect
- Hernia interferes with alveolar development during last 2 months of intrauterine growth
- Embryologic defects occur early and may be associated with other syndromes
- Associated anomalies include oligohydramnios, prune-belly syndrome, Potter's syndrome, and scimitar syndrome
- If associated with diaphragmatic hernia, the hypoplastic lung should not be removed at surgery, as it will recover some function with time

**Congenital Lobar Emphysema**
- Definition: over-expansion of a pulmonary lobe with compression of other lobes and shifting of mediastinum

**A. Pathogenesis**
- Accounts for about 50% of all congenital lung malformations
- Intrinsic causes: bronchomalacia due to abnormal cartilaginous support, mucus plugging, bronchial torsion, redundant mucosa, foreign body aspiration
- Extrinsic causes: bronchial compression from pulmonary artery sling, great vessel aneurysms, enlarged cardiac chambers
- Pulmonary hypoplasia: decreased number of alveoli become overdistended due to air trapping
- Alveolar hyperplasia: excessive number of alveoli overexpanded a polyalveolar lobe
- Most common in LUL, then RUL, then RML
B. Symptoms
- Respiratory distress occurs in 50% of patients in the first week of life (50%)
- 80% of infants will be symptomatic by 6 months of age
- Most common symptoms are tachypnea, cough, cyanosis, and dyspnea
- Pulmonary infection in the affected lobe occurs most commonly between 1 and 6 months of age
- Presentation is uncommon after age 6 months
- Physical findings include hyperresonance and decreased breath sounds on the affected side
- CXR shows hyperlucency on the affected side and mediastinal shift to the opposite side
- Air bronchography demonstrates bronchial wall collapse with expiration if bronchomalacia is the cause

C. Treatment
- Indication for surgery is life-threatening progressive insufficiency from normal lung compression
- Careful induction of anesthesia and positive pressure ventilation
- Immediate thoracotomy necessary in the critically ill infant, as ventilation may worsen normal lung compression by rapidly expanding the affected lung
- Surrounding atelectatic normal lung tissue should be preserved
- Lobectomy should result in cure
- Long-term outlook is good with relatively normal PFT's

**Pulmonary Cysts**
- Definition: cystic structures within the pulmonary parenchyma. The composition of the cyst wall is determined by its origin: bronchial glands, cartilage, or alveolar epithelium.

A. Pathology
- Congenital cysts are typically unilocular and confined to a single lobe; the lower lobes are more commonly involved
- Congenital cysts that persist for more than 1 year are unlikely to resolve spontaneously
- Multiple cysts are rarely congenital and are probably acquired; causes include staphylococcal pneumonia and cystic fibrosis.
- Multiple cysts may fluctuate in size and can develop rapidly
- CXR usually adequate for identification

B. Symptoms
- Expansion results in respiratory distress
- Infection causes fever, cough, and sepsis

C. Treatment
- Solitary congenital cysts can be treated with cystectomy or lobectomy if necessary
- Infected solitary cysts should be treated with antibiotics and resected when quiescent
Multiple cysts should be treated as part of underlying systemic disease; surgical intervention is rarely required and is contraindicated for pneumatoceles. Chest tube placement or aspiration for diagnosis is discouraged for tension cysts, as this can result in empyema.

**Cystic Adenomatoid Malformation**
Definition: thoracic hamartoma with overgrowth in varying amounts of bronchioles and alveoli, so it characteristically can range from cystic to nearly solid masses within the lung. Cartilage, however, is not present in this lesion.

A. Pathology
- Typically confined to a single lobe
- Progressive air trapping in cystic areas leads to over distension of involved lobe
- Three subtypes (see table)
- High incidence of associated congenital anomalies and death with type II

<table>
<thead>
<tr>
<th></th>
<th>Type I</th>
<th>Type II</th>
<th>Type III</th>
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<tbody>
<tr>
<td><strong>Morphology</strong></td>
<td>Multiple large cysts or single large cyst</td>
<td>Multiple, evenly spaced cysts not over 1.2 cm</td>
<td>Multiple small cysts less than 0.5 cm</td>
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<tr>
<td><strong>Contents</strong></td>
<td>Air of fluid</td>
<td>Air</td>
<td>Solid</td>
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<tr>
<td><strong>Wall</strong></td>
<td>Smooth muscle and connective tissue</td>
<td>Terminal bronchioles</td>
<td>Adenomatoid hyperplasia or bronchial</td>
</tr>
<tr>
<td><strong>CXR</strong></td>
<td>Unilateral large cyst or homogenous mass, may have mediastinal shift and air-fluid level</td>
<td>Smaller nonhomogenous cyst</td>
<td>Homogenous mass</td>
</tr>
</tbody>
</table>

B. Symptoms
- Progressive respiratory distress in a newborn infant
- Tachypnea, subcostal retraction, cyanosis
- Older child - chronic pulmonary infection
- Differential should include congenital diaphragmatic hernia, and barium swallow will differentiate the two

C. Treatment
- Identification of the lesion is the indication for surgery, with or without symptoms
- Lobectomy is usually adequate
- Attempt at segmentectomy is usually met with prolonged air leak and complications

**Bronchogenic Cysts**
Definition: congenital cystic lesions arising from abnormal budding of primitive
tracheobronchial tree; composed of fibrous tissue interposed with normal bronchial elements

A. Pathology
- Cysts can occur either in the parenchyma (70%) or the mediastinum (30%)
- The most common locations are paratracheal, carinal, hilar, and paraesophageal
- Generally round and unilocular
- Lined with ciliated columnar epithelium
- Most do not communicate with the tracheobronchial tree
- Can mimic lobar emphysema from bronchial obstruction
- Can become secondarily infected

B. Symptoms
- Most common presentation in the neonate is progressive dyspnea, wheezing, stridor, and cyanosis
- Obstructive symptoms occur most commonly in infants less than 1 year of age
- Paratracheal, carinal, and hilar cysts are commonly asymptomatic
- Communicating cysts are almost always symptomatic: productive cough, fever, hemoptysis
- CXR shows homogenous, sharply delineated cyst; air/fluid levels may be present in communicating cyst
- CT is the test of choice for diagnosis and anatomic delineation

C. Treatment
- Indications for surgery include increasing cyst size, air/fluid level, symptomatic cyst, and subcarinal cyst
- Small, asymptomatic cysts can be followed with interval CXR
- Cyst excision with sparing of surrounding pulmonary tissue is the treatment of choice

**Intralobar Pulmonary Sequestration**
Definition: segment of lung parenchyma that is within the normal pleural confines, but does not communicate with the tracheobronchial tree and is supplied by the systemic circulation.

A. Pathology
- Unicystic or polycystic parenchyma with extensive fibrosis and vascular sclerosis
- Arterial supply is usually from the thoracic aorta (75%) or abdominal aorta (20%)
- Venous drainage is usually to the pulmonary veins
- Right-sided lesions more often have other venous drainage
- Much more frequent than extralobar type

B. Symptoms
- Recurrent episodes of infection in older children and adolescents
- CXR shows cystic structure with or without air-fluid level
CT is procedure of choice; aortography and barium swallow may be necessary for anatomy.

C. Treatment
- Identification of the lesion is indication for surgery
- Careful ligation of the anomalous artery followed by resection
- Prevents long-term infection and possible neoplastic changes

**Extraobbar Pulmonary Sequestration**
Definition: segment of lung parenchyma with distinct and separate pleural investment; does not communicate with the tracheobronchial tree and is supplied by the systemic circulation.

A. Pathology
- Mass of loose, spongy parenchyma with multiple small cysts and dilated bronchioles and ducts
- Arterial supply is also usually from the thoracic or abdominal aorta
- Venous drainage is usually to the azygous or hemiazygous system
- More common on the left side and usually found between the lower lobe and the diaphragm

B. Symptoms
- Most present in neonatal period due to respiratory distress
- CXR shows triangular homogenous mass with apex pointing toward hilum
- CT may provide additional localization, but vessels often too small to identify

C. Treatment
- Identification of the lesion is indication for surgery
- Careful ligation of the anomalous artery followed by resection
- As with intralobar sequestration, resection prevents long-term infection and possible neoplastic changes

**Comparison of ILS and ELS**
(Adapted from Sabiston and Spencer)

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<thead>
<tr>
<th></th>
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<th>ELS</th>
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<td>Gender predominance</td>
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<td>Male</td>
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<tr>
<td>Location predominance</td>
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<td>Left</td>
</tr>
<tr>
<td>Pleural investment</td>
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<td>Yes</td>
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<td>Arterial supply</td>
<td>Thoracic/abdominal aorta</td>
<td>Thoracic/abdominal aorta</td>
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<td>Venous drainage</td>
<td>Pulmonary</td>
<td>Azygous/hemiazygous</td>
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<td>Other anomalies</td>
<td>Rare</td>
<td>Common</td>
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<td>Age at diagnosis</td>
<td>Adolescent/young adult</td>
<td>Neonate</td>
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<tr>
<td>Symptoms</td>
<td>Cough, fever</td>
<td>Respiratory distress</td>
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</tbody>
</table>

**Selected Articles**

Sources for further reading

Textbook Chapters
Bullous & Bleb Diseases

Bullous Emphysema

1. Definition

WHO and ATS Definition of Emphysema
Emphysema is characterized by an increase beyond normal in the sizes of air spaces distal to the terminal non-respiratory bronchiole that arises from the destruction of their walls

2. Characteristics

Definition confused by overlap in etiology and symptomatology among

- emphysema
- asthma
- chronic bronchitis

2/3 of adults show some emphysema at autopsy

- 10% have severe clinical disease
- 10% of cigarette smokers have significant chronic airflow obstruction associated with chronic bronchitis

3. Pathogenesis

Earlier studies: Infective, degenerative, obstructive mechanical factors
Present studies: Enzymatic mechanisms of tissue destruction

Protease pathogenesis hypothesis

- Destruction of the interstitium is due to an excess of proteolytic enzymes (elastase) in relation to the availability of proteolytic inhibitors
- Heritable alpha -1 anti-trypsin deficiency
- Animal studies with elastolytic proteolases

4. Alpha -1 protease inhibitor (alpha-1 anti-trypsin)

- Major protease in human lower respiratory tract
- Cigarette smoke - oxidative inactivation of alpha-1 anti-protease by oxidants in smoke or econdarily by active oxygen species liberated by pulmonary phagocytes
Alveolar macrophage cells of smokers - increased amounts of oxygen radicals and peroxide
Decrease elastin resynthesis after elastolytic destruction of lung tissue in animals

5. **Alpha-1 Antiprotease (anti-trypsin)**

Plasma protease inhibitor - synthesized in liver
Primary site of action is alveolar structure of lung
Inhibits PMN leukocyte elastase
Protects elastic fibers from hydrolysis

Enzyme deficiency - risk of pulmonary disease 20-30 times that of the general population

40,000 people in the US
1-2% of those with emphysema
Synthesis controlled by autosomal and allelic gene system

Most are homozygous for PiM - nl phenotype
PiZ phenotype - severe deficiency of the enzyme
Homozygous with PiZ phenotype have 10-15% of nl

6. **Anatomic Classification of Emphysema**

Four types - by the way it involves the acinus

Proximal acinar emphysema (centrilobular)

Associated with cigarette smoking and inflammation of distal airways

Symptomatic chronic airflow obstruction

Panacinar (panlobular)

Involves entire acinus uniformly

Alpha-1 anti-trypsin deficiency and other Pi-associated emphysema

Worse in lower zones of the lung

7. **Distal acinar (paraseptal)**
Distal acinus, ducts, and alveolar sacs
Fibrosis
Subpleural location - PTX and BULLOUS disease

Irregular
Affects acinus in an irregular manner
Always associated with scarring and fibrosis
Occurs to some degree in all lungs

8. Clinical Classification

Compensatory emphysema
Not really emphysema - no acinar destruction
Infantile lobar emphysema; localized emphysema with infection; bronchial tumor or aspirated FB; compensatory changes after pulmonary resection

Diffuse obstructive emphysema
Major component of COPD
Type A or dry emphysema: Cough, dyspnea, barrel chest, CXR with overinflation, flat diaphragms, no fibrosis and decreased pulmonary vasculature; pan-acinar type destruction; prognosis good
Type B or wet emphysema: No obvious CXR or clinical signs; severe cough; copious sputum production; rales; wheezing; cyanosis; dyspnea later; CXR - moderate hyperinflation; fibrosis in lower lobes; increase in central pulmonary vascularity with tapering
Centrilobular changes; prognosis poor

9. Surgical Treatment

Unsuccessful in providing improvement
Associated with high mortality
Limited resections have some validity

Bullous emphysema: Congenital cysts to blebs
Bleb: Intrapleural airspace - separated from alveoli by a thin pleural covering that can rupture spontaneously
Bulla: Subpleural airspace usually larger than a bleb that results from the destruction of pulmonary tissue

Bullous emphysema: Refers to thin walled air sacs under tension that cause compression atelectasis of normal pulmonary tissue
Single/multiple/coalesce
Air/fluid/infection

10. Bullae

Can form all pathologic forms of emphysema
Periacinar bullae are probably most common in patients who are referred for surgery
Can develop fluid
Infection

11. Selection of patients for bullous surgery is based upon clinical, radiologic and physiologic data

Must compare symptoms of bulla to symptoms of underlying pulmonary disease
Dyspnea is most common symptom of bullous disease
Presence alone implies good surgical result
Cor-pulmonale and right heart failure does not necessarily contraindicate surgery
PFT's: +/-
Review old CXR's
Bronchography - clumping of airways
Perfusion scans - split pulmonary functions
Pulmonary arteriography
Exercise PFT's
CT scanning

12. No single test shows which patients with bullous emphysema will benefit from surgery

Each requires careful study

Surgical techniques
Surgical objective: Remove as little functioning pulmonary tissue as possible
Complications:

Air leaks (prolonged)
Residual PTX

Mortality rate: 10-22%

Related to severity of underlying disease
Better selection, mortality rate decreases
Median sternotomy - less morbidity
Intracavitary suction
Epidural anesthesia with lateral thoracotomy

13. Alpha-1 Anti-trypsin Deficiency

Onset before 40 years
Higher incidence in females
Family history important
CXR: Emphysematous changes in lower ½ of chest
Angiograms and scintigrams show greater perfusion in upper lobes than the bases
Ventilation scans show basal air trapping
Tx:

Replacement Tx with alpha-1 protease inhibitor - some early success
Lung transplantation

Pneumothorax

14. Classification

Spontaneous

Primary

No underlying pathology

Secondary

Underlying pulmonary disorders

Catamenial
Neonatal

Traumatic

Iatrogenic

Thoracentesis, mechanical ventilation, central vein cath., post-operative

Blunt, penetrating

Diagnostic
Air-contrast study of pleuropulmonary pathology

15. Causes of Secondary Spontaneous Pneumothorax

Airway disease

Bullous disease
COPD
Asthma
Cyst (congenital)
Cystic fibrosis

Interstitial disease

Idiopathic pulmonary fibrosis
Eosinophilic granuloma
Sarcoidosis
Tuberous sclerosis
Collagen vascular disease

16. Causes of Secondary Spontaneous Pneumothorax

Infections

Anaerobic pneumonia
Staphylococcal pneumonia
Gram-negative pneumonia
Lung abscess
Actinomycosis
Nocardiosis
Tuberculosis
Atypical mycobacteria

Neoplasms

Primary
Metastatic

17. Other diseases

Endometriosis
Ehlers-Danlos syndrome
Pulmonary embolism
Marfan's syndrome
18. Indications for Thoracotomy

Massive air leak that prevents re-expansion of the lung
Persistent air leak > 7-10 days
Second episode of spontaneous PTX
Complications of PTX

Hemothorax
Empyema
Chronic PTX

Specific surgical indications for conditions that cause secondary spontaneous PTX

Occupational indications after first episode
Airline pilots
Scuba divers
Individuals in remote areas

Previous contralateral PTX
Bilateral simultaneous PTX
Presence of large cysts visible on CXR

19. Clinical Presentation and CXR

In 80% symptoms occur at rest or during normal activity
Pain - most frequent - pleuritic/sharp
Dyspnea - second most common symptom

Large PTX
Underlying pulmonary disease
Pronounced with tension PTX

Orthopnea
Hemoptysis
Non-productive cough
> 25% - diminished motion of chest wall on the affected side
Cyanosis
Hyper-resonant; tympanitic
Decreased breath sounds
Subcutaneous emphysema/mediastinal emphysema
Tracheal deviation
CXR

20. Primary Spontaneous Pneumothorax
Young adults, 85% < 40 years
9 per 100,000
Tall, thin male, 25 to 30, smoker, family history
Previous history, 90% chance it is on the same side
Simultaneous bilateral - 10%
Ruptured bleb - 15% seen on CXR at apex, along fissures

85% found at thoracotomy

Recurs with increasing frequency

50% after first episode
62% after second episode
80% after third episode

Secondary spontaneous pneumothorax

20% event is related to underlying pulmonary disease

21. Spontaneous Pneumothorax

Neonatal Spontaneous Pneumothorax

- Hyaline membrane disease
- Renal malformation
- Potter's syndrome
- Meconium aspiration
- Cystic fibrosis in children

Catamenial Spontaneous Pneumothorax

- Occurs during menstruation
- Third and fourth decades
- 90% on the right side
- Does not occur during periods of non-ovulation
- Four possible causes

  - Rupture of bleb
  - Alveolar rupture due to PF2
  - Air into pleural cavity from GYN tract
  - Pleural/pulmonary endometriosis

22. Management of Spontaneous Pneumothorax
Observation if PTX < 20%
Thoracenteses 30-70% effective
Thoracostomy
Chemical pleurodesis
Mechanical pleurodesis
Treatment of underlying disease

23. Caveats

One can never be faulted for placing a chest tube (unless the chest tube was placed in the abdomen).

The first thing into the chest is your finger.

Usually, do not place a chest tube below the nipple line.

Pneumothorax

Selected Articles


Sources for further reading

Textbook Chapters
Infections of the Lung

Lung Abscess, Bronchiectasis & Empyema

1. Definition
A pyogenic pneumonia develops, causing localized suppuration with parenchymal destruction. There is central necrosis of lung tissue, which then liquefies and communicates with the bronchial tree. This partial internal drainage results in the classic cavity with an air-fluid level.

2. Etiology
A. Aspiration
   · Location: predilection for the posterior segment of the RUL, the superior segment of the RLL, and the LLL
   · Bacteriology: anaerobes and aerobes

B. Post-pneumonic
   · Location: any segment, may be in multiple segments
   · Bacteriology: *staphylococcus* and *streptococcus*

C. Endobronchial obstruction
   · Neoplasms and foreign bodies can result in distal infection and abscess formation

3. Clinical Presentation
A. Symptoms
   · Fever, chills, severe cough, hemoptysis, and copious foul smelling sputum

B. Signs
   · Tachypnea, consolidation, local chest wall tenderness

4. Diagnosis
   · CXR: pneumonitis pattern early, followed by the air/fluid level when bronchial communication has been established
   · Bacteriological/fungal evaluation: aerobic, anaerobic, fungal, TB all important
   · Bronchoscopy is indicated to rule out obstructing foreign bodies or neoplasms and can provide drainage

5. Treatment
   · Most abscesses respond to bronchoscopy and appropriate medical treatment
   · Surgery reserved for medical failure, carcinoma, significant hemoptysis, and complications such as empyema and bronchopleural fistula
   · Lobectomy is typically required when resection is in order, as segmentectomy is often not possible and pneumonectomy rarely necessary
   · Percutaneous drainage can be useful in patients who are not candidates for standard surgical intervention
Bronchiectasis

1. Definition
   · Chronic bronchial dilatation with parenchymal infection and inflammatory reaction. There are three types: cylindrical, varicose, and saccular/cystic.

2. Etiology
   · Acquired infection is the most common cause, typically when occurring in childhood.
   · Other acquired causes include bronchial obstruction and scarring.
   · Congenital causes include cystic fibrosis, Kartagener's syndrome, various immunodeficiency disorders, and bronchopulmonary sequestration.
   · Typically affects the basal segments of the lower lobes.

3. Clinical presentation
   · Recurrent pneumonia, persistent cough, copious foul smelling sputum.
   · Hemothysis is common in adults but rare in children.

4. Diagnosis
   · CXR usually demonstrates nonspecific findings, although a honeycomb pattern may be found.
   · Bacteriologic studies typically return *H. influenza*, *E. coli*, and *Klebsiella* as the causative agents.
   · Chest CT with fine cuts has replaced bronchography as the test of choice.
   · Bronchoscopy can help localize the process, rule out obstructing lesions, and provide pulmonary toilet.

5. Treatment
   · Medical therapy is the primary approach, using antibiotics, humidification, bronchodilators.
   · Surgical intervention is indicated for failure of medical management, persistent symptoms, recurrent pneumonias, and hemothysis.
   · The ideal surgical candidate has unilateral disease confined to one lobe, usually lower.
   · Most patients, however, have bilateral disease, and surgery should be reserved for localized disease, operating on the worst side first.

Empyema

1. Definition
   Accumulation of pus within the pleural space. It occurs in three phases: exudative/acute phase, fibrinopurulent/transitional phase, and organizing/chronic phase.

2. Etiology
   · About half are secondary to a pneumonia (postpneumonic empyema).
   · Other causes include pulmonary or esophageal operations, chest trauma, spontaneous pneumothorax, and subphrenic abscess.
Pneumonias caused by *S. aureus, E. coli, Pseudomonas*, and anaerobes are the most likely to result in empyema

### 3. Clinical Presentation
- Pleuritic chest pain, fever, tachycardia, and tachypnea are common
- Persistent fever after resolution of pneumonia is suspicious for empyema

### 4. Diagnosis
- CXR may not differentiate pleural collection from lung consolidation or atelectasis
- CT or US will help localize the fluid collection
- Thoracentesis and aspiration of pus establishes the diagnosis
- Chemical analysis of the fluid is critical

<table>
<thead>
<tr>
<th>Empyema fluid characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH &lt; 7.0</td>
</tr>
<tr>
<td>Glucose &lt; 40 mg/dL</td>
</tr>
<tr>
<td>LDH &gt; 1000 IU/dL</td>
</tr>
<tr>
<td>Positive Gram stain</td>
</tr>
<tr>
<td>Positive culture (50%)</td>
</tr>
<tr>
<td>Specific gravity &gt; 1.018</td>
</tr>
<tr>
<td>WBC &gt; 500 cells/mm3</td>
</tr>
<tr>
<td>Protein &gt; 2.5 g/dL</td>
</tr>
</tbody>
</table>

### 5. Treatment

A. Acute and Transitional Empyema
- Thoracentesis followed by chest tube insertion
- Ensure complete drainage of all localized collections

B. Chronic Empyema
- Open drainage with thorough cleansing of the cavity (saline or Dakin's solution)
- Open chest tube drainage is then instituted, and the tube is slowly withdrawn at 10-14 day intervals
- If the cavity is not closed after 6 weeks, a decortication (good candidates) or open rib resection or Eloesser flap (poor candidates) should be performed

### Selected Articles


Sources for further reading

Textbook Chapters

Pulmonary Fungus & Tuberculosis

Fungal Infections Of The Lung
1. Indications for Thoracic Surgical Intervention
   Establish a diagnosis
   Failure of medical therapy
   Fungal disease vs. lung carcinoma

2. Fungal Infections of the Lung
   The three major mycotic infections are histoplasmosis, coccidiomycosis, and blastomycosis
   The fungal agent in each case is dimorphic: exists in nature as mycelium (mold) that bears infectious spores, which enter host and develop into a yeast-like phase that is the tissue pathogen
   These fungi require special staining and culture methods
   Amphotericin B is primary therapy for all three fungal infections

3. Histoplasmosis
   Systemic disease caused by H. capsulatum, which is found in soil with high concentration of fecal material of chickens, pigeons and bats
   Endemic areas are the valleys of Ohio, Missouri, and Mississippi rivers
   Occurs as an intracellular yeast and is seen best on silver stain
   Farmers, construction workers, and people who enjoy outdoor activities are the most at risk by inhaling spores
   1 in 2000 people will develop chronic pulmonary disease
   Most cases of primary histoplasmosis are asymptomatic or mild flu-like syndrome
   Progressive pulmonary disease associated with chronic lung disease occurs in middle-aged men
   CXR demonstrates dense nodules with central calcification
   Chronic cavitary histoplasmosis is less common
   Mediastinal histoplasmosis results in fibrosing mediastinitis, which is the most frequent benign etiology of SVC obstruction
   Healed histoplasmosis causes a solitary pulmonary nodule, which can be confused with carcinoma

   Indications for surgery:
   A. Chronic cavitary pulmonary disease - persistent thick-walled cavity after 2g to 3g course of Amphotericin B for 2-3 months
   B. Fibrosing mediastinitis with middle lobe syndrome
   C. SVC syndrome

4. Coccidiomycosis
   Causative agent is C. immitis
   Endemic areas are the Southwestern USA and Mexico
   The spherules have a thin wall containing endospores which are seen on wet mount slides
Infection occurs after spore inhalation and 60% of patients are asymptomatic
Acute valley fever is characterized by pneumonitis, erythema nodosum, and arthralgias
Only 5% of patients with symptomatic pulmonary disease develop irreversible bronchiectasis, pulmonary nodules, pulmonary abscesses or residual cavities
The most frequent long-term complication is a chronic cavitary lesion (solitary, thin-walled)
CXR demonstrates nonspecific infiltrates, hilar adenopathy, or pleural effusions
Diagnosis is made by serologic testing for IgM or IgG antibodies; a rising titer suggests possible dissemination
The most important extra pulmonary manifestation is meningitis
Most patients require no therapy
Amphotericin B is indicated if there is severe, prolonged pulmonary disease; primary disease with risk of dissemination (pregnancy, immunosuppression); symptomatic, chronic cavitary disease; and as an adjuvant to surgical resection

Indications for surgery:
A. Enlarging cavitary lesion
B. Hemoptysis
C. Secondary infection
Peri-operative Amphotericin B is recommended for these patients

5. Blastomycosis
Causative agent is *B. dermatitides*
The endemic areas are the southeastern and southwestern USA, mostly the Ohio and Mississippi river valleys and the Great Lakes area
Classically seen as a round, thick-walled single yeast cell on staining
Acute infection typically involves the lower lobes and is asymptomatic, or can result in influenza-like syndrome
Chronic infection typically involves the upper lobes and results in a pyogranulomatous process
The most common extrapulmonary manifestation is cutaneous ulcers
Chronic, disseminated disease typically involves the skin and ribs
Primary treatment is typically Amphotericin B - 2 to 2.5g over 2-3 months or ketoconazole as an alternative agent

Indications for surgery:
A. Rule out malignancy
B. Drainage of large cavitary abscesses
C. Closure of bronchopleural fistulas

6. Other Fungal and Opportunistic Infections of the Lung
A. Cryptococcosis
Caused by *C. neoformans*, found in soil contaminated by pigeon droppings
India ink staining reveals round, budding yeast which has gelatinous polysaccharide capsule
Primarily involves the bronchopulmonary tree, with special predilection for the
meninges
Lesions often involve the lower lobes and are solid
Amphotericin B and 5-fluorocytosine are both effective medical treatment
Always examine CSF if *C. neoformans* is isolated from sputum or surgical specimen
10% of patients develop cryptococcal meningitis after resection of a pulmonary lesion

B. Aspergillosis
Most are caused by *A. fumigatus*, an organism found in hay and grains
Appears as mixture of coarse, fragmented hyphae and ball-like clusters on histology
Three clinical syndromes occurs: aspergillar bronchitis, aspergilloma, and invasive aspergillosis
Aspergillomas are the most common surgically resected lesion of this type and usually occur in a upper lobe cavity
These may be asymptomatic for years or cause hemoptysis
Hemoptysis occurs in 50% of patients with Aspergilloma, in 10% the hemoptysis is severe and recurrent
Once hemoptysis develops, the aspergilloma should be resected
Medical therapy usually not effective because Amphotericin penetrates aspergillus cavities poorly
Prophylactic resection in asymptomatic patients is generally not indicated because of significant complication rate

C. Actinomyces
Causative agent is usually *A. israelii*, a microaerophilic organism
Appears as branching hyphae which contain "sulfur granules"
Thoracic infection occurs after aspiration of oropharyngeal organisms
Presents as empyema, infiltrate, consolidation, or hilar mass
Treatment of choice is high dose penicillin for 1-3 months

D. Nocardiosis
Causative agent is *N. asteroides*
Appears as long-branching filaments that can be confused with *M. tuberculosis*
Opportunistic infection which occurs in immunocompromised patients
CXR shows solitary nodules, nonspecific infiltrates, or cavitations
Chest wall sinus tracts and empyema may occur, as well as CNS dissemination
Treatment of choice is sulfadiazine, sulfisoxazole, minocycline, or Bactrim for 2-3 months

E. Candidiasis
Causative agent is *C. albicans*, which is normal flora in GI tract, oral cavity, and female genital tract
Most common fungal infection in humans
Becomes invasive in immunocompromised host
Can cause deep thoracic infections or endocarditis
Treatment of choice is Amphotericin B
F. Protozoal Infections
Most common causative agent is *P. carinii*
Occurs as a diffuse interstitial pneumonitis in immunocompromised patients
CXR shows diffuse infiltrates radiating from the hilum
Often causes hypoxemia, hypocapnia, and pneumothoraces
Open lung biopsy may be required to establish diagnosis
Treatment of choice is pentamidine or Bactrim

G. Pulmonary Echinococcosis
Causitive agent is *T. echinococcus*, a small tapeworm
Results in intrathoracic cyst that can rupture, causing asphyxiation or allergic reaction
CXR shows homogenous, oval shaped densities with clearly defined borders
Surgical therapy involves cystectomy or pericystectomy with instillation of formalin or 10% NaCl solution
Some success has been reported with medical treatment using benzimidazole derivatives

**Pulmonary Tuberculosis**

1. Etiology
*M. tuberculosis* is a virulent organism transmitted by airborne droplets that can rapidly destroy lung tissue if left untreated
Three million deaths occur worldwide due to TB
The incidence had been declining until 1985 and is now rising
Resectional therapy is becoming increasingly utilized with the rise in multidrug resistant organisms

2. Diagnosis
Classic symptoms include night sweats, fever, cough, and occasionally hemoptysis
Tuberculosis is most common cause of severe hemoptysis
Asphyxiation rather than hypovolemia is usual cause of death from hemoptysis
The diagnosis is made by acid-fast staining and culture of the sputum
The Ghon complex is characterized by a peripheral lesion with associated hilar adenopathy
Other forms of mycobacterium, most commonly *M. avium*, can cause indolent infections that attack diseased pulmonary tissue

3. Medical Therapy
First line drug therapy includes isoniazid, ethambutol, pyrazinamide, and streptomycin
A minimum of 3 drugs should be initiated when the diagnosis is made
The preferred regimen is isoniazid and rifampin for 6 months, with pyrazinamide for 2 months
If the sputum is positive after 3 months of treatment, either the patient is noncompliant or the organism is an uncommon mycobacterium or is resistant; the patient should be recultured
Pure tuberculous effusions almost always resolve spontaneously or respond promptly to chemotherapy.
Tube thoracostomy rarely provides a cure because dense pleural reaction interferes with full re-expansion of the underlying lung.

4. Indications for Surgical Resection
Persistently positive sputum cultures with cavitation after 5-6 months of continuous optimal chemotherapy with 2 or more drugs.
Localized pulmonary disease cause by M. avium-intracellulare; other atypical mycobacterium or M. tuberculosis which is drug resistant.
Mass lesion of the lung in an area of tuberculous involvement.
Massive life-threatening hemoptysis or recurrent severe hemoptysis (massive = 600 cc or more/24 hr, severe = 200 cc/24 hr).
Bronchopleural fistula in association with mycobacterial infection that does not respond to tube thoracostomy.

5. Contraindications to Resection in TB
Widespread pulmonary or endobronchial disease.
Children with mycobacterial disease.
FEV1 less than 800-1,000 cc.
Active endobronchial disease, as this interferes with healing of bronchial stump (pre-op bronchoscopy in all patients prior to resection).

6. Operative Management
Lobectomy or pneumonectomy usually necessary with active mycobacterial disease.
Extrapleural pneumonectomy for extensive pulmonary parenchymal disease with chronic empyema (rare).
Complications of resection include empyema with or without broncho-pleural fistula and bronchogenic spread of mycobacterial disease.
Both complications are more frequent when the sputum is positive at the time of operation.

Selected Articles


Sources for further reading

Textbook Chapters
Chapter 20: Lung Infections and Diffuse Interstitial Lung Disease. Surgery of the Chest (Sabiston and Spencer), 5th ed., 622-44.

Lung Cancer

1. Epidemiology of Lung Cancer
190,000 new cases in 2000
149,000 patients will die of lung cancer
50 deaths per 100,000 per year
5 yr survival 1981-87 - 13%. 1950-54 - 6%
Lung cancer is second to ischemic heart disease as the most frequent cause of death
Heart disease mortality is decreasing
Cancer mortality is increasing mostly due to lung cancer

2. Surgeon General's landmark report (1964) on smoking (85% of lung cancers)
Asbestos exposure is the most common occupational cause - 5%
1964 smoking incidence 54%, 1989 - 33% (80 million)
NCI target was 15% by 1990
In spite of decreased incidence of smoking there is a long latency period between smoking cessation and normalization of risk (15 years)
Risk of CAD is decreased by 50% after one year of abstinence.

3. Pathology of Lung Cancer
A. Squamous cell carcinoma
   · Most common (40-70%), centrally located, more common in men
   · Local metastases, plentiful eosinophilic cytoplasm, keratin "pearls", bridging.

B. Adenocarcinoma
   · Less common (5-15%), peripherally located, more common women
   · Distant metastases, vacuolization, mucus synthesis, glandular differentiation

C. Undifferentiated carcinoma
   · Two subtypes (20-30%)
   · Large cell carcinoma: aggressive clinical behavior, moderate cytoplasm, no mucus or keratin
   · Small cell carcinoma: nonsurgical lesion, high incidence of metastases, spindle or oat shaped cells, dense nuclei, sparse cytoplasm

D. Bronchoalveolar carcinoma
   · Uncommon (3-7%) adenocarcinoma variant, favorable prognosis, alveolar "scaffolding", tends to recur as a second primary tumor

E. WHO Classification

4. Clinical Manifestation of Lung Cancer
Cough (most common 75%), hemoptysis (33%), pain (50% poor prognostic signs), anorexia and weight loss (poor prognostic sign), shortness of breath, pleural effusion,
hoarseness (1-8%)
Cushing's syndrome (most common), inappropriate ADH secretion, eosinophilia (tumor necrosis) and neuromyopathies (15%)

6. **Primary Tumor (T)**
   Full TNM Staging Classification

   TX  Primary tumor cannot be assessed, or tumor proven by the presence of malignant cells in sputum or bronchial washings but not visualized by imaging or bronchoscopy

   T0  No evidence of primary tumor

   Tis  Carcinoma in situ

   T1  Tumor 3 cm or less in greatest dimension surrounded by lung or visceral pleura, without bronchoscopic evidence of invasion more proximal than the lobar bronchus (not in the main bronchus)

   T2  Tumor with any of the following features of size or extent:

   More than 3 cm in greatest dimension

   Involves main bronchus, 2 cm or more distal to the carina

   Invades the visceral pleura

   Associated with atelectasis or obstructive pneumonitis that extends to the hilar region but does not involve the entire lung

   T3  Tumor of any size that directly invades any of the following: chest wall (including superior sulcus tumors), diaphragm, mediastinal pleura, parietal pericardium; or tumor in the main bronchus less than 2 cm distal to the carina, but without involvement of the carina; or associated atelectasis or obstructive pneumonitis of the entire lung

   T4  Tumor of any size that invades any of the following: mediastinum, heart, great vessels, trachea, esophagus, vertebral body, carina; or separate tumor nodules in the same lobe; or tumor with a malignant pleural effusion.

7. **Lymph Node (N)**
   NX Regional lymph nodes cannot be assessed

   N0 No regional lymph node metastasis
N1 Metastasis to ipsilateral peribronchial and/or ipsilateral hilar lymph nodes and intrapulmonary nodes including involvement by direct extension of the primary tumor

N2 Metastasis to ipsilateral mediastinal and/or subcarinal lymph node(s)

N3 Metastasis to contralateral mediastinal, contralateral hilar, ipsilateral or contralateral scalene, or supraclavicular lymph node(s)

8. Distant Metastasis (M)
MX Distant metastasis cannot be assessed

M0 No distant metastasis

M1 Distant metastasis (includes synchronous separate nodule(s) in a different lobe)

9. Staging of Lung Cancer

<table>
<thead>
<tr>
<th>Stage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ia</td>
<td>All T1 tumors and T2 tumors without lymph node metastasis</td>
</tr>
<tr>
<td>Ib</td>
<td></td>
</tr>
<tr>
<td>Iia</td>
<td>T1 and T2 tumors with involvement of ipsilateral hilar nodes</td>
</tr>
<tr>
<td>Iib</td>
<td></td>
</tr>
<tr>
<td>IIIa</td>
<td>Ipsilateral mediastinal disease</td>
</tr>
<tr>
<td>IIIb</td>
<td>More widespread disease</td>
</tr>
<tr>
<td>IV</td>
<td>Unresectable disease</td>
</tr>
</tbody>
</table>

Important for prognosis and therapy.

10. Complete Pulmonary Resection

Surgeon is morally certain he or she has encompassed all tumor disease
Proximal margins of resected specimen are microscopically free of tumor
Within each major lymphatic drainage region, the most distal node is microscopically free of tumor
Capsules of resected nodes are intact.

11. Lymph Node Mapping in Lung Cancer

Only 50% of patients with lung cancer are surgical candidates
50% of surgical patients have mediastinal N2 disease
Mediastinal lymph node dissection is:
Only definitive way of staging lung cancer
Identifies patients with skip metastasis (33% incidence especially in adenocarcinoma)
Identifies intranodal V/s perinodal metastasis
Identifies multilevel disease (poor prognosis)
Is required by many neoadjuvant and adjuvant protocols
Is a part of a complete resection
12. **CT Staging of the Mediastinum**

Current imaging techniques determine size not histology

Malignant mediastinal nodes are not larger than benign lymph nodes

(58% > 15 mm benign)

Small mediastinal nodes (< 10 mm) are not infrequently malignant (15%)

Benign adenopathy is more common in patients with acute pulmonary inflammation

Pathologic confirmation rates higher than radiologic estimation

CT identification of enlarged hilar/mediastinal nodes is not diagnostic of advanced stage disease. CT, therefore adds an extra cost without contributing to the management plan

13. **Survival after Surgical Resection in Lung Cancer**

<table>
<thead>
<tr>
<th>Stage</th>
<th>Survival Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>IA (511)</td>
<td>- 67%</td>
</tr>
<tr>
<td>IB (549)</td>
<td>- 57%</td>
</tr>
<tr>
<td>IIA (76)</td>
<td>- 55%</td>
</tr>
<tr>
<td>IIB (375)</td>
<td>- 39%</td>
</tr>
<tr>
<td>IIIA (399)</td>
<td>- 23%</td>
</tr>
</tbody>
</table>

Factors influencing survival in N2 disease

- Multiple levels of involvement
- Nodal vs extranodal disease
- Superior vs inferior mediastinum
- Bulky clinical vs discrete CT nodes
- Recurrences - 80% within 2 years
- Second primary 3-4% per year, especially in high risk patients

14. **Manifestations of Preoperative Inoperability**

- Distant metastases (absolute)
- Malignant pleural effusion (absolute)
- Superior vena caval syndrome
- Horner's syndrome
- Vocal cord paralysis
- Phrenic nerve paralysis

15. **Neoadjuvant Therapy for Lung Cancer**

Neoadjuvant therapy has been successful in anal, bladder and esophageal cancers. Head and neck cancers do not respond to neoadjuvant therapy

**Rationale for neoadjuvant therapy**

- Surgical resection disrupts blood supply and adjuvant therapy may not be deliverable
- Preoperative therapy may minimize seeding
- Preoperative therapy may accomplish downstaging
- Tumor growth is inversely related to size. Micrometastases grow faster
- Chemotherapy related killing follows first order of kinetics
Goldie Coldman hypothesis - with each cell division cells become resistant due to continued mutation

16. Completed Neoadjuvant Therapy Trials in Stage II and III NSCLC

<table>
<thead>
<tr>
<th>Study</th>
<th>Therapy</th>
<th>No. of Patients</th>
<th>Overall Survival P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roth et al, 1994</td>
<td>CT+S+CT/S</td>
<td>60</td>
<td>&lt;.008</td>
</tr>
<tr>
<td>Rosell et al, 1994</td>
<td>CT+S+RT/S+RT</td>
<td>60</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Yoneda et al, 1995</td>
<td>CT+RT+S/S</td>
<td>83</td>
<td>NS</td>
</tr>
<tr>
<td>CALGB, 1997</td>
<td>CT+S+CT+RT/RT+S+RT</td>
<td>57</td>
<td>NS</td>
</tr>
</tbody>
</table>

Steven M. Keller, MD (1998)

17. Current Neoadjuvant Therapy Trials

<table>
<thead>
<tr>
<th>Study</th>
<th>Therapy</th>
<th>Accrual Goal</th>
<th>Eligibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTOG 9309</td>
<td>CT+RT+S+CT/CT+RT+CT</td>
<td>510</td>
<td>Stage IIIA (T1-3N2)</td>
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<tr>
<td>EORTC 08941</td>
<td>CT+S/CT+RT</td>
<td>812</td>
<td>Stage IIIA (N2)</td>
</tr>
<tr>
<td>MRC LU20</td>
<td>CT+S or CT+RT/RT</td>
<td>350</td>
<td>Stage IIIA (T3N1, T1-3N2)</td>
</tr>
<tr>
<td>MRC LU22</td>
<td>CT+S/S</td>
<td>450</td>
<td>Resectable disease</td>
</tr>
<tr>
<td>Despierre et al</td>
<td>CT+S/S</td>
<td>406</td>
<td>Stage I-IIIA</td>
</tr>
</tbody>
</table>

Steven M. Keller, MD (1998)

18. Conclusions from randomized trials

Well tolerated with high response and resectability rates (70%)
Trend towards increased disease free survival and even overall survival
I believe some form of neoadjuvant therapy is the best we have to offer today and recommend it to every patient with N2 disease

19. Chest Wall Invasion of Lung Cancer

Incidence of about 5%
Does not imply a hopeless prognosis
Mortality and morbidity for surgical resection are acceptable
Extensive resections possible
EXTENDED OUTLINE

VI. Epidemiology

A. World
1. 900,000 people/yr
2. Most common cause of death for men
3. Incidence will rise through the 1990’s

B. USA
1. More cancer deaths for men and women than any other
2. 10th in world

C. Men
1. Increased from 5/100,000 to 57/100,000 (1930’s to 1990)
2. Death rates declining for younger men (<55 yo), increasing in older

D. Women
1. 1965-1990 = 8-fold increase in lung cancer incidence in women
2. Leading cause of cancer death age 55-74
3. More likely to be non-smokers

E. Young adults
1. < 5% are < 40 yo
2. More aggressive - adeno and small-cell more common (than in older pts)
3. M:F= 1.7:1 vs 3.47:1 for older pts

VII. Etiology

A. Tobacco
1. 90% of cancers are in smokers
2. Latent period  20-25 years
3. Dose-related (heavy smoker 25x risk of non-smoker)
4. “Most serious drug addiction in the world”

B. Components of cigarette smoke
1. Tumor initiators
a) 3, 2 dozen polycyclic aromatic hydrocarbons
2. Tumor promoters (or cocarcinogens)
a) Fatty acids, phenols, N-methylated indoles, insecticides
b) Low-dose nicotine
c) N-nitrosamines
3. Complete carcinogens
   a) Nickel, arsenic
   b) Radioactive plutonium (80 pk-yr = 1300 rem from polonium) - enough to cause Ca

C. 2nd hand smoke
   1. Side-stream smoke more carcinogenic per weight
   2. Respiratory symptoms and illnesses in kids
   3. Risk enhanced 25% in non-smoking “passive smokers”

D. Industrial exposure
   1. Arsenic, chromates, nickel, asbestos, silica, iron, coal
   2. Organic chemicals: benzopyrene, vinyl chloride, chloromethyl ether
   3. Radioactive emissions
   4. Newspaper workers, miners, halothane workers
   5. Asbestos
      a) Synergy w/tobacco (50-90x risk of Ca c/w control)
      b) 1/5 deaths from bronchogenic Ca, 1/10 from pleural/peritoneal mesothelioma, 1/10 from GI Ca

E. Atmospheric pollution
   1. Radon
   2. Chernobyl (Hungary is #1)

F. Genetic factors
   1. Specific “lung cancer genes” not yet identified
   2. ras- and myc- oncogenes associated w/ growth regulation

VIII. Histogenesis and Pathogenesis of lung Ca

A. Background
   1. Stem cell theory - cells may differentiate and lose differentiation
      Small Cell
      Adenocarcinoma
      Squamous Cell Carcinoma

   2. ras, myc or neu oncogene mutations may be associated with a particular tumor type
   3. Pulmonary epithelial cells - limited repertoire of response
      a) Basal cell hyperplasia with metaplasia & differentiation toward goblet or squamous cell
b) Proliferation of Kulchitsky cells
c) Proliferation of type II pneumocytes (stem cell, produces surfactant)

B. Stages of Carcinogenesis
1. Initiation - irreversible, rapid, 2° to genotoxin
2. Promotion - reversible, clonal expansion of initiated cells
3. Progression, invasion, metastasis - less well understood
4. nm23 gene - high expression associated w/ low metastatic potential (murine model)

C. Squamous carcinogenesis - (better defined stages than adenocarcinogenesis)
1. Hyperplasia
   a) growth factors à # of basal (reserve) cells in bronchial epithelium
   b) Cells are benign, respond to normal control mechanisms
2. Metaplasia
   a) Reversible
   b) Ciliated bronchial epithelial cells à goblet or squamous cells
3. Dysplasia
   a) Reversible
   b) Thickened epithelium
   c) Cellular orientation and maturation disordered, but present
   d) Cytologically abnormal with Nuc/Cyt ratio
   e) Quantitative DNA analysis may risk stratify degrees of dysplasia
4. Carcinoma in situ
   a) Thickened, severely atypical epithelium
   b) Cytologic features similar to, but more severe than dysplasia
   c) Similar to carcinoma, but no invasion of basement membrane
   d) Several foci frequently seen outside of tumor in resected specimens

IX. Staging - see American Joint Committee for Cancer Staging and End Results Reporting (AJC) and Union Internationale Contre Cancer (UICC) nomenclature, next page

X. Classification of lung tumors - see text for histology

A. Usual tumors constitute 95%

B. 45% have mixed histologic pattern by light microscopy

XI. Squamous cell carcinoma (SCC)

A. 90% in segmental or larger bronchi

B. Grow endobronchially and invade peribronchial soft tissue
C. Central tumors can be dx’d by sputum cytology - most common neoplasm detected in screening program

D. Typically metastasize within thorax
   1. Pleura involved in 1/3 - cells in pleural effusion uncommon
   2. Only 20-25% have extra-thoracic mets

E. Peripheral SCC
   1. Keratin pools
   2. Cavitate

F. Concomitant upper and lower airway SCC
   1. Poor prognosis
   2. Stage I, II, asymptomatic, may be cured
   3. Segmentectomy due to poor pulm. fxn and likelihood of further Ca

XII. Adenocarcinoma

A. Incidence
   1. Increasing
   2. Most common in Japan and in females in USA

B. 30% arise in surface epithelium and submucosal glands of bronchi smaller than in SCC

C. Non-ciliated bronchiolar epithelial cell (Clara cell) may be common cell of origin

D. Appearance
   1. Hard, gray or white mass in periphery
   2. Necrosis can occur, cavitation is rare
   3. Desmoplastic response

E. Grow more rapidly than SCC

F. Metastasize early - > 80% present w/mets (adrenal, liver, bone, brain)

G. Presentation
   1. Asymptomatic mass in periphery
   2. FNA most common method of dx

H. Subtypes - most show more than one subtype
   1. Acinar - most common
   2. Papillary
   3. Mucin-producing
XIII. Bronchoalveolar (Bronchiolar) Carcinoma (BAC)

A. Incidence increasing, 9.3-20.3% from 1978-1989

B. Clinical presentation
   1. Arises in periphery
   2. Tends to be multicentric
   3. Radiographically, may be an infiltrate rather than a mass, may not change for years
   4. Relationship to smoking debated

C. Segmentectomy, when possible, as end stage is frequently respiratory failure

D. Histology
   1. Subtype of adeno
   2. Clara cells and type II pneumocytes are cells of origin
   3. Grow along alveolar septa
   4. 3 morphologic types
      a) Well-differentiated tall columnar
      b) Tall columnar w/“hobnail” caps
      c) Cuboidal

XIV. Large Cell undifferentiated

A. 50% arise in subsegmental or larger bronchi (between SCC and adeno)

B. Aggressive - often stage III or IV, poor prognosis

XV. Combination carcinomas

A. 45-50% of all Ca

B. Assume it will behave like most malignant component

XVI. Scar carcinoma

A. 1/3 adeno, 1/5 SCC have sufficient scar around tumor to raise ?

B. 50% assoc. w/healed infarcts or arrested granulomatous inflammation, 25% w/non-
specific inflammation

C. Most often in upper lobes, creating diagnostic challenge
   1. Is excision of a long-standing scar warranted if there is a slight radiographic D?
   2. FNA of a “new” mass yields scar, is that representative?

XVII. Neuroendocrine (Kulchitsky Cell) Carcinomas
A. Background
1. APUD (Amine precursor uptake derivative) origin
2. First evidence that DNA ploidy correlates with aggressiveness
3. Common cell of origin for typical and atypical carcinoid tumors
4. 10% thought to have carcinoid have had Small-cell
5. Small-cell carcinomas included in this group (a genetic variant of carcinoid)

B. Carcinoid: Typical (KCC I) and Atypical (KCC II)
1. 3-5% of all lung Ca
2. 90% are central, arising in lobar or segmental bronchi, and grow in a polypoid manner
3. Covered by an intact mucosa, most are 2-4cm at time of dx
4. 5% metastasize - usually to regional nodes
5. Typical carcinoid (KCC I)
   a) May manifest w/hemoptysis and nl CXR
   b) Bx (bronchoscopy), then complete resection (sleeve resection useful))
   c) Laser ablation not recommended, as tumor is deep to mucosa
   d) Carcinoid syndrome <3%
   e) 94-100% 5-yr survival
6. Atypical carcinoid - 10% (KCC II)
   a) 46% are stage II or III
   b) 20% have M1 dz
   c) Mean survival 25 months
   d) Dx may be confused w/SCLC
7. Spindle cell carcinoid - resembles smooth muscle cell

C. Small Cell undifferentiated Carcinoma
1. Arise from basal cells of bronchial epithelium
2. Neuroendocrine differentiation
3. Metastasize early and widely
   a) Hilar adenopathy
   b) Brain
4. With treatment, may “mature” to SCC
5. Need adequate bx specimen to establish dx (vs atypical carcinoid, lymphoproliferative dz)
6. Stage I may be tx’d w/resection + chemo tx (?Stage II)
7. Histology
   a) Oat cell
   b) Intermediate cell

D. Large Cell Neuroendocrine Carcinoma - behaves between KCC II and SCLC

XVIII. Other neoplasms of respiratory tract

A. Adenoid cystic carcinoma (cylindroma)
1. Mainstem or major bronchus
2. Complete excision can result in cure, but local late recurrence possible
3. Histology similar to salivary gland

B. Mucoepidermoid carcinoma
1. Low-grade, slow-growing
2. Glandular and/or squamous differentiation

C. Carcinosarcoma

D. Pulmonary blastoma, fibrosarcoma, hemangiopericytoma

E. Pulmonary lymphoma - resection is tx of choice

XIX. Paraneoplastic syndromes: see chart

XX. Diagnostic pitfalls

A. FNA - sampling error

B. Bronchoscopy
1. Obtain several specimens
2. Await permanent sections due to small specimens

C. Fungal infection notorious for cellular atypia (mimic cancer)

Surgical Treatment of Lung Carcinoma

VI. Extent of resection

A. 1933 - Graham and Singer - First pneumonectomy for carcinoma

B. 1950 - Churchill - Lobectomy is effective for Ca and safer than pneumonectomy

C. Less than lobectomy
1. Jensik - Peripheral Stage I (n=168)
   a) Wedge or segmentectomy
   b) 53% 5-year
   c) 45 pts died of disease, 16/45 - local recurrence
2. In retrospective series, loco-regional recurrence: 4.4-22.7% vs 4.9-11.5%
3. Ginsberg & Rubinstein
   a) Randomized: lesser resection vs lobectomy
   b) Loco-regional recurrence: 17.2% vs 6.4%
   c) 5-yr survival: 68% vs 50%
4. Recommendation (Glenn’s): May be useful for high-risk, elderly pt with limited reserve

D. Incomplete resection
1. 1-yr = 26%, 3-yr = 8.5%, 5-yr = 4%
2. All 5-yr survivors had SCC with + bronchial margin

E. Mediastinal lymph node dissection - necessary for pathologic + surgical staging
1. Superior mediastinal/paratracheal - Right
   a) Anterior mediastinum (ant to SVC) nodes resected if palpable
2. A-P window - Left
   a) Supraaortic and superior mediastinal palpable nodes excised
3. Subcarinal & lower mediastinal - Bilateral

F. VATS
1. Controversial
2. Criteria for VATS resection
   a) Stage I
   b) ≤ 2cm
   c) Lower lobes preferable
   d) Incomplete fissure makes resection difficult

VII. Occult non-small cell lung carcinoma (NSCLC) = TX N0 M0

A. + sputum cytology on screening or hemoptysis without radiographic manifestations

B. 1/3 with + sputum represent head and neck primary

C. FOB if head and neck exam is normal
   1. If appearance is normal, do segmental brushings and cytology

D. Tx is lobectomy or pneumonectomy
   1. Median survival 9 years
   2. 45% develop new carcinomas usually airway

E. 1/3 have mediastinal and/or lymphatic spread

F. Screening
   1. Low yield (53/10,040 smokers)
   2. In-vivo fluorescence - Y sensitivity of bronchoscopy in screening and in TX cases

VIII. Stage I NSCLC - T1 N0 M0, T2 N0 M0

A. Older staging included T1 N1 M0 as stage I
B. ~ 20% of patients

C. T1 = £ 3cm, surrounded by lung or visceral pleura

D. T2 = >3cm or any size w/ visceral pleural invasion or atelectasis extending to hilum and >2cm distal to carina

E. Staging
1. H&P
2. Lab: SGOT, Af, LDH
3. CT chest + upper abd to include liver and adrenals
4. Without symptoms, bone and brain scan unnecessary (controversial)

F. Lobectomy, bilobectomy or pneumonectomy + mediastinal LND
1. OR mortality = 0-2.3%
2. 5-yr survival 63-85% (75%)
3. Prognostic factors
a) NOT- age, sex, pleural involvement, grade, histologic type
b) DNA ploidy & grade - Ichinose
4. 39% develop recurrence or new lung 1° (5-10 yr)
   a) 56% distant mets
   b) 20% new lung 1°
5. F/U = CXR + PE q 3months x 1st yr, q4mo 2nd yr, then q 6mo

G. No adjuvant tx recommended (?chemoprevention)

IX. Stage II NSCLC - T1 N1 M0, T2 N1 M0

A. 10% of pts

B. T1,2 as above (III B,C) and peribronchial or ipsilateral nodes

C. Lobectomy, bilobectomy or pneumonectomy + mediastinal LND
1. 39-49% 5- yr survival
2. 40-54% (T1N1) / 38-40% (T2N1)
3. Prognostic factors
   a) tumor size and # of nodes
   b) Not -age sex, pleural involvement
   c) ? histology (SCC better)
4. Recurrence - 55%
   a) 21% loco-regional
   b) 79% distant (47% brain mets)
   c) SCC à loco-regional / Adenoà distant

-90-
D. Adjuvant Tx
1. Chemo-tx - role unclear, not recommended
2. Rad tx à β loco-regional recurrence, no D in survival
3. Post-op immuno-tx not beneficial

X. Stage IIIA NSCLC

A. New international staging
1. Adds stage IV for distant mets (M1)
2. Divides Stage III
   a) IIIA (T3 N0-1 M0, T1-3 N2 M0)
      (1) Limited extrapulmonary extension, or ipsilateral or subcarinal nodes
      (2) Pts may be offered surgical resection
   b) IIIB (Any T N3 M0, T4 any N M0)
      (1) Pts should be considered for surgery only in a special protocol setting

B. T3 - Chest wall invasion (Excluding superior sulcus tumors)
1. 5% of pts
2. Surgical Tx
   a) Pulmonary resection
      (1) Extrapleural if parietal pleural involvement noted at thoracotomy and tumor-free plane exists
      (2) En-bloc if plane cannot be achieved
   b) Soft tissue resection
   c) Mediastinal LN dissection
   d) Chest wall reconstruction
      (1) Chapter 34
      (2) Methylmethacrylate/Marlex sandwich
3. Operative mortality 4-12%
4. 5-year survival 26-40%
5. Prognosticators (poor)
   a) Incomplete resection - median 9 mo survival, 0 3-yr survival
   b) LN involvement (N1-2) - 21% vs 56%
   c) Chest wall vs parietal pleura alone 16% vs 48%
6. Radiation
   a) No randomized, controlled data
   b) Patterson (retrospective) - 56% vs 30% 5-yr

C. T3 - <2cm from carina
1. Bronchoscopy
   a) Proximity to carina
   b) Submucosal spread
2. Sleeve lobectomy
   a) 30-64% 5-yr survival
   b) 0-8% operative mortality (pneumonectomy - 6% operative mortality)
   c) By stage:
(1) I - 38% 5-yr
(2) II- 20%
(3) III- 15%
3. Sleeve pneumonecctomy
   a) Bulky central tumor in proximity to or involving carina or tracheobronchial angle
   b) 4-31% operative mortality
   c) Anastomotic dehiscence à 100% mortality
   d) 16-23% 5-yr survival

D. N2 dz
1. 45% of pts
2. Some feel N2 is not resectable (with or without RT/Chemo)
3. Pearson’s mediastinoscopic contraindications to resectability
   a) Contralateral nodal dz
   b) Extraneural extension
   c) High paratracheal nodal dz
4. Survival = 20-30% 5-yr survival without pre-op mediastinoscopy, with post-op RT
5. 706 pts w/N2 dz (see table below)
   a) T1 - 46% 5-yr survival
   b) T2 - 27%
   c) T3 - 14%
   d) Level 1, 2 nodes (upper paratracheal) à 20% vs 32 %
   e) Level 7 (subcarinal) à 22% vs 33%
   f) A-P window à 35%
6. Adjuvant tx
   a) LCSG - Post-op RT vs no RT
      (1) No survival benefit for stage II, III epidermoid
      (2) loco-regional control
   b) LCSG - Adeno & Large-cell post-op immuno (BCG +levamisole) vs Chemo (Cytoxan, adriamycin, cisplatin)
      (1) Survival similar
      (2) Dz-free survival better w/chemo-tx
   c) Roth, Rosell - pre-op Chemo vs surgery alone in IIIA
      (1) 3-yr = 30, 56% vs 0, 15%
   d) Recommendation: Pre-op chemo-tx should be offered as part of a trial
      Clinical N2 (CXR, Bronchoscopy, +/- mediastinoscopy) Clinical N1,N0 (CXR, Bronch)
      Complete Resection 18% 53%
      3-yr survival 9% 47%
      5-yr survival 9% 37%

VI. IIB

A. T4 - Pleural effusion
1. Cytology is usually positive à median 6-9 month survival
   a) Palliative tx - Chest tube, then chemical pleuradesis (80%)
b) Subtotal pleurectomy for failures or incomplete re-expansion
2. Cytology negative, non-bloody, not an exudate - exclude this pleural effusion for staging purposes
3. Evaluation
   a) Thoracentesis
   b) Thoracoscopy w/bx of pleural lesions

B. T4 - Mediastinum (n=225)
   1. Complete resection
   2. Incomplete resection + brachytherapy
   3. Brachytherapy alone
   4. Incomplete or no resection w/o brachytherapy
   5. Overall, 22%, 13%, 7% at 2, 3, 5 yrs
   6. Consider adjuvant tx

VII. Stage IV M1 NSCLC

A. Brain mets
   1. 27-48% in autopsy series
   2. 47% of pts w/M1 dz
   3. Survival from onset of symptoms = <1 month to 6 months

B. Resection of solitary brain metastasis
   1. Operative mortality 2-44%
   2. 2.6-12 mo survival
   3. Retrospective data
      a) Surg + RT vs RT alone à 16 vs 4 mo survival
      b) 13% 5-yr survival, median 14 mo survival
   4. Prospective (Patchell)
      a) Surg + whole brain RT vs whole brain RT alone
      b) 9.2 vs 3.4 mo median survival
   5. Recommendation
      a) Synchronous, solitary brain met, no other mets à craniotomy, then thoracotomy
      b) Brain met discovered after lung resection à craniotomy
      c) RT after resection of brain met controversial

VIII. Small Cell Carcinoma

A. Most patients have abnormal mediastinum, \( bx \) for dx, then RT + Chemo tx

B. Small-cell discovered at thoracotomy
   1. Stage I à resect
   2. 5-yr 60/28% survival for T1/T2
   3. Chemo tx recommended
   4. Stage II, III à RT + Chemo (no resection)
IX. Closing comments

A. 2% operative mortality

B. High-risk (consider lesser resection)
   1. > 70 yr old for major resection
   2. Cardiovascular dz
   3. Poor lung fxn

Selected Articles


Sources for further reading

Textbook Chapters

Lung Cancer Staging

I. Staging Process

A. Histology
   - small cell vs. non-small cell

B. Sputum
   1. 20-70% sensitive, but tumor location plays a significant role
   2. histology is predictive of yield, i.e. squamous is more often positive followed by adenocarcinoma, and finally small cell
   3. when cytology is positive it predicts the cell type with 85% accuracy

C. Bronchoscopy
   1. direct visualization or positive biopsy in 25-50% of patients with lung cancer

D. Fine needle aspiration
   1. percutaneous or transbronchial
   2. 84-95% accurate with peripheral lesions

E. VATS

F. Thoracotomy

II. Staging Classification

A. International Staging System for Non-Small Cell Carcinoma
   1. T Primary Tumor
      Tx - positive cytology only
      To - no evidence of tumor
      Tis - carcinoma in situ
      T1 - size < 3 cm
         no pleural invasion
distal to lobar bronchus
      T2 - size > 3 cm
         any size invading the visceral pleura
         associated atelectasis or pneumonitis to the hilum
         >2 cm from the carina
      T3 - any size with chest wall, diaphragm, mediastinal pleura, or pericardium, (i.e. locally metastatic to resectable ipsilateral hemithorax)
         < 2 cm from the carina
      T4 - invasion of the mediastinum, heart, great vessels, vertebral body, esophagus, or carina
2. N Nodal Involvement
   N0 - no nodes
   N1 - peribronchial or ipsilateral hilar
   N2 - ipsilateral mediastinum or subcarinal
   N3 - any contralateral node
     ipsilateral supraclavicular or scalene nodes

3. M Distant Metastasis
   Mo - no mets
   M1 - distant mets

B. Small Cell Carcinoma

1. localized - disease of the ipsilateral hemithorax including the supraclavicular
   nodes and a positive pleural effusion
2. extensive - disease beyond the ipsilateral hemithorax

III. Clinical Presentation
A. Sputum
1. bronchopulmonary
2. extrapulmonary intrathoracic
3. extrapulmonary metastatic
4. extra pulmonary nonmetastatic (i.e. paraneoplastic)
   a. carcinomatous neuromyopathy is the most common paraneoplastic syndrome with
      15% of patients with lung cancer affected
      1) myasthenia gravis - like syndrome
      2) polymyositis
   b. Cushing’s - small cell
   c. SIADH - small cell
   d. hypercalcemia - squamous
   e. gynecomastia - small cell
   f. Gonadotropin - undifferentiated large cell

B. Signs
1. clubbing is the most common
2. Hypertrophic pulmonary osteoarthopathy
   a. periosteal elevation at the ends of long bones
   b. 2-12% of all lung cancer patients
   c. not seen in small cell

C. Tumor Makers/ Oncogenes
1. generally not help for diagnosing lung cancer

V. Diagnostic Evaluation
A. CXR
- CXR findings proceed symptoms by 7 months
- sensitive to 1 cm
- nodule most common finding
  1. squamous
     a. obstructive pneumonitis
     b. collapse
     c. consolidation
     d. 1/3 are peripheral
     e. 20% have cavitation
  2. adenocarcinoma
     a. peripheral
     b. < 3 cm
     c. bronchoalveolar have parenchymal changes
  3. Large cell (undifferentiated)
     1. 60% are peripheral
     2. 2/3 > 4 cm
  4. small cell
     1. 80% hilar abnormalities
     2. 2/5 associated parenchymal changes

B. Other Studies
  1. CT
     a. best for evaluating the mediastinal adenopathy and adrenals
     b. chest wall invasion is poorly seen
     c. paraesophageal and inferior pulmonary nodes not well seen
     d. nodes < 1 cm have a 7% chance of being malignant
     e. nodes > 1 cm have a 55-65% chance of being malignant
  2. MRI
     a. better than CT at evaluating vascular invasion and chest wall invasion esp. superior sulcus
  3. Ultrasound
     a. ? TEE for evaluating mediastinal adenopathy
  4. PET
     a. may help determine malignant vs. benign peripheral nodules
  5. Bone Scan
     a. helpful in stage IIIA and IIIB disease

VI. Lymph Nodes

A. Biopsy
  1. biopsy palpable neck nodes
  2. mediastinoscopy is controversial
B. FNA
   1. 85-95% sensitive

C. VATS
   1. good for evaluating aortopulmonary window

VII. Completion of Staging

- 25% of patients worked up will be resectible
- 25% will have stage IIIB
- 50% will have stage IV

VIII. Postthoracotomy provides the definitive stage and should be the basis of treatment plans

IX. Functional Status

A. Associated with prohibitive operative risk
   1. FEV1 < 40%
   2. Predicted postop FEV1 < 30%
   3. MVV < 45-50%
   4. DLCO < 40%
   5. PCO2 > 45 mmHg
   6. peak VO2 < 10 ml/kg

Selected Articles


Sources for further reading

Textbook Chapters

Oncogenes in Lung Cancer

I. Classification
A. Dominant oncogenes
1. Alter one allele of a gene
2. Mutation results in overproduction of a protein or loss of regulatory function of protein production
3. Both result in uncontrolled cell growth and division
B. Tumor-suppressor anti-oncogenes
1. Mutation on two alleles of a gene
2. Lose ability to control growth
3. Results in malignant transformation of the cell
4. Include inherited retinoblastoma

II. ras
A. Rat sarcoma
B. Expression frequently enhanced in pulmonary neoplasm (all histologic types, especially NSCLC)

III. myc
A. L-myc (homolog found in lung cancer), N-myc, c-myc, etc.
B. Expression is associated with uncontrolled proliferation
C. Cells express only one homolog at a time
D. SCLC - Three levels of expression:
   1. Low
   2. Medium - amplification from chromosomal duplication
   3. High - gene amplification
E. Enhanced expression
   1. Associated with treatment (chemo-tx), and with shortened survival
   2. Probably a secondary event

IV. A. Suppressor gene
B. Found in many types of carcinoma
C. Mutations found frequently in lung cancer cell lines

V. HER-2/neu (c-erb-2)
A. Encodes for protein
   1. Transmembrane protein related to tyrosine kinase activity
   2. Significant homology with epidermal growth factor receptor
B. Expression in adenocarcinoma associated with ↓ survival
C. Expresed more frequently in NSCLC
D. Radiolabeled monoclonal antibody may help image tumor
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Surgery for Lung Cancer

Introduction
Lung carcinoma is the second most common form of cancer in the U.S. and is the leading cause of death in men
1. (33% of cancer related deaths)
2. Lung cancer is the most common cause of death in women (23%) breast ca (18%)
3. Overall cure rate is 10-13% of patients at 5 years
4. 1909 intratracheal anesthesia was introduced
5. Graham and Singer in 1933 reported the first successful pneumonectomy for lung carcinoma
6. In 1950, Churchill proposed that a lobectomy could be effective in the resection of lung carcinomas

Lung Cancer Study Group randomized 247 patients to compare segmentectomy versus lobectomy in the treatment of lung cancer
a. for segmentectomy the local recurrence rate was 17.2% versus 6.4% for lobectomy
b. 5 year survival was 50% for segmentectomy versus 68% for lobectomy
1. for incomplete resection for bronchogenic carcinoma the 5 year survival is 4%
2. mediastinal lymph node dissection should be included in the resection
   a. important for pathological staging
   b. adds minimal time and morbidity to the procedure
   c. compartments include:
      i. superior mediastinal
      ii. A-P window
      iii. subcarinal and inferior mediastinal

Surgical Treatment of Occult (TX NO MO) Non-Small Cell Lung Carcinoma
1. Low incidence, 1.5% in Memorial Hospital experience
2. these are individuals who participate in early screening programs and submit sputum for cytological analysis on a routine basis, or have hemoptysis with normal CXR
3. 33% of patients with positive sputum cytology and negative CXR will have head and neck cancer
4. detailed head and neck examination is important in the diagnosis
5. bronchoscopy
   a. careful examination required
   b. endobronchial brushing of each segmental bronchus required
   c. fluorescent staining is possible with parenterally administered hematoporphyrin derivative

Treatment
f. photoablation has been described (3 yr survival 50-70%)
g. surgical resection is the treatment of choice
h. local recurrence is low, median survival is 9 years
i. close follow up is required since up to 45% of patients will develop a second primary, most of which will be airway carcinomas
Surgical Treatment of stage I (T1 N0 M0, T2 N0 M0) Non-Small Cell Lung Carcinoma
1. 20% of patients
2. Includes patients with tumors:
   a. 3 cm size or less surrounded by lung or visceral pleura, without extension proximal to a lobar bronchus
   b. Tumors > 3 cm, or tumor of any size that invades visceral pleura or has associated atelectasis extending to the hilum, and is >2 cm distal to carina (T2)
   c. Have no nodal metastases (N0 M0)
3. Staging
   c. Patients should be preoperatively and intraoperatively staged
   d. Pre-op includes H&P, LFT’s, CXR, CT scan
   e. Controversy exists over pre-op routine bone and brain scans for asymptomatic patients
   f. Intra-op node dissection
   g. Prior to 1986, the TNM classification included T1N1 tumors under stage 1, therefore reported overall survival was lower

Results of surgery
Overall reported 5 year survival is 50-85% (82-85% T1, 67-68% T2)
Histology not a prognostic factor in survival
Close follow up required since recurrence rate is 27-39%
   i. 60% recur within 2 years and 91% in 5 years
   ii. 34% develop second primaries: 33% lung, 16% breast, 13% head and neck, 8% colorectal, 7% bladder
Adjuvant therapy not warranted
Some evidence to suggest Vitamin A supplementation may have an effect on lowering the incidence of second primary tumors

Surgical Treatment of Stage II (T1N1M0, T2N1M0) Non-Small Cell Lung Carcinoma
1. 10% of patients
2. Includes patients with tumors:
   a. Primary tumors confined to the lung and >2 cm distal to carina, with metastases to peribronchial or ipsilateral hilar lymph nodes
   b. Treatment is lobectomy, bilobectomy or pneumonectomy with MLND

Results of surgery
Overall survival is 39-49% 5 year
Prognostic factors include size of primary and number of metastatic lymph nodes
Recurrence rate in one study (Martini et al) was 55% with 21% loco-regional and 79% distant
No adjuvant therapy has improved survival
Postoperative radiotherapy has been shown to decrease locoregional recurrence rate. Adenocarcinoma tends to recur distally more often while SCCA tends to recur locally.

**Surgical Treatment of Stage IIIA (T3 N0-1 M0, T1-3 N2 M0) Non-Small Cell Lung Cancer**

1. Includes patients with tumors:
   a. With limited, circumscribed extrapulmonary extension of the primary tumor (T3)
   b. And/or metastases confined to the ipsilateral mediastinal or subcarinal lymph nodes (N2)

**Surgical Treatment of T3 (Chest Wall Invasion) Non-Small Cell Lung Carcinoma (exclusive of superior sulcus tumors)**

1. 5% tumors invade parietal pleura and chest wall
2. Surgical treatment
   a. Includes pulmonary resection with contiguous soft tissue and rib resection and chest wall reconstruction
   b. When peripheral tumors is attached to parietal pleura, extrapleural resection can be attempted with good success or en bloc resection will be required
   c. Marlex mesh and methylmethacrylate can be utilized for reconstruction
   d. Overall operative mortality is 4-12%
   e. Overall 5 year survival is 26-40%
   f. Lymph node status and depth of invasion correlates with survival
   g. Most important prognostic factor is whether a complete resection can be performed

**Surgical Treatment of T3 (Proximity to carina) Non-Small Cell Lung Cancer**

1. Lesion within 2 cm of carina
   Treatment includes
   a. Pneumonectomy
   b. Sleeve lobectomy
   c. Sleeve pneumonectomy
   1. Most important diagnostic procedure is bronchoscopy in order to determine proximity of the tumor to the carina

2. Results of surgical treatment
   a. Sleeve lobectomy
      i. Overall mortality 0-%
      ii. Overall 5 year survival is 30-64%
   a. Sleeve pneumonectomy
      ii. Overall mortality 4-27%
      iii. Overall 5 year survival 16-23%
      iv. Indication is for bulky tumors in proximity to or involving the carina or tracheobronchial angle
      v. Major complication is anastamotic dehiscence with a mortality of 100%
Surgical Treatment of N2 Disease (Mediastinal Lymph Node Metastases) in Patients with Non-Small Cell Lung Cancer

1. 45% of presenting patients
2. Overall 5 year survival is 20-30%
   a. 151 cases completely resectable
   b. Post-operative XRT used in 90% patients
   c. Mediastinoscopy not routinely performed
   d. 79% underwent lobectomy, 17% pneumonectomy and 4% segmentectomy
   e. Overall 5 year survival was 30%
   f. No difference in survival between SCCA or adenocarcinoma
   g. Patients presenting with obvious N2 disease had poorer survival
   h. Number of nodes affected survival, upper paratracheal nodes affected survival with an overall 5 year survival of 20%
   i. 73% patients developed recurrent disease

1. Adjuvant therapy
   d. Lung Cancer Study Group
      i. Stage II and III patients
      ii. Found that post-operative radiotherapy significantly decreased local recurrence but no affect on survival
      iii. Also randomized patients with adenocarcinoma and large cell cancer to receive postop BCG and levamisole vs. Chemotherapy and found increased disease free survival in those patients that received chemotherapy
      a. Stage IIIA patients
      ii. Three randomized trials of preoperative chemotherapy plus surgery vs. Surgery alone revealed survival benefit in patients receiving preoperative chemotherapy with a response rate 60%

Surgical Treatment of Stage IIB Non-Small Cell Lung Cancer

Surgical Treatment of T4 (pleural Effusion) Non-Small Cell Cancer

1. patients with malignant pleural effusions
2. if cytologically negative, the effusion is excluded as staging element and is staged as T1, T2 or T3 lesion
3. evaluation of patients with pleural effusions
   a. Thoracentesis
   b. thoracoscopy- perform if thoracentesis cytologically negative fluid
      i. if pleural metastases is found then patient is non-operable (T4)
      ii. if no pleural metastases are found then the patient is an operable candidate (only 6% of patients)
1. median survival for patients with malignant pleural effusions is 6 months
2. tube thoracostomy, pleurodesis, VATS may be required to control recurrent pleural effusions
Surgical Treatment of T4 (Mediastinum) Non-Small Cell Lung Cancer

1. patients with tumors of any size invading heart, great vessels, trachea, esophagus, vertebral body or carina
2. most patients are considered inoperable if biopsied pre-operatively or are found unresectable intra-operatively
3. MSKCC experience
   c. 225 patients in their review
   d. overall survival 22% at 2 years, 13% at 3 years and 7% at 5 years
   e. therapy was either complete resection, incomplete resection with brachytherapy,
      brachytherapy alone or incomplete resection alone
   d. 5 year survival for patients that underwent complete resection was 9%
4. patients should receive pre-op chemotherapy if possible in attempt to down stage the tumor
5. a small study by Macchiarini (23 patients) utilizing induction chemotherapy with patients with T4 tumors demonstrated a 3 year survival of 54%

Surgical Treatment of Stage IV (T1-4, No-2, M1) Non-Small Cell Cancer

1. this includes any patient with distant metastatic disease (M1)
2. small role for surgical therapy limited to patients with solitary brain metastases
   a. if both lesions are resectable (brain metastases and lung tumor) then craniotomy should be performed followed by thoracotomy
   b. patients who receive post-operative whole brain radiation have an improved median survival 9.2 months vs. 3.4 months

The Problems of Surgical Therapy For Small Cell Carcinoma

1. in general is not a surgical disease
2. surgery indicated in only a small number of patients
3. it is usually discovered intra-operatively in a patient with presumed non-small cell cancer
4. if at thoracotomy the diagnosis of stage I small cell cancer is made, then complete resection should be attempted
5. the VA Surgical Oncology Group demonstrated 5 year survival rates of 60% for T1N0 and 31% for T1N1 disease (54% received post-op chemotherapy)
6. post-operative chemotherapy is recommended
7. patients with stage II or III are best served by chemotherapy and radiation

Superior Sulcus Tumors

Definition

a bronchogenic carcinoma located in the extreme apex of the lung which invades the pleura and adjacent structures and produces classic symptoms and signs.
The presenting symptom most frequently cited is pain localized to the shoulder. If left untreated the pain becomes unremitting and spreads medially to the scapula, extends along the ulnar nerve distribution of the arm to involve the elbow, forearm and hand. Other involved structures include the cervical sympathetics (Horner’s syndrome), vagus and phrenic nerves, carotid artery, and the vertebral bodies.

Squamous cell is the most common cause followed by adenocarcinoma and large cell. Small cell is rare

**Location**

All are T3 since they invade the chest wall; classified as T4 when mediastinal and/or cervical invasion has taken place.
- Posterior—stellate ganglion, posterior ribs, brachial plexus (upward extension), and vertebral bodies (medial extension)
- Anterior—1st rib, scalene muscle, subclavian vessels, phrenic nerve

Resection possible even with brachial plexus, stellate ganglion, rib, transverse process, subclavian artery (adventitia), vertebral body (<25%).

Mediastinal invasion (vena cava, vertebral foramina, vagus nerve) precludes cure

Nodal involvement is the key to potential curability once resectability is established—lymph node involvement is usually late in these tumors

**MSK series**—129 patients
- 109 patients—negative mediastinal nodes
  - median survival—20 months
  - 5yr—29%
- 20 patients—positive mediastinal nodes
  - median survival—9 months
  - 5yr—10%

Paulson—131 patients
- 78 patients resected (pre-op RT)—5yr survival 44%
- 17 patients with positive lymph nodes—0% survival at 2 years

**Radiologic evaluation**

—usual CXR finding mass in apex clouding the lung markings above the clavicle when contrasted to the clarity of the opposite side; however, may only resemble pleural thickening. Bony destruction may be apparent.

CT will identify involvement and invasion of the brachial plexus, the chest wall, vertebral bodies, vena cava, trachea, esophagus, and the subclavian vessels. Will also depict lymph node involvement

MRI is recommended to delineate the extent of cervical invasion and some consider routine in the preoperative evaluation.

**Operative approach**
Posterior
Incision follows the contour of the scapula

Enter pleura 3rd or 4th intercostal space
Vascular structures identified
Brachial plexus involvement identified and resected
Vertebral bodies are assessed
Lobectomy performed
Along with the possibility of usual complications, one other possibility is spinal cord leakage that may lead to meningitis or pneumoencephally—from air leaks and causes severe headaches

Anterior transcervical approach

Usually combined with the posterior approach
Sternocleidomastoid incision
Scalene fat pad dissection
Clavicular resection
Vein dissection
Jugular and subclavian veins freed—exposure of thoracic duct and vertebral veins facilitated
Arterial dissection
Subclavian, IMA, thyrocervical trunk, vertebral artery
Nerve dissection
Brachial plexus
Overall, major advantage is the ability to deal with the invasion of the subclavian vein and related structures. It is not effective for tumors that invade the posterior aspects of the ribs and their transverse processes, the stellate ganglion and sympathetic chain, and the vertebral bodies.

Radiation therapy

Primary therapy for unresectable or inoperable patients
Excellent for pain relief
No long term survival if primary tumor not controlled
Most common site of recurrence is the brain—consider prophylactic cerebral RT if local control achieved and histologic dx is adeno or large cell

PRE-OP RT

MSK—126 patients; 100 resected; 117 pre/post op RT; 102 brachytherapy
69 complete resection (49 of these had brachytherapy)
22 had lobectomy; 47 large wedge resection
5yr survival—60% for lobectomy; 33% for wedge resection
Intraoperative brachytherapy had no influence on loco-regional recurrence or survival in patients with completely resected tumors.

Adverse prognostic factors—Horner’s syndrome, N2, N3, and vertebral body invasion. This series indicates that pre operative RT is useful in patients when combined with lobectomy. Unresectable disease should be treated with external RT. +/- Intraoperative brachytherapy in patients who are explored but incompletely resected.

**POST OP RT**

Not indicated in patients who are completely resected and have no nodal metastasis. There are some retrospective studies that show benefit in patients with nodal disease, however the LCSG showed no survival benefit in completely resected patients—it did decrease the incidence of local (intrathoracic) recurrence.

MSK—Post operative RT following immediate operation and brachytherapy was as effective as pre-op RT and brachytherapy in achieving complete resection, loco-regional control, and ultimate curability.

There are no studies documenting the usefulness of chemotherapy in this disease.
Pulmonary Metastases

1. Pathogenesis
   · The lung is the first capillary bed draining most primary sites, with tumor cells usually depositing in the periphery
   · 10-20% of patients with pulmonary metastases have disease confined to the lungs (especially with sarcomas)

2. Diagnosis
   · CT scanning is sensitive but not specific, and may underestimate the number of malignant nodules
   · Needle biopsy rarely adds additional information
   · Sarcomas and melanomas are the most likely to cause a solitary metastasis

3. Patient Selection
   · There are four criteria which should be met prior to resection of pulmonary metastases:
     1. Resection should only be performed if removal of all disease is possible
     2. The patient must have adequate pulmonary reserve to tolerate resection
     3. Local control of the primary tumor
     4. Absence of metastases elsewhere in the patient

4. Prognostic Factors
   · Histologic cell type affects the pattern of metastasis as well as outcome
   · Tumors with longer doubling time have better survival
   · The number of metastases, the disease-free interval, and unilateral vs. bilateral disease are not prognostically significant
   · Complete resectability is the most important indicator of improved survival

5. Operative Technique
   · Wedge resections should be performed wherever possible to preserve parenchymal tissue
   · Manual exploration is preferred to thoracoscopic examination to identify all nodules
   · Bilateral disease may be treated either by staged bilateral thoracotomy or median sternotomy for a single operation

6. Results
   · Outcomes vary according to primary tumor type

<table>
<thead>
<tr>
<th>Tumor type</th>
<th>5-year survival</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soft tissue sarcoma</td>
<td>25%</td>
</tr>
<tr>
<td>Osteogenic sarcoma</td>
<td>20-40%</td>
</tr>
<tr>
<td>Colon/rectal carcinoma</td>
<td>8-37%</td>
</tr>
<tr>
<td>Renal cell carcinoma</td>
<td>13-50%</td>
</tr>
<tr>
<td>Breast carcinoma</td>
<td>14-49%</td>
</tr>
</tbody>
</table>
Head/neck carcinoma 40-50%
Melanoma 25%

7. Pancoast Tumor (Superior Sulcus Tumor)
- Primary lung cancer which arises from the apex of the lung
- Structures susceptible to invasion include pleura, brachial plexus, sympathetic chain, ribs, and vertebra
- The Pancoast syndrome, or superior sulcus tumor syndrome, is characterized by ipsilateral shoulder/arm pain
- Horner's syndrome (ipsilateral anhidrosis, ptosis, enophthalmus) develops with invasion of sympathetic nerves

8. Treatment of Pancoast Tumor
- Preoperative radiation therapy followed by operative resection 4 weeks later (Paulson protocol)
- Contraindications include extensive involvement of the brachial plexus, subclavian artery, or vertebrae; SVC or recurrent laryngeal nerve involvement; distant metastasis; and mediastinal node involvement (relative)

Selected Articles


Combined preoperative CT and VATS had a 56% failure rate in detecting all lesions. The authors conclude that VATS should only be used as a diagnostic tool and thoracotomy remains the procedure of choice to achieve complete resection.


This important article reports five-year survival of 37% for resection of a solitary metastasis and 30% after a second resection for recurrent metastasis. Multiple metastases and increased CEA levels portend a lower survival rate.


This series of 33 patients shows an increased survival for resection (36% vs 11%) over medical therapy. The authors suggest that resection be considered in patients without evidence of concomitant extrapulmonary disease.
Sources for further reading

Textbook Chapters

Benign Respiratory Tract Tumors

1. Respiratory Tract
   Tissue examination
   Most lesions are peripheral
   Radiographic features- major diagnostic aid
     Calcification
     "Popcorn" type
     Well defined margins
     Lobulated
     Growth (?)
     Wedge resection
     Frozen section

2. Epithelial tumors

   Mesodermal tumors
     Vascular tumors
     Bronchial tumors
   Neurogenic tumors
   Developmental or unknown origin tumors
   Inflammatory and other pseudo-tumors

3. Tumors of Epithelial origin

   Papilloma- 5 sib-classifications
     Solitary benign papilloma
     Multiple benign papillomas
     Combined bronchial mucous gland and surface papillary tumor
     In situ papillary bronchial carcinomas
     Bronchiolar papillomas
   Proximal
     Squamous, stalk
   Distal
     Clara cells
   One of few lesions that can be managed by bronchoscopic resection
   Recurrence is high
   Rare malignant transformation

4. Polyps

   Related to inflammatory polyps or URT
   Squamous metaplasia; ciliated columnar epithelium and granulation tissue
   Bronchoscopic removal
   Tumorlet
     Epithelial proliferation
Originates from Kulchitsky cells  
Multifocal: < 4 mm; associated with pulmonary fibrosis  
Form of peripheral carcinoid with rare metastases  

5. Tumors of Mesodermal Origin  

Hemangioma  
Subglottic area of larynx or upper trachea of infants  
Airway obstruction  
Dx: Bronchoscopy  
Other vascular lesions of skin, mucous membranes  
Tx: Radiation therapy  

Lymphangioma  
Upper airway obstruction in infancy  
Associated with other lesions- cystic hygroma, hemangioma in the neck  
Tx: surgical excision  

6. Endothelioma  

More solid  
Lymphatic or vascular origin  
Angiomatous formation- may ne found only in lung  
Most often described in newborns  
Lethal course over a short period or time  

Lymphangiomatosis  
Rare- may be related to tuberous sclerosis  
Slowly progressive- death within 10 years from pulmonary insufficiency  
Young females presenting with dyspnea  
Spontaneous PTX; chylothorax, hemoptysis  
CXR: fine, multinodular lesions in bases- honeycombing  

7. A-V Fistula  

Lower lobes  
Associated with hemorrhagic telangiectasia (Rendu-Osler-Weber Syndrome) in 50% of cases  
R > L shunting PA-PV  
Cyanosis  
Clubbing  
Polycythemia  
DOE  
Pulmonary murmur  
Brain abscess or peripheral embolization  
Dx: CXR.; pulmonary angiogram  
Tx: Surgical resection; angiographic embolization A-V Fistula
8. Sclerosing Hemangioma

- Uncommon; originates from Type II pneumocyte precursors
- Coin lesion, lower lobes
- Hemothysis
- Associated with hemorrhagic telangiectasia

Intravascular Bronchoalveolar Tumor

- Rare; females < 30 years old
- Originates from vascular endothelium
- CXR: multiple pulmonary nodules - incidentally discovered
- Mild dyspnea
- Stable, slowly growing metastases reported
- Tumor considered to be malignant

9. Hemangiopericytoma

- Solitary, encapsulated, asymptomatic
- Originates from pericytes associated with pulmonary capillaries
- Considered malignant
- Tx: Surgical resection for cure or radiation therapy for palliation

10. Fibroma

- Mostly tracheobronchial in origin
- Most common benign tumor of mesodermal origin in adult and pediatric age group
- Collagenous/spindle cells - myxomatous/adipose elements
- Tx: Bronchoscopic resection if stalk is present vs conservative pulmonary resection

11. Chondroma and Osteochondroma

- Arise in major bronchi
- May appear as true enchondrosis of bronchial cartilage
- Firm, translucent; ossified/calcified material
- Second most common mesodermal tumor
- Carney's triad: associated with extra-adrenal paragangliomas and gastric leiomyosarcomas

12. Lipoma

- Rare, intrabronchial lesion; male predominance
- Slowly growing, avascular, obstructive, pedunculated
- Tx: Bronchoscopic removal for small lesions; bronchotomy for larger ones
- Arise in fat cells
- Associated with bronchiectasis (chronic obstruction)

13. Leiomyoma
Fourth in order of frequency
Originates from smooth muscle cells
  Bronchiolar smooth muscle cells
  Pulmonary vessels
Sx: cough, hemoptysis, pneumonia, bronchiectasis
50% intrabronchial- 50% peripheral
Can be associated with similar cutaneous lesions
Tx: Conservative surgical approach
Malignant variant: Leiomyosarcoma

14. Order of Frequency of Mesodermal Tumors

Fibroma
Chondroma
Lipoma
Leiomyoma

15. Granular Cell Tumors (Myoblastoma)

Previously thought to originate from myoblasts
Originates from Schwann cells or histiocytes
Arises from the tongue or skin
6% originate endobronchially
Tx: Surgical removal with wide margins
  Bronchoscopic removal associated with recurrence < 8 mm

16. Developmental or Unknown Origin

Hamartomas
Most common benign tumor of the lung
8% of coin-shaped lesions
0.25% of general population
CXR: "Popcorn" lesion
Malignant transformation- rare
True neoplasm
Malignant transformation of the epithelial component
  Chondromatous hamartoma
  Adenomatous hamartoma of infancy
  Pulmonary blastoma

17. Teratoma

Rare: 50% are benign
Characteristics of all germ layers
Must be differentiated from metastatic lesion
Testicle
Direct invasion from mediastinum

18. Chemodectoma

One reported case
Arise from chemoreceptor cells in the lung

19. Clear Cell (sugar) Tumor

Resembles hypernephroma
Abundant glycogen content
Characteristics of Type II glycogen storage disease

20. Thymoma

Ectopic thymus tissue (rare)
Intrapulmonary thymoma may be associated with Myasthenia Gravis

21. Inflammatory and Other Pseudotumors

Plasma Cell Granulomas (Histiocytoma)
  Solitary pulmonary nodule
  May be associated with: systemic disease, plasma protein imbalance, NS local
  inflammatory reaction
  Micro: Plasma cells and lymphocytes
  Local exclusion/ lobotomy- cure
  May be associated with multiple myeloma or other malignancies
  Do not confuse with plasmacytoma- a malignant lesion

22. Pseudolymphoma

Discrete localization
Unilateral
Resembles lymphoid interstitial pneumonitis
Rare conversion to malignant lymphoma
Tx: Lobectomy/ segmental resection with follow-up

23. Xanthoma

Post-inflammatory lesion- encapsulated
Micro: foam cells
Conservative resection
No reports of recurrence
24. Amyloid
Deposition may be diffuse or localized
Occasionally may be obstructive
Tx: Bronchoscopic removal/ resection

25. Tracheobronchopathia Osteoplastica
Multiple cartilaginous/ osseous projections into lower tracheal lumen
Usually found at autopsy
Rarely obstructive
Tx: Bronchoscopic removal/ tracheal resection

Bronchial Adenomas

26. Most are not benign adenomas but are malignant neoplasms

Long natural histories
5% of all primary pulmonary neoplasms
Two groups
- Carcinoid tumors
- Bronchial mucous gland tumors

27. Classification

Carcinoid tumors
- Typical
- Atypical
Bronchial gland tumors
- Adenoid cystic carcinoma (Clindroma)
- Mucoepidermoid carcinoma
- Bronchial gland adenoma

28. Carcinoid Tumors

85-90% or bronchial adenomas
Neuroendocrine tumor from Kulchitsky's cells (argentaffin)
APUD tumor
Mostly in lobar bronchi (70%); others quote higher incidence in periphery or lung
More frequent on right and in lower lobes
"Mulberry" lesion
Small cell uniform tumor cells in a vascular stroma
Atypical carcinoid 10-15%
- Pleomorphism
- Nuclear irregularity
- Increased mitotic activity
29. Atypical carcinoid

More active biologic behavior
50-60% lymph node metastases (5-10% with typical carcinoids)
10% distant metastases
Poorer prognosis
Most patients - 5th to 6th decade; slight female predominance
25-30% asymptomatic- present with abnormal CXR
Sx: Cough, hemoptysis, recurrent pneumonitis
   Carcinoid syndrome- 1-2%; usually associated with metastases
   Cushing's syndrome; hyperinsulism
60-80% seen bronchoscopically: Biopsy (?)

30. Treatment

Resection: lobectomy, pneumonectomy
Resect recurrent and metastatic disease
Bronchoscopic resection- high rate of recurrence
Ten year disease-free interval
   Typical carcinoids- 85-90%
   Atypical carcinoids or typical carcinoids with lymph node metastases- 50%

31. Bronchial Gland Tumors

Adenoid Cystic Carcinoma (Cylindroma)
   Occurs in trachea
   30% lymph node metastases
   Submucosal and perineural lymphatic spread
   Sx: cough, hemoptysis, wheezing, obstructive pneumonitis in 6th decade
   Tx: wide surgical excision with lymph node dissection- RT palliative
   50% long-term survival with wide surgical resection

32. Mucoepidermoid Carcinoma

Epidermoid and mucous producing elements
Behavioral correlates with microscopic appearance
Tx: Complete resection
Prognosis
   Low-grade: good with adequate resection
   High-grade: poor despite therapy
Rare; mainly in lobar/ mainstream bronchi

33. Mixed Tumors

Rare; similar to salivary gland tumors
Require tracheal reconstruction
Bronchial Mucous Gland Adenomas
    Rare; benign; conservative resection

**Extended Outline**

**Benign Tumors of the Lung**

1. 5% of all tumors of the tracheobronchial tree
2. most are within lung parenchyma
3. usually asymptomatic unless associated with bronchial obstruction
   **Classification of benign tumors of the lung and tracheobronchial tree (see chart)**

**Clinical features**

1. mode of presentation depends on location and size
2. most are peripheral and found on routine CXR
3. chronic cough and chest pain are most frequent symptoms (40%)
4. central lesions are more likely to be symptomatic
5. diagnosis
   a. CXR, CT scan
   b. bronchoscopy for central lesions
   c. peripheral lesions- needle biopsy, thoracoscopy, open biopsy
   d. conservative resection is indicated unless there is a surrounding destructive process

**Tumors of epithelial origin**

**Papillomas of the tracheobronchial tree**

1. most common laryngeal tumor in children
2. rare in adults
3. single or multiple lesions
4. subclasses
   a. solitary benign
   b. multiple benign
   c. benign combined with bronchial mucous gland and surface papillary tumors
   d. papillary bronchial CIS
   e. bronchial papillomas
5. Approximately 50% of solitary bronchial papillomas are associated w/ lung carcinoma

**Tumors of Mesodermal Origin**

**Hemangioma**
1. infrequent in lung, more common in trachea and mainstem bronchi
2. multiple one third of cases
3. 60% of cases are associated with generalized hereditary telangiectasia (Oler-Rendu-Weber disease)
4. surgical treatment is conservative resection, YAG laser for endobronchial lesions

**Lymphangioma**

**Hemangioendothelioma**

**Hemangiopericytoma**

1. may arise anywhere in the body
2. lesions are large and 50% malignant
3. originate from capillary endothelium
4. centrally located, highly vascular
5. treatment is conservative surgical resection unless malignant

**Pulmonary Lymphangiomyomatosis**

1. extensive hamartomas involving smooth muscle of the lungs, lymphatics, hilar, abdominal and lower cervical lymph nodes
2. progressive disorder of childbearing age females with diffuse interstitial proliferation of smooth muscle in the lungs, lymph nodes and thoracic duct
3. lesions can produce SOB, emphysema, pneumothoraces, pulmonary hemorrhage with hemoptysis and chylothorax
4. treatment is conservative surgical resection

**Bronchial Tumors**

**Fibroma**

1. extremely rare
2. may arise from the peripheral parenchyma of the lung of from the walls of the trachea and bronchi
3. treatment is bronchoscopic removal or YAG laser therapy

**Chondroma and Osteochondroma**

**Lipoma**

1. least common benign tumors of the lung
2. may occur endobronchially or in parenchyma
3. 90% are in middle aged males
4. Typically present as solitary nodules
Granular Cell Myoblastoma

1. arise in tongue, skin, subcutaneous breast tissue and occasionally in the lungs
2. occurs in larger bronchi producing obstructive symptoms
3. high recurrence rate if not completely excised

Leiomyoma

1. primary neoplasm of muscular origin
2. sheets of smooth muscle cells predominate
3. rare

Tumors of Developmental or Unknown Origin Hamartoma

1. most common benign tumor of the lung- 75% of all benign tumors
2. constitute 80% of all coin lesions
3. derived from embryological remnants
4. 90% are located in the periphery
5. most commonly in subpleural position
6. conservative resection treatment of choice

Pulmonary Teratoma

Chemodectoma

Inflammatory and other Pseudotumors of the Lung

Plasma cell Granuloma (Histiocytoma)

1. usually in younger patients
2. composed of plasma cells, lymphocytes and fibrous tissue
3. conservative surgical resection

Pseudolymphomas of the Lung

1. Presents as a solitary nodule that can mimic bronchogenic carcinoma
2. composed of lymphoid cells including mature lymphocytes and plasma cells
3. diagnostic feature is the presence of germinal centers
4. may lead to malignant lymphoma
5. long term follow up required

Amyloid Tumors

1. may be localized in bronchus or multiple or diffuse bronchial deposits
2. can be a diffuse or localized parenchymal process
3. disease may eventually prove fatal
4. tumors are shelled out readily from surrounding parenchyma

**Benign Pulmonary Disease**

**Interstitial Lung Disease**

A. Classifications:
1. Acute vs. chronic
2. Acinar vs. interstitial

B. Acute, Diffuse, Benign Pulmonary Disease
1. Acute infectious pneumonias
2. ARDS
3. Acute cardiogenic pulmonary edema
4. Vasculitic-immunologic syndrome

C. Chronic Diffuse Benign Pulmonary Disease
1. Sarcoidosis
2. Hypersensitivity pneumonitis (organic ducts)
3. Pneumoconiosis
4. Connective tissue diseases
5. Lung Irradiation
6. Drug-induced toxicity
7. Eosinophilic granuloma
8. Congenital (neurofibromatosis, tubular sclerosis)
9. Carcinoma with lymphatic spread
10. CHF

D. Interstitial Pneumonias
1. Affects the supportive structure of the alveolar walls and terminal airways
2. Symptoms: chronic dyspnea and nonproductive cough
3. PFT's: Restrictive disease, decreased DLCO, decreased compliance
4. Sarcoidosis is most common cause of interstitial pneumonia

E. Nomenclature:
1. UIP (Usual Interstitial Pneumonia)
   a. thickened alveolar wall with fibrosis and an inflammatory exudate
2. DIP (Desquamative Interstitial Pneumonia)
   a. large # of macrophages in the alveoli
   b. very responsive to steroids because underlying lung architecture is intact
3. LIP (Lymphocytic Interstitial Pneumonia)
   a. Lymphocytes accumulate around the bronchioles and blood vessels
   b. may have a monoclonal gammopathy which may be detectable via serum electrophoresis
   c. unpredictable response to steroids
d. may go unto lymphoma of the lung  
e. other causes  lymphocytic infiltrate AIDS, sarcoidosis, Sjogren's  
4. GIP (Giant Cell Interstitial Pneumonia)  
a. look for exposure to organic dust oral pneumonias  
b. viral pneumonias  
5. BO (Bronchiolitis Obliterans)  
a. variety of insults  
b. unresponsiveness to steroids  
c. associated with rheumatoid arthritis and connective tissue disorders  
6. BOOP (Bronchiolitis Obliterans Organizing Pneumonia)  
a. plugs of fibrous tissue (Masson bodies)  
b. many associations but, most are idiopathic  
c. responsive to steroids  

F. Hypersensitivity Pneumonitides  
1. increase in T lymphocyte CD-8 (suppressor cell) in the lung secondary to inhalation of organic antigens  
2. Biopsy: noncaseating granulomas typically around terminal bronchioles with a mixed inflammatory infiltrate  

G. Inorganic Pneumoconiosis  
a. inhalation of nonorganic dusts and fibers  
b. three most common:  
1) silicone  
2) coal dust  
3) Asbestos  
c. Asbestosis  
1) characteristic pleural plaques in the chest wall and diaphragm on CXR  
2) increases the risk of malignant mesothelioma  
3) lung carcinoma increased synergistically with asbestos and tobacco  
4) affects lower lobes/ pleural thickening  
5) Biopsy: ferruginous bodies  
6) long delay between exposure and onset of disease  

H. Connective Tissue Diseases  
a. almost all connective tissue disorders have a pulmonary component  
b. Biopsy: does not aid in differentiating between diseases  

I. Pulmonary Drug Toxicity  
a. Abx: Bleomycin, sulfa  
b. Alkylating Agents: Cyclophosphamide, Melophan  
c. Immunosuppressive: Immuran, Methotrexate  
d. Antiarrhythmic: Procainamide, Amiodarone (foamy cells)  
e. Diuretic: HCTZ  
f. Antihypertensive: Hydralazine  
g. Opiates: Methadone, Heroin, Propoxyphene
J. Chronic Eosinophilic Pneumonia
   a. elements of interstitial & acinar infiltrates
   b. steroid response in the early phase
   c. diagnosis by blood Cx and biopsy with eosinopiles
   d. Biopsy Charcot Leyden crystals

K. Pulmonary Vasculitides & Granulomas
   a. rule out infection before beginning steroids

L. Idiopathic
   a. 20-30% of interstitial lung disease
   b. Sx: dyspnea, cough, clubbing and arthralgias
   c. Bx: collagen deposition with inflammatory responsive
   d. 4-5 yr. survival
   e. DIP pattern has a better response time
Esophageal Diseases

Esophageal Diagnostic Procedures
Molecular Pathology
1. Definition
There are several procedures utilized for the diagnosis of esophageal disease, and the approach must be tailored to the specific disease entity. Contrast swallow and esophagoscopy are commonly used for most patients with esophageal disorders, with CT scanning, endoscopic ultrasound, and reflux testing reserved for more specific indications.

2. Esophagoscopy
A. Indications
· Dysphagia, odynophagia, regurgitation, hematemesis, chest pain, foreign body ingestion, or history of traumatic esophageal tear
· Should usually be preceded by contrast swallow/cineesophagogram to help localize the site of disease
· Contraindications include aortic aneurysm (can rupture), recurrent nerve paralysis, esophageal diverticulum (can perforate blindly), corrosive strictures (can perforate - stop when you see the stricture), and kyphoscoliosis (may be impossible)
· Use rigid technique when Zenker's diverticulum or disease of the upper third is suspected, as flexible esophagoscopy is done blindly and can perforate in these areas

B. Technique - Rigid Esophagoscopy
· Topical or general anesthesia may be used; general anesthesia generally provides better relaxation, lowering the risk of perforation
· The 9mm scope is adequate for most adult patients
· The patient is positioned supine with head and shoulders over the end of the table
· Introduce the esophagoscope into the right side of the mouth and rest the shaft on your left thumb
· The scope is advanced behind the right arytenoid cartilage into the right pyriform fossa
· Lower the patient's head as the scope is advanced past the cricopharyngeus
· Lower the head further and move to the right to pass through the gastroesophageal junction
· Full examination is done on withdrawal, as folds of mucosa may hide pathology during advancement of the scope

C. Technique - Flexible Esophagoscopy
· Topical anesthesia with sedation is usually adequate
· The patient is placed in the left lateral position
· The esophagoscope is introduced blindly with gentle pressure as the patient swallows
· Insufflation of air distends the esophagus for complete visualization
D. Complications
· Perforation occurs in 0.1-0.25% of patients
· Most commonly occurs posteriorly at the upper opening of the esophagus when forceful pressure is applied against the cricopharyngeus
· Other sites include the diaphragmatic hiatus and diverticuli
· Perforation can also occur after deep biopsy, forceful dilation of strictures, or during removal of foreign bodies
· Chest pain after esophagoscopy is an indication of perforation and should be promptly evaluated

E. Findings in Disease

<table>
<thead>
<tr>
<th>Reflux Esophagitis</th>
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<tr>
<td><strong>Stage I</strong></td>
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<td><strong>Stage II</strong></td>
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<td><strong>Stage III</strong></td>
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<td><strong>Stage IV</strong></td>
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· Barrett's esophagus: stratified squamous epithelium replaced by columnar epithelium and may become discrete ulcer; biopsy should be performed to look for malignancy
· Stenosis: congenital stenoses usually have normal mucosa; acquired stenoses are usually associated with esophagitis or ulcers
· Corrosive esophagitis: acute inspection shows edematous, friable walls which are easily perforated; stop at first area of injury
· Diverticulum: exclude ulcers and neoplasms at the site of the diverticulum
· Varices: range from small bluish elevations to large dilated veins at the lower end of the esophagus--commonly found in cirrhotics
· Hiatal hernia: redundant folds in the lower esophagus and lack of diaphragmatic support are characteristic only in true hiatal hernia
· Achalasia: markedly dilated, inflamed esophagus with thickened walls; GE junction has normal tone but may be hard to negotiate
· Carcinoma: typically large fungating mass that bleeds easily, less commonly a smooth stenosis with edematous mucosa. Microinvasive carcinoma presents as slight discolorations of the mucosa, known as leukoplakia or erythroplakia.
· Benign neoplasms: leiomyomas, fibromas, and lipomas are all covered with normal mucosa

3. Endoscopic Ultrasound
· Particularly applicable in defining tumors and varices
· May become useful in staging of esophageal cancer
5 layers are identified: mucosa, deep mucosa, submucosa, muscularis, and adventitia
- Extension of tumors into periesophageal structures and lymph nodes can be evaluated
- Carcinomas appear as indistinct, echo-poor lesions; varices appear as round, echo-poor lesions

4. Gastroesophageal Reflux Evaluation

*Note:* Radiographic tests for GE reflux are not highly reliable for pathologic reflux, as up to 25% of patients will have reflux without associated pathology. Such tests can rule out patients with no reflux, however.

A. Manometry
- Intraluminal pressures are measured using a continuous infusion catheter system while the patient is lying supine
- This catheter is withdrawn at 1-cm intervals to obtain resting pressures
- The catheter is reinserted, and pressures measured after swallowing at 1-cm intervals
- This test is essential in delineating the various esophageal motility disorders

B. pH Reflux Test
- A pH probe is placed 5 cm above the GE junction
- 200 to 300 ml of 0.1N HCl is instilled in the stomach
- A fall in pH below 4.0 during various maneuvers indicates GE reflux

C. Acid Perfusion Test
- The distal esophagus is perfused in an alternating fashion with 0.1N HCl and saline
- The test is positive if atypical chest pain occurs during acid perfusion and resolves during saline perfusion
- High rates of false positivity and false negativity make the test somewhat unreliable

D. 24-hour pH Monitoring
- a pH probe is placed 5cm above the GE junction
- The patient records any symptoms and pH changes are monitored constantly over 24 hours
- Analysis includes percentage of time pH was less than 4.0, and percentage of time patient was upright and supine
- The number of reflux episodes, the duration of the episodes, and the longest episode of reflux are also evaluated
- This test gives the most objective evidence of reflux

5. Therapeutic Esophagoscopy

A. Removal of Foreign Bodies
- Rigid esophagoscope is best
- Most common sites are just below the cricopharyngeus and at the diaphragm
- Sharp objects carry the highest risk of perforation

B. Dilation of Strictures
- Savary-Gilliard dilators are the safest
- A metal guidewire is passed through the stricture using the esophagoscope
· The stricture is then dilated using progressively larger dilators passed over the guidewire
· Retrograde dilation may also be done using Tucker dilators over a string passed through a gastrostomy and out the mouth

C. Corrosive Esophagitis
· Esophagoscopy should be performed to confirm the burn, but do not pass the injured area
· Dilation can be performed after burn have healed (usually 3-4 weeks) if strictures have formed

D. Carcinoma
· Palliative dilation usually is only temporary, and should be followed with either laser resection or stenting
· The Nd:YAG laser can be used from above or below to core a passage through tumor and permit swallowing
· Brachytherapy can be applied after endoscopic dilation for inoperable carcinoma

E. Achalasia
· Dilation can be performed of the GE junction if surgical myotomy is contraindicated
· Perforation, however, is a definite risk and can present as either chest or abdominal pain

F. Variceal bleeding
· Electrocautery and laser therapy of bleeding varices do not prevent rebleeding
· Sclerotherapy is probably best and obliterates current varices; however, rebleeding occurs in 40% of patients

6. Radiographic Examples

A. Schatzki's ring

B. Achalasia

C. Diffuse Esophageal Spasm

D. Leiomyoma

E. Carcinoma

Selected Articles

This series of 82 patients shows that dilatation of benign strictures produces better results than in malignant strictures, although it is useful to facilitate biopsy.


Several articles in this supplement cover areas such as sclerotherapy, laser photocoagulation, and electrocoagulation. Most are brief review articles.


A brief article which has representative case presentations to illustrate this difficult complication.


The author covers proper technique, potential difficulties and complications. Other articles in this supplement specifically address particular disease profiles on endosonography.

Sources for further reading

Textbook Chapters


Congenital Esophageal Disease
1. Congenital esophageal stenosis
Esophageal web: middle 1/3, complete or incomplete, dilatation
Intraluminal cartilaginous rest: tracheobronchial origin, local resection with primary
repair
Segmental hypertrophy: mucosa and submucosa, residual web
Laryngotracheoesophageal cleft
  Varying degrees of communication between larynx-trachea and esophagus
  High incidence of GER
  10 - 40% mortality

2. Esophageal atresia +/- TEF

Most common congenital esophageal anomaly
Salivary regurgitation, abdominal bloating, pneumonia
Dx: cannot pass NG tube, radiologic confirmation
Mortality related mostly to other congenital lesions

Esophageal Anomalities
3. Esophageal atresia +/- TEF: types

Atresia with distal TEF: 87%
Atresia without TEF: 8%
TEF without atresia (H type): 4%
Atresia with proximal TEF: 0.8%
Atresia with prox/distal TEF: 0.7%

4. Waterston Classification (pneumonia increases one level)

<table>
<thead>
<tr>
<th>Congenital Esophageal Atresia</th>
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Esophageal Injuries

ESOPHAGUS - CAUSTIC BURNS
Acid or alkaline injury
Accidental - children < 5 yrs, household cleaners
Intentional - adults with psych disorders, suicide attempts
Severity related to strength / duration of exposure (prox < distal)
Laryngeal edema - respiratory distress

6. Phases

Inflammation, edema, necrosis - initial few days
Ulceration, sloughing, granulation - 3 - 4 weeks
Cicatrization, scar formation - weeks - months
Long-term
  Recurrent strictures
  Respond to dilatation
Pre-cancerous: may develop up to 40 yrs later
  Increased cancer risk 1000 fold (debated)

7. Treatment

Appropriate dilution, no emesis
Fluids, antibiotics, (steroids controversial)
Fiberoptic laryngoscopy / intubation
Esophagoscopy - 48 hours, stop at first evidence of burn
Barium swallow 3 - 4 weeks, intermittently thereafter
Later dilatation for strictures
Surgery usually not necessary early
Sepsis / full-thickness necrosis: cervical esophagostomy, gastrostomy with isolation, later reconstruction, (resection controversial)

8. ESOPHAGUS - STRICTURES

Causes
  Malignancy
  Peptic stricture - at GE junction
  Mid-esophageal stricture - usually related to Barrett's esophagus
  Caustic stricture
  Schatzki's ring - submucosal fibrous band at squamocolumnar junction
  Post-operative/anastomotic
  Congenital
  Motility disorders, vascular rings

9. Evaluation and Therapy

If cause not obviously apparent, malignancy must be ruled out
Barium swallow
Esophagoscopy, brushings, biopsy
If peptic: anti-reflex therapy
If benign: dilatation - up to 50 Fr
If mucosa / bx normal: external compression, motility disorder, submucosal lesions

10. Bougienage

Usually successful for benign strictures
Safest with rigid esophagoscopy, general anesthesia (rarely practiced)
May worsen gastroesophageal reflux
Retrograde via G-tube (children)
Other methods: fluoroscopic bougienage, pneumatic dilatation, stents
For tight stricture, wire-guided Savory dilators
11. Surgical Considerations

Tight strictures, severe scarring, repeated dilatations increase risk of perforation
Consider surgery, particularly in young patient
Anti-reflux procedure (peptic stricture)
High stricture - intra-op dilatation + anti-reflux procedure
Consider motility disorder, pre-op motility studies

12. Esophageal lengthening procedure (Collis-Nissen) for shortened, scarred esophagus

For extensive scarring, multiple or long strictures, Barrett's with dysplasia
Consider esophageal replacement
Gastric pull-up (intrathoracic anastomosis assoc. with recurrent reflux)
Colon interposition
Jejunal interposition

EXTENDED OUTLINE

Congenital Esophageal Abnormalities

Esophageal Atresia
1. embryology
   a. esophagus first appears at four weeks gestation
   b. esophageal atresia results from incomplete separation of the laryngotracheal groove between the third and sixth weeks of gestation
2. common forms of esophageal atresia
3. esophageal atresia with fistula occurs in ~1/8000 births
4. incidence of associated anomalies is about 50%
   c. cardiac defects are important to identify preoperatively
   d. VATER association is common- three or more of the following: vertebral defects, anal atresia, tracheoesophageal atresia and radial and renal dysplasia
   e. CHARGE association: choanal atresia, heart anomalies, esophageal atresia and GI tract anomalies

Esophageal Atresia With Tracheoesophageal Fistula

Signs and Symptoms
1. related to esophageal obstruction and respiratory complications resulting from reflux
2. infants have copious salivary secretions and tend to choke during feeds
3. gastroesophageal reflux causes aspiration pneumonia and respiratory distress
4. air is eventually forced through the TEF and creates abdominal distension

Diagnosis
1. some are diagnosed on prenatal ultrasound
2. most are diagnosed after birth
3. if suspected then a rigid nasogastric tube should be placed and a CXR should be obtained which will demonstrate blind esophageal pouch
4. can also use water soluble contrast to study pouch to delineate the anatomy
5. if a right aortic arch is suspected, then echocardiography should be performed

**Treatment- Preoperative Management**

1. place baby in the semisitting position
2. place sump tube for control of saliva or use frequent suctioning
3. resuscitate in the ICU, correct electrolyte and acid base status
4. antibiotics are given
5. mechanical ventilation if required
   a. in patients with increased pulmonary resistance, high frequency ventilation with low mean airway pressure may be more effective than conventional ventilation
   b. lower mean airway pressures should help control abdominal distension

**Surgical Treatment**

1. surgical approach and timing of surgery depend upon the size of the infant and condition
2. primary repair is preferable for almost all infants unless weight is less than 1500 g or they have associated severe respiratory distress syndrome for which delayed primary or staged repair should be completed 1-8 weeks after birth
3. some infants may be delayed secondary to critical congenital cardiac disease
4. most patients do not require gastrostomy before thoracotomy unless a staged procedure is planned
5. in patients that require high ventilatory airway pressures, a gastrostomy may become a source of an air leak exacerbating respiratory status
6. if the infant has an associated doudenal atresia or imperforate anus, these defects are corrected first then the esophageal fistula (author had no deaths in 24 patients with this sequence)
7. approach:
   a. right thoracotomy- standard approach
   b. left thoracotomy- when there is a right aortic arch
   c. can be extrapleural or transpleural
   d. division of azygous vein and identification of vagus nerve will facilitate locating fistula
   e. fistula is closed utilizing running suture
   f. esophagus is reapproximated with either a single or double layer anastomosis
   g. the esophagus can be elongated with circular or longitudinal myotomies, but a staged procedure may be required if enough length cannot be attained

**Complications**

1. most common complications are pneumonia and atelectasis
2. anastomotic leak
3. anastomotic strictures
   a. occur most commonly after leak has occurred
   b. most can be dilated
4. gastroesophageal reflux
   d. may be associated with laryngospasm and apnea spells
   e. 10-50% patients require Nissen fundiplication

Results

1. risk classification by Waterston
   group A- birth wt > 2.5 kg in good medical condition
   group B- birth wt 1.8-2. Kg with mild pneumonia or an associated congenital anomaly
   group C- birth wt < 1.8 kg or higher with severe pneumonia or life threatening anomaly
2. in author’s experience with 100 patients there was no mortality with group A or B patients and a 15% early mortality in group C patients
   a. overall early mortality was 4.6%
   b. late mortality was 10% over 10 year period

Isolated Esophageal Atresia

Signs and Symptoms

1. similar presentation with those with a tracheoesophageal fistula
2. most weigh less than 2.5 kg
3. almost all have associated maternal polyhydramnios
4. scaphoid, gasless abdomen

Surgical Treatment

1. lower esophageal segment is usually short
2. primary repair is not feasible
3. gastrostomy should be performed
4. daily lengthening of the upper esophageal pouch is completed with an orogastric tube
5. after 6 weeks to 3 months repair is attempted
6. it is usually necessary to perform myotomy to gain length

Esophageal Replacement

1. if esophageal replacement is necessary, then a gastrostomy and cervical esphagogastomy should be performed
2. these patients are then treated until the age of 1 year or more with G-tube feeds
3. techniques:
   a. jejunal interposition is no longer used
b. colonic inerposition with right or left colon  
   i. substernal  
   ii. intrathoracic  
   a. gastric transposition  

3. Complications  
   a. most common complication of colonic replacement is leak  
   b. most serious complication is gangrene due to congestion  
   c. peptic ulceration of the cologastrostomy can occur  

**Results**  

1. 30 patients operated on without mortality  
2. 12 patients received esophageal lengthening, myotomy and delayed primary anastomosis with stricture formation in 10 patients (9/10 dilated successfully) H-Type Fistula  

**Signs and Symptoms**  

1. have symptoms of aspiration  
2. may present later in life up to 1-2 years of age  
3. have difficulty with thin feeds  

**Diagnosis**  

1. some advocate use of contrast studies to demonstrate fistula  
2. author utilizes endoscopy to make diagnosis  
3. bronchoscopy may also demonstrate fistula  
4. most fistulae are located low in the neck and rarely in the thorax  

**Treatment/Results**  

1. performed electively  
2. preliminary gastrostomy not required  
3. fistula can usually be approached via a neck incision unless it is thoracic  
4. preoperative placement of a fogarty catheter may facilitate identification  
5. esophagus is dissected from the posterior trachea and the fistula closed with two layered closure and paraspinous muscle interposition  
6. recurrent laryngeal nerve may occur  
7. no mortality in 24 patients, one leak  

**Esophageal Stenosis**  

1. usually acquired but can be congenital  
2. stenosis presents as a web or diaphragm amenable to dilation  
3. if associated with cartilaginous tracheobronchial remnants, resection is required
4. may have associated anomalies such as esophageal atresia or anorectal malformations
5. most webs occur in the upper and middle esophagus; those associated with esophageal atresia tend to be located in the lower esophagus

**Esophageal Duplications**

1. generally lie in the posterior mediastinum
2. usually asymptomatic, found on CXR
3. approximately 30% of mediastinal masses in children are of foregut origin
4. usually do not communicate with the lumen of the esophagus

**Diagnosis**

1. barium esophagram may reveal filling defect
2. CT scan is procedure of choice
3. USG of abdomen to rule out associated abdominal duplications

**Treatment/Results**

1. preferred approach is complete resection
2. may be necessary to divide diaphragm or make separate abdominal incision to resect associated abdominal duplication cyst
3. no long-term sequela encountered, no deaths or serious complications

**Esophageal Diverticula**

1. extremely rare
2. have complete muscular wall (unlike Zenker’s)
3. risk of aspiration
4. resection is treatment of choice

**Gastroesophageal Reflux**

1. in patients with intact esophagus and no other esophageal anomaly, the most likely cause of GER is failure of maturation of the LES
2. the LES is usually competent by 6-7 weeks of life
3. most common presenting symptoms are frequent regurgitation, upper GI tract bleeding, apneic spells, and chronic intermittent pneumonia
4. if symptoms persist for > 6 months then surgical intervention is recommended
5. diagnosis can be made by 24 hour pH monitoring, upper GI swallow and endoscopy
6. most patients respond to medical therapy- H2 blockade, bethanechol, reglan
7. Nissen fundiplication is procedure of choice

**Achalasia**
1. uncommon in childhood
2. diagnosed with barium swallow and esophageal manometry
3. trial of pneumatic dilatation is recommended first then surgical therapy if recurrence occurs rapidly (90% success rate is author’s experience)
4. cricopharyngeal achalasia may also occur in children which requires myotomy via cervical approach

**Selected Articles**


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**Sources for further reading**

**Textbook Chapters**


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**Esophageal Motility Disorders**

1. Embryology
Muscular epithelial-lined tube
Derived from primitive foregut
Second week of embryologic development
Mesoderm forms and separates ectoderm from endoderm--provides material necessary for
connective tissue, muscular coats, serous coverings

2. Histology and Final Development

Adventitia: outer loose connective tissue containing nerves, lymphatics, blood vessels
Muscularis: two layers of muscle--outer longitudinal and an inner circular
Submucosa: connects muscularis with the mucosa--strongest layer--elastic tissue;
collagenous fibers; network of vessels & nerves
Mucosa: squamous, columnar; Z-line

3. Vascularity

Arterial: 3 sources
1. Inferior and superior thyroid arteries: cervical esophagus
2. Tracheobronchial, aortic arch and esophageal branches:
   body of esophagus
3. Left gastric and splenic arteries: GEJ
Veins: drainage pattern similar to lymphatics
Submucosal plexus--communicating veins--
perforating veins that pierce the muscularis
Eventually drain into inferior thyroid, azygous, hemiazygous,
left gastric, splenic, left gastroepiploic systems

4. Lymphatics:

Submucosal lymphatics form long channels that run parallel to esophageal axis
May travel long distances before draining into regional nodes

5. Innervation

Nerves: extraesophageal
Sympathetic: cervical, thoracic chains; celiac plexus and ganglia
Parasympathetic: vagus nerve muscular plexus around the circular layer of the muscularis
(Auerbach's plexus)
Submucosal plexus (Meissner's plexus)
Auerbach's and Meissner's plexus are interconnected and are responsible for the fine-
control mechanism of esophageal function

6. Nerves: central

Nucleus ambiguous
Dorsal motor nucleus of Vagus through the myenteric plexus
Both work together on the longitudinal and circular muscles to propel a bolus—peristalsis

7. Peristalsis

Primary: normal propulsive wave in response to the stimulation of normal voluntary deglutition
Secondary: normal wave without voluntary deglutition: best defense
Tertiary: abnormal; may occur spontaneously or following deglutition

8. Normal function

Upper Esophageal Sphincter (UES)
Level of cricoid cartilage C 5-6
Composed of cricopharyngeus and inferior pharyngeal constrictors
Remains contracted between swallows due to continuous stimulation by IX and XI
Resting tone: 45 - 65 mmHg (range 32 -101 mmHg)
Swallow: inhibition of all motor nerve stimulation; UES opens; closes; rebound; baseline pressures

9. Esophageal Body

Proximal striated muscle: direct innervation to its motor end plate from nucleus ambiguous
Smooth muscle: indirect neural input from dorsal motor nucleus (X) via myenteric plexus
Innervation: longitudinal muscle shortens; circular muscle contracts; peristalsis
Duration and amplitude: weaker in proximal esophagus; stronger, longer in distal esophagus

10. Lower esophageal sphincter (LES)

Specialized muscle arrangement 3 - 4 cm above gastroesophageal junction (GEJ)
High pressure zone with resting tone 15 - 25 mmHg (24.8 mmHg)
Influenced by neural and hormonal factors; drugs
Relaxes at time of swallowing; closes with passage of contraction through sphincter
Manometry

11. Diagnostic Techniques

Radiology
Endoscopy
   Reflux Disease
   Esophageal Malignancies
   Esophageal Biopsies
Motility Studies
24 Hour pH Monitoring
Acid Perfusion Tests (Bernstein's Test)
Radionuclide Emptying Studies

12. Oropharyngeal Dysphagia

Neurologic: central vs peripheral
Myogenic
Cricopharyngeal Muscle Dysfunction
Iatrogenic
Lower esophageal disease

13. Idiopathic Motor Disorders

Hypomotility Disorders
Achalasia
Hypermotility Disorders
Diffuse Esophageal Spasm
Hyperperistalsis (Nutcracker; Supersqueeze)
Hypertensive LES
Nonspecific Esophageal Motility Disorders

14. Achalasia

Young adults -- 1 in 100,000 -- Cause unknown
Loss of control at the postganglionic, nonadrenergic and noncholinergic inhibitory nerves
-- LES dysfunction and esophageal body changes
? denervation; Chagas' Disease
Compounded by physical & psychologic stress
LES: normal or increased resting pressure
Incomplete or absent relaxation

15. Symptoms: dysphagia; odynophagia; regurgitation; aspiration and its complications; made worse by cold liquids and stressful situations

Squamous cell carcinoma 1-10%
Peristalsis absent in esophageal body; high resting pressure
Contractions weak at all recording levels
Esophageal dilatation; megaesophagus
Barium swallow: "bird's beak" esophagus

16. CXR: widened mediastinum; air-fluid level in posterior mediastinum; absence of gastric bubble

Endoscopy: changes vary with stage
Normal
Food/fluid retention in fasting state  
Thickened mucosa with wide folds  
Hyperemia: stasis esophagitis  
Achalasia Upper GI  
Achalasia Manometry

17. Treatment

Medication: calcium channel blockers--decrease LES resting pressures--improves symptoms, not emptying  
Early disease with minimal symptoms
Dilatation: stretches/ruptures fibers of the LES  
Lowers LES resting pressure; improves emptying  
Good to excellent short term results in 65% of patients  
Esophageal rupture seen in 4%  
Reflux seen in 7 - 17%

18. Esophageal myotomy: improves obstructive symptoms more effectively than dilatation

Can be done via left thoracotomy, laparotomy, or scope  
5 - 7 cm myotomy on distal esophagus  
Extends 1 cm onto gastric wall  
Mucosa dissected from muscularis  
90% relief of dysphagia short and long term  
? concomitant antireflux procedure: partial fundoplication

19. Diffuse Esophageal Spasm

Rare--cause is unknown; muscle hypertrophy; degenerative changes in Vagus branches  
Symptoms: odynophagia, dysphagia, unexplained chest pain  
Anxious individuals  
Symptoms worsened by stress  
Must differentiate from CAD

20. Simultaneous segmental contractions on x-ray

Corkscrew / rosary bead esophagus  
Diverticulum: intermittent or epiphrenic  
Endoscopy: usually normal  
Peristalsis:>30% repetitive tertiary contractions  
Duration and amplitude occasionally abnormal  
LES: occas. hypertensive; occas. incomplete relaxation  
Spasm Upper GI  
Spasm Manometry
21. Treatment

- Nitroglycerin
- Calcium channel blockers: decreases amplitude of contraction & reduces LES pressure
- Control anxiety and precipitating factors
- Esophageal myotomy: results not as good as in achalasia; good to excellent results in 67 - 70%
- If LES is transected must do a partial fundoplication
- Dilatation if hypertensive LES is documented

22. Nutcracker or Supersqueeze Esophagus

Normal peristalsis
Contraction amplitude is > 2 standard deviations above normal > 180 mmHg in distal esophagus
Duration of contractions > 6 sec.
LES: occas. hypertensive; usually normal
Primary symptoms is chest pain
Strong emotional influence / hypochondriacal
Nutcracker Esophagus Manometry

23. Treatment

1. Psychologic assessment and support
2. Calcium channel blockers
3. Dilatation or myotomy are of little or no benefit
4. Hypertensive LES
5. Resting pressure > 45 mmHg; normal relaxation and peristalsis
6. Conservative medical / psychiatric management

24. Idiopathic Gastroesophageal Reflux

Peristalsis and contraction amplitude are normal
LES is weak (gradient < 6 mmHg) allowing gastric acid to reflux and bathe the lining of the lower esophagus--responsible for 60 - 70 % of all GERD
Sphincter failure
Primary muscle dysfunction
Increased exposure to acid further weakens the LES leading to further reflux and mucosal damage
Esophageal contraction abnormalities with poor amplitude and aperistalsis
Correlation between the severity of sphincter hypotension and extent of functional abnormalities in the esophageal body
(DeMeester)
? correction cures abnormalities
26. Reflux Disease and Scleroderma

Seen in 90% of patients with scleroderma
Atrophy of smooth muscle components
Fibrous infiltration
Incompetence of LES with disappearance of propulsive and emptying mechanisms
Antireflux procedures not as successful though some improvement is seen

27. Idiopathic Gastroesophageal Reflux

Frequent association with Type I hiatal hernia
   Alterations in the anatomy of the hiatus
   Phrenoesophageal membrane
Secondary causes
   Delay of gastric emptying
   Pyloric stenosis
   Gastric mass
   Poor esophageal wall muscle tone (scleroderma)

28. Reflux: two factors must occur

1. Acid-peptic or pancreaticobiliary secretions must reach the esophagus with increased frequency
2. Esophagus must be unable to clear those refluxed materials back into the stomach

Treatment
   Medical treatment
   Surgical treatment if medical treatment fails

29. Diagnosis

- Barium swallow
- Fiberoptic / rigid endoscopy
- Multiple biopsies if findings consistent with severe esophagitis, stricture, Barrett's epithelium, ulceration
- Esophageal function test (manometry, acid reflux, perfusion and clearing tests, 24 hr pH monitoring)

30. Indications for surgery

1. Symptomatic after 3 months of medical therapy
2. Persistent esophagitis, stricture, aspiration, bleeding
3. Positive 24 hr pH study
4. Manometry suggesting dysfunctional LES and adequate esophageal motility (peak amplitude > 30 mmHg)
5. Barrett's mucosa if biopsies are benign (no CIS)

31. Operation of choice
Restoration of the anatomic and physiologic relationships of the LES at the GEJ
- 360 degree wrap (normal esophageal motility)
- 270 degree wrap (dysfunctional esophagus)
- Esophageal resection (rare)
- Totally unyielding (fibrotic) esophagus
- Barrett's esophagus with CIS or frank malignancy
- Gastroplasty: falling out of favor

Procedures
- Nissen Fundoplication
- Belsey Mark IV
- Hill Fundoplication
- Collis Gastroplasty
- Collis-Belsey Procedure

EXTENDED OUTLINE

Anatomy and functional evaluation

1. Anatomy
   a) Begins (transition from pharynx to esophagus) at lower end of sixth cervical vertebra/cricoid cartilage
   b) Ends (transition to stomach) at 11th thoracic vertebra
   c) Esophagus is midline, passing to the left in lower neck and upper thorax, then back to midline, then to left again in lower thorax to pass through diaphragmatic hiatus
   d) Follows curve of vertebral column except to pass anteriorly to pass through diaphragmatic hiatus
   e) Sites of perforation during rigid esophagoscopy:
      i) Cricopharyngeus
      ii) Terminal left anterior deviation
   f) Measurements
      i) Incisors to cardia = 38-40cm (men), 36-38 (women)
      ii) Cricopharyngeus to cardia = 23-30cm, avg. 25
      iii) Incisors to cricopharyngeus = 14-15cm
      iv) Incisors to tracheal bifurcation/indentation of aortic arch = 24-26cm
   g) Anatomic relations of esophagus
      i) Trachea and cervical spine
      ii) Recurrent laryngeal nerves - in tracheoesophageal groove - left is closer to esophagus
      iii) Above tracheal bifurcation, esophagus passes to the right of the aorta
      iv) From arch down, esophagus lies to the right of the aorta
      v) 8th vertebra - left wall of esophagus is covered only by mediastinal pleura - common site of perforation in Boerhaave’s syndrome
      vi) Passing through diaphragmatic hiatus, phrenoesophageal membrane surrounds
vii) 2cm of abdominal esophagus between membrane and cardia - subjected to positive pressure
viii) Thoracic duct - through diaphragm behind aorta - in thorax, dorsal to esophagus, from 5th thoracic vertebra up, it passes to left, then departs from esophagus in neck to join L SCV at junction of IJV
h) Musculature of the esophagus
i) Opening is collared by cricopharyngeus muscle
ii) Outer longitudinal layer and inner circular layer
iii) Circular muscle is elliptical
iv) Upper esophagus is only striated muscle
v) At upper/middle 1/3 junction - 50% smooth muscle
i) Arterial supply of the esophagus
i) Cervical = inferior thyroid artery (mainly) + common carotid, SCA
ii) Thoracic = bronchial arteries (75% have one R and 1-2 L)
iii) Abdominal = branches of left gastric and inferior phrenic arteries
iv) After penetrating esophagus, arteries branch in T to form longitudinal anastomoses
v) Esophagus can be mobilized from stomach to aortic arch w/o devascularization
j) Venous drainage
i) Cervical = inferior thyroid
ii) Thoracic = bronchial, azygos and hemiazygous veins
iii) Abdominal = cardiac vein
k) Innervation
i) Parasympathetic = vagus
ii) Cricopharyngeus and cervical esophagus - recurrent laryngeal nerves
iii) RLN injury causes vocal cord paralysis and dysfunction of cricopharyngeus and of cervical esophagel motility, predisposing to aspiration
iv) Esophageal plexus receives fibers from vagus and from thoracic sympathetic chain
l) Lymphatic drainage
i) Submucosal plexus - lymph flow is longitudinal - extensive submucosal spread (of tumor) can occur

2. Normal structure and function
a) Pharyngeal phase of swallowing
i) Tongue is piston - propels food bolus as soft palate is closed
ii) Swallowing is reflex, once initiated
iii) Larynx is elevated and epiglottis covers opening of larynx
iv) Pharyngeal pressure increases to 45mm Hg
v) Food propelled by pressure gradient into thoracic esophagus
vi) Upper, striated portion of esophagus relaxes, then contracts within 0.5 seconds to twice its resting level of 30mm Hg
vii) A peristaltic wave of 30mm Hg begins in the esophagus
viii) Afferent nerves of pharynx are glossopharyngeal and superior laryngeal branch of vagus
ix) Efferent nerves arise from CN V, VII, X, XI, XII and C1-3
x) Motor disorders of pharyngeal swallowing:
a) Incomplete upper sphincter relaxation
b) Loss of skeletal portion of cervical esophagus
b) Esophageal phase of swallowing
i) Pressure gradient of -6mm Hg in thoracic esophagus to +6mm Hg intraabdominal
ii) Lower 1/3 of esophagus is most important
a) Peristaltic wave of 30-120 mm Hg
b) Rises to a peak in 1 sec, lasts 0.5 sec, then subsides in 1.5 sec
c) Wave moves down the esophagus at 2-4 cm/sec, reaches distal esophagus 9 sec after swallow starts
d) Vagal modulated wave
e) If vagi are preserved, muscle can be divided and propagate wave
f) Vagal fibers end in myenteric plexus
g) No known sympathetic innervation of the esophagus
iii) Pathologic states
a) Diffuse esophageal spasm - simultaneous contraction
b) Achalasia - failure of LES relaxation
c) Scleroderma - loss of contraction of smooth muscle portion of esophagus

3. The antireflux mechanism
a) LES
i) No distinct anatomic sphincter, but muscular architecture of cardia acts like a sphincter
ii) Gastric contraction results in increased LES pressure
b) Resting LES pressure
i) Correlates with incidence of GERD
ii) Truncal vagotomy has no effect
iii) Atropine (and other anti-cholinergics) reduces LES tone but does not cause GER
iv) In pharmacologic doses:
a) Secretin, cholecystokinin, glucagon, prostaglandins reduce LES pressure
b) Gastrin, bombesin, motilin augment it
v) Low LES tone in GERD is probably due to abnormal myogenic function
vi) Results of antireflux operations are independent of changes in resting LES pressure
vii) Myotomy can be performed along the length of the LES without resulting in reflux
c) Phrenoesophageal ligament
d) Intra-abdominal esophagus
i) Laplace’s law - pressure required to distend a soft tube is inversely proportional to its diameter
ii) Small-diameter esophagus requires high intragastric pressure to allow reflux
iii) LES competence directly proportional to length of intra-abdominal esophagus in cadaver studies by DeMester

4. GERD
a) Results from decrease in LES pressure, shortening of the intra-abdominal esophagus or both
b) Competence of cardia
i) Requires adequate LES pressure + intrabdominal length
ii) 80% prob of GERD when LES <5mmHG (independent of length)
iii) 80% prob of GERD when length <1cm (independent of pressure)
iv) Low incidence when pressure > 20mmHg and >2cm abd length
c) Gastric function
i) Delayed gastric emptying
ii) intragastric pressure and distention shorten intraabdominal length
d) Overall LES length is also a factor in GERD
e) Esophageal clearance
i) Gravity, salivation and swallowing
ii) Pts w/complications of GERD (Barrett’s and stricture) have higher proportion of weak
amplitude and simultaneous contractions
iii) frequency of swallows (0.87à 2.59/min) during episodes of reflux
iv) Any impairment of motility may exposure time
f) LES relaxation-abnormal will à increased exposure
g) Hiatal hernia
i) Phrenoesophageal ligament and snug hiatus prevent distention of abdominal esophagus
h) Antirreflux operations restore to normal the failed components of a mechanically
defective sphincter

5. Objective assessment of esophagus
a) Esophageal and upper GI barium studies
i) accuracy with video/cine
ii) accuracy with solid and liquid boluses
iii) Intraluminal abnormalities, landmarks
iv) Some motor dysfunction - spastic contractions
v) Mucosal lesions better seen with double contrast
vi) GERD- reflux only seen in 40% of those with manometry proven
b) Esophagoscopy
i) Any patient who reports dysphagia
ii) Confirm structural abnormalities w/bx
iii) Hiatal hernia = a pouch lined with gastric rugal folds lying 2cm above crural
indentation (identify w/a sniff)
iv) Esophagitis
a) Grade I= reddening w/o ulceration
b) Grade II= erosive and invasive, not circumferential
c) Grade III= confluence of erosions (cobblestone) - no stricturing
d) Grade IV= complications
v) Stricture
a) Multiple biopsies
b) Dilate
vi) Barrett’s
a) Difficulty visualizing squamo columnar jxn
b) Mucosa is red, more luxuriant
c) Biopsy proximal to lesion to determine junction w/nl squamous mucosa
d) Surveillance = 4 circumferential biopsies a t 2cm intervals
vii) Submucosal lesions - do not biopsy
c) The acid perfusion test
i) 0.1N HCl or H2O infused 15 cm above LES
ii) Pt reports symptoms
iii) Positive test is pt reporting symptoms w/acid relieved by saline
iv) Reduced sensitivity in pts w/stricture or Barrett’s

d) Manometry
i) Indications
a) Motor abnormality of esophagus suspected
b) Dysphagia or odynophagia w/o definite structural abnormality on Ba swallow
c) Confirm dx of achalasia, esophageal spasm, scleroderma
d) GERD - assess esophageal clearance prior to surgery
e) Determine LES pressure, total and intra abdominal length
ii) Pressure measuring catheter is withdrawn rapidly or stepwise across cardia
iii) Measurements
a) Relaxation of LES to gastric levels during swallow
b) Respiratory inversion point - reference point for LES
c) Response to 10 pharyngeal swallows-wet swallows are more sensitive
iv) Achalasia (Fig 39-21)
a) LES does not fully relax
b) All waves in body are simultaneous
c) No primary peristaltic waves are seen
d) Resting pressure of body is usually elevated
v) Scleroderma (Fig 39-22)
a) All muscular function of distal esophagus is obliterated
b) No high pressure zone
c) No contractions in body (lower 2/3 of esophagus)
vi) Simultaneous, repetitive or broad-based powerful contractions
a) Partial obstruction
b) Esophageal spasm
e) 24-hour esophageal motility monitoring
i) Advantages
a) Multiplies amount of data
b) Various physiologic conditions
ii) Limitations of stationary monitoring
a) Pt is supine
b) Limited to 10 swallows
iii) Technique
a) Drugs are stopped 48h before test
b) 3 transducers - 5, 10, 15 cm above upper border of LES
c) Pt diary of eating, position, sleeping, symptoms
iv) Diagnostic criteria (Table 39-2)
v) Little correlation with stationary manometry - especially for normal or nutcracker by ambulatory
vi) Primarily useful in pts with noncardiac chest pain
a) Amplitude and duration of contractions associated w/ pain are similar to asymptomatic
b) Frequency of contractions prior to episodes is increased
c) Esophageal claudication
d) Long esophageal myotomy can eliminate ability of esophagus to produce these bursts of abnormal activity

vii) Other findings
a) Esophageal contractility deteriorates with mucosal injury
b) Assess esophageal clearance function = peristaltic contractions with amplitude > 30mm Hg
f) 3-D imaging of LES
i) Overall length or intra abdominal length below 5th percentile can nullify normal LES pressure
ii) Increases the sensitivity of esophageal manometry in identifying pts who will benefit from “early” antireflux surgery (i.e., before the development of mucosal injury)


g) Esophageal pH tests
i) pH electrode withdrawal test
a) Normal is sharp rise in pH from stomach to 5-7 in esophagus
b) 20% false positive - abandoned
ii) SART
a) pH electrode 5cm above LES - 0.1N Hcl infused into stomach - pt performs maneuvers
b) > 2 drops in pH = abnormal cardia
iii) Acid clearance test
a) Performed after SART
b) Acid infused into esophagus
c) Normal=pH > 5 with < 10 swallows
iv) 24-hour pH monitoring
a) Most sensitive method for reflux-related problems
b) Indications
(1) GERD symptoms, other tests equivocal
(2) Prior to antireflux operation
(3) Atypical GERD symptoms
(4) Dysphagia and motor disorder (?GERD)
(5) Recurrent symptoms after esophageal or gastric surgery
c) Technique
(1) pH electrode 5cm above LES
(2) Acid reflux = pH <4
(3) Alkaline reflux = pH >7
(4) Restrict intake to food pH 5-6
d) Measure
(1) Cumulative time pH < 4 as percentage of time supine, total, upright
(2) Frequency of episodes of pH<4/24h
(3) Duration of longest episode 
(4) Number of episodes > 5 min
h) Radionuclide studies
i) Localization of Barrett’s - not used
ii) Dx and quantitation of GERD - not physiologic
iii) Measure esophageal transit - ?screening test prior to manometry
iv) Measurement of gastric emptying
i) Bilirubin monitoring with fiberoptic probe
i) Complications are related to acid and alkaline reflux
ii) 5cm above LES
iii) Uses bilirubin as a marker of exposure to duodenal contents

**Hiatus Hernias**

**Paraesophageal Hiatal Hernia**

All herniations of the fundus/body of the stomach into the chest which are anterior or lateral to the esophagus are paraesophageal hernias.
They account for 3-6\% of operations for hiatal hernia.
The presence of a paraesophageal hernia, regardless of the size or symptoms, is an indication for repair S

**Types:**

#1—true sliding hernia; the phrenoesophageal ligament fails to keep the esophagogastric junction below the diaphragm and within the abdomen. The LES is usually inadequate and reflux esophagitis exists

#2—true paraesophageal hernia with the esophagogastric junction in its normal location below the diaphragm. The fundus/body of the stomach is rotated into the chest with the greater curve as the leading point; usually no esophagitis present.

#3—combination of upward movement of the esophagogastric junction above the diaphragm and herniation of the stomach into the chest. The patient usually has symptoms of esophagitis.

**Anatomy:**

- Intact posterior fixation of the esophagus to the preaortic fascia and the median arcuate ligament
- The reason why the greater curve of the stomach herniates is because it is the most mobile portion—gastric cardia is fixed by the left gastric vessels, the gastroplenic and gastrohepatic ligaments; the pylorus is fixed by the duodenum.
- As the hernia enlarges the stomach moves upward and to the right utilizing the fixed lesser curve as an axis of rotation—organoaxial rotation. This is the path of least resistance because the aorta lies to the left and the heart lies left and anterior.
- This is a true anatomic hernia with a sac

**Symptoms:**

- produce few symptoms when small, which is why the defects are large when discovered
- long history of postprandial distress/discomfort
- substernal fullness and belching
- true dysphagia uncommon
- absence of heartburn/esophagitis
- pulmonary complications are common: recurrent pneumonia; chronic atelectasis; dyspnea classically after a large meal—from pleural space compression by the huge
hernial sac
-ulceration of the herniated stomach with resultant bleeding and anemia
-incarceration, obstruction, torsion, gangrene, and perforation
-most feared and lethal complication is gastric volvulus with strangulation which usually occurs post-prandially—this is a true surgical emergency if the stomach cannot be decompressed. Almost 30% of paraesophageal hernis present in this fashion. The stomach becomes twisted and angulated in its midportion just proximal to the antrum. Most prominent manifestation is the inability to swallow or regurgitate. Borchardt’s triad: chest pain, retching but unable to vomit, and inability to pass a nasogastric tube indicate gastric volvulus

Diagnosis/Therapy

-CXR--retrocardiac air-fluid level
-Barium Swallow to show an intrathoracic upside down stomach; look for signs of peptic esophagitis/position of GE junction

-Technical points:
  - antireflux procedure—routinely vs. those with signs of peptic esophagitis
  - surgical approach—transthoracic [ease of hernial sac dissection and esophageal mobilization when necessary] vs. abdominal [placement of a gastrostomy tube]

-Technique—principals of repair are reduction of the hernia and its contents to the abdominal cavity along with repair of the defect
  - mobilize esophagus; GE junction below diaphragm
  - narrow the hiatus posteriorly first until tip of finger can be admitted
  - fix stomach below the diaphragm (Hill repair—stomach fixed to median arcuate lig)
  - +/- Nissan fundoplication
  - gastrostomy
  - resection for gangrene/perforation

Results

-elective repair has ~1% mortality
-emergent procedures (volvulus) has ~15% mortality
-long term results are generally excellent whether or not an anti-reflux procedure is performed

Benign Esophageal Disease: Benign Strictures, Tumors, Cysts & Duplication

1. Anatomy of the esophagogastric junction
   a) Phrenoesophageal membrane
   i) Fascial attachments of the esophagus to the diaphragm
   ii) Attached to esophagus several centimeters above G-E jxn
ii) Maintains intraabdominal esophagus

2. Hiatal herniae
   a) Type I (sliding)
      i) Phrenoesophageal ligament is stretched
      ii) G-E jxn can migrate to an intrathoracic position
      iii) G-E jxn remains cephalad to stomach
      iv) Reducible, unless esophagus is foreshortened from stricture
   b) Type II (paraesophageal hiatal hernia)
      i) Rare
      ii) Phrenoesophageal ligament remains firm, binding esophagus to preaortic fascia and median arcuate ligament
      iii) G-E jxn at or near normal location
      iv) Fundus and body of stomach roll into chest alongside esophagus
   c) Type III (sliding and rolling hernia)
      i) E-G jxn and most of greater curve and body of stomach herniate
   d) Etiology
      i) Most are acquired
      ii) Obesity and pregnancy increase intraabdominal pressure, stretching phrenoesophageal ligament

3. Pathophysiology of G-E reflux
   a) LES - resting pressure, length, site
   b) Esophageal clearance - gravity and esophageal peristalsis
   c) Mucosal resistance
   d) Salivary neutralization
   e) Gastric secretion
      i) Sensitivity to gastric acid, pepsin, alkaline bilious material
      ii) Additive effect
      iii) Gastric emptying (40% of pts w/reflux esophagitis
   f) Complications
      i) Anemia (chronic blood loss)
      ii) Stricture
      iii) Barrett’s esophagus
   g) Pts w/G-E jxn incompetence should be treated the same as those w/ concomitant hiatal hernia

4. Symptoms
   a) Most patients are free of symptoms
   b) Very small risk of incarceration, strangulation, or obstruction of bowel (seldom involved)
   c) Retrosternal pain, heartburn, postural regurgitation, gaseous eructation
   d) Symptoms worse after a meal or when supine
   e) Pain may radiate to jaw, neck, ears or arms
   f) Respiratory involvement in 20%
   i) Acid alone may exacerbate asthma
g) Shatzki ring  
i) Membrane or diaphragm on swallow  
ii) Most are asymptomatic, but may produce intermittent or persistent dysphagia (solid > liquid)  
iii) Always associated with hiatal hernia  
iv) Squamous mucosa on top and gastric mucosa on bottom  
v) Smooth muscle, fibrous tissue and scar between  
vi) Tx  
a) Dilatation w/balloon or bougie  
b) If symptomatic from hiatal hernia- repair hernia and dilate  
h) Barrett’s esophagus  
i) “Invariably” associated w/sliding hiatal hernia and severe GE reflux  
5. Diagnosis  
a) Radiographic - Ba swallow w/maneuvers to assess reflux  
b) EGD for all respiratory or GER symptoms  
c) Formal testing of esophageal function  
i) Not necessary for typical symptoms of GER  
ii) 24hr pH monitoring and manometry prior to surgical intervention  

5. Medical treatment  
a) Lifestyle modification  
i) Elevation of head of bed  
a) Head 6-10 inches above the feet  
b) Reduces number of reflux episodes and increases rate of clearance  
ii) Weight reduction - can improve symptoms  
iii) Smoking  
a) Can decrease LES pressure and frequency of GER episodes  
b) Cessation reduces frequency of episodes  
iv) EtOH - Lowers LES pressure and impairs peristalsis  
v) Diet modification  
a) Coffee, chocolate, peppermint and fatty foods - lower LES pressure  
b) Citrus and tomato juice - direct mucosal irritation  
c) Cola and milk products stimulate acid secretion  
d) Timing of meals - avoid recumbency  
vi) Medications  
a) Theophylline, dopamine, nitrates, opiates, diazepam, calcium channel blockers - all lower LES pressure  
b) Pharmacologic therapy  
i) Cytoprotective agents - sucralfate  
a) Controversial data on efficacy  
b) Primary use is adjunctive (add to acid suppression)  
ii) Antacids - increase LES pressure and alkalinize gastric acid  
iii) Acid suppression - H2 blockers  
a) Decrease volume and concentration of gastric acid  
b) Less effective for GER than for PUD  
c) 50-60% healing in grade II-III esophagitis (cimetidine)
d) Healing is slow - treat for 3-6 months  
iv) Acid suppression - proton pump inhibitors - omeprazole  
a) Suppresses basal and stimulated gastric acid secretion  
b) Superior to placebo, ranitidine and cimetidine for GER  
c) Recommendation is cessation after 2 months  
v) Prokinetic agents  
a) Metachlopramide-dopamine antagonist - disappointing  
b) Cisapride - enhances acetylcholine release from myenteric plexus  
(1) Better than placebo for GER symptoms  
(2) w/ cimetidine is better than cimetidine alone  
c) Strategy of medical therapy  
i) First phase = lifestyle changes - behavior, food and drugs  
ii) Second phase = Pharmacologic management  
a) H2-blocker, then add cisapride or sucralfate  
b) Proton pump inhibitor for failure of combo tx  
c) Continue tx for 3-6 months  
d) Up to 90% will relapse by one year  
iii) Surgical treatment for failure of medical tx or complications (stricture, bleeding, severe ulceration)  

6. Surgical therapy  
a) Failure of medical tx or complications (stricture, bleeding, severe ulceration)  
b) Significant symptoms and esophagitis in a young pt.  
c) Operative approach  
i) Restore 4-6cm of intraabdominal esophagus  
ii) Thoracic approach  
a) Shortening of the esophagus - to immobilize esophagus  
b) Prior esophageal procedure  
c) Esophageal dysmotility requiring myotomy  
d) Suggested mechanisms for improvements  
i) LES manipulation  
ii) Accentuation of angle of His  
iii) Increased opening of the cardia  
e) Procedures  
i) Complete fundoplication - Nissen/Nissen-Rosetti  
a) 87% free of symptoms long-term  
b) 3cm loose Nissenà4% free from post-op symptoms  
ii) Partial fundoplication  
a) Belsey Mark IV - 240° wrap  
b) Lind - 300°  
c) Toupet - 180°  
iii) Angelchick prosthesis  
a) 20% persistent dysphagia  
b) Migration
Barrett’s esophagus

1. Anatomy and physiology
a) Definition: esophagus is lined w/columnar mucosa more than 3cm proximal to the distal end of the muscular esophageal tube
b) 3 types of mucosa - gastric fundic, junctional, specialized columnar (80%)
c) Acid (and pepsin and gastrin) is produced, but amount is insufficient to explain peptic ulceration of Barrett’s

2. Pathogenesis
a) Nearly every patient has pathologic reflux
b) Metaplasia of pleuropotential cells in submucosa
c) Migration of gastric mucosa not felt to be mechanism

3. Epidemiology
a) 1% in pts w/o symptoms who undergo endoscopy
b) 10-20% in pts w/symptoms of reflux
c) 8-13% of children endoscoped for GER
d) Age 50-60
e) Men=3xwomen
f) Relative lack in African-Americans

4. Diagnosis
a) GER symptoms
b) Symptoms may improve with progression of Barrett’s
c) >80% - hiatal hernia
d) 75% - stricture
e) Nearly 50% - ulcer
f) Endoscopy
  i) Irregular squamocolumnar junction
  ii) Strictures typically involve squamocolumnar junction
  iii) Biopsy at multiple levels
g) LES pressure is lower in pts w/Barrett’s than normal people and lower than pts w/reflux but w/o Barrett’s

5. Benign (non-neoplastic) complications
i) Stricture, bleeding, mucosal ulceration
ii) Severe bleeding - 25% (rare in GER)
iii) Penetrating ulcer in 10%
  a) May be successfully treated w/acid suppression
  b) Resection for mediastinal perforation

6. Dysplasia and adenocarcinoma
i) Persistent acid reflux responsible for Barrett’s is involved in dysplasia and malignant change
ii) Other premalignant markers
  a) Increased G2 tetraploidy
b) DNA aneuploidy
c) ras oncogenes (H-ras, K-ras, N-ras) - not a factor

iii) Risk of malignant degeneration related to
a) Duration and severity of GER
b) Tobacco
c) Overall extent of columnar spread

iv) Cancers
a) Arise almost exclusively in specialized columnar epithelium
b) Most have transmural extension with + nodes at time of dx

v) 1/140 pt years = 40x usual risk in this country = 10-20% of all esophageal ca

7. Medical management
a) Lifestyle changes - behavior, food and drugs
b) Medications
c) Resolution of symptoms does not correlate with regression of Barrett’s

8. Surveillance
a) Surveillance allows detection at an early stage and improves long-term survival
b) Endoscopy at least every year

9. Surgical treatment of benign disease
a) Indications = failure of medical tx or complications (same as for GERD)
b) Unknown whether regression of Barrett’s or reversion of dysplasia can be expected
c) Fundoplication and resection if necessary
  i) Remove all Barrett’s mucosa
  ii) Cervical esophagogastrectomy (intrathoracic esophagogastrectomy carries a high
d) Surgical treatment of dysplasia and adenocarcinoma
  i) High grade dysplasia (separate from carcinoma in situ)
  ii) Intensive med tx w/rebiopsy q 3months or resection
  iii) When resecting, remove all Barrett’s epithelium

Malignant Tumors
Esophageal Cancer Palliation

Of patients amenable to resection, 72% have LN mets, 25% are resectable for cure

I. Palliative resection or bypass
A. Bypass
   1. Mortality=20-40%
   2. Morbidity 25%
   3. Orringer noted increased incidence of anastomotic leak with bypass
   4. Retrosternal route offers best conduit to neck
      a) Portals for palliative RT can avoid neoesophagus
      b) Reduces possibility for malignant dysphagia
c) Remove upper manubrium and clavicular heads to enlarge thoracic inlet & decrease anastomotic leak and stricture

5. Substernal if retrosternal unavailable
6. Gastric-emptying procedure recommended
7. Kirschner - Roux-en-Y drainage of esophageal remnant - others say it is unnecessary

B. Indications
1. Esophagorespiratory fistula in young, fit pts
   a) Avoids constant aspiration
   b) Other option is esophageal intubation
2. Disease unresectable for cure (discovered at operation) when bypass or resection will add little to morbidity

II. Esophageal dilatation
A. Multiple dilatations and return trips to the hospital are usually required
B. Mercury-filled, red rubber (Maloney or Hurst) are most common
   1. Short strictures with visible lumen
   2. Fluoroscopy increases safety
C. Guide-wire systems
   1. For long, angulated, or eccentric strictures
   2. Puestow - supпланted by hollow-core polyvinyl (American, Savary-Gillard)
   3. Require endoscopic or fluoroscopic placement of guide-wire into stomach
D. Balloons
   1. Potentially decreased risk of perforation (radial vs. Vector force!)
E. Dilate to max 45 French

I. Esophageal intubation (intentional)
A. Tubes have a proximal funnel and a lumen >= 10mm
B. Traction method (Celestin tube)
   1. Surgical procedure
   2. Pilot bougie is passed through gastrotomy and tube is sutured to lesser curve over a teflon pledget
C. Pulsion method
   1. Shorter hospital stay (8.4 vs. 18.6 days) and lower mortality (14% vs. 23%) c/w traction
   2. Tube is inserted endoscopically over a guidewire w/fluoroscopic control
   3. Celestin tube, Atkinson, Wilson-Cook
   4. Savary-wire reinforced polyvinyl - resistant to compression
D. Expandable wire stents
   1. For Ca and esophagorespiratory fistula
   2. Dilating tumor not necessary prior to insertion
   3. Problems: expense, inability to move after placement, tumor ingrowth
E. Complications
   1. Perforation 4-12%, 4-9% of patients die.
      a) Surgery usually contraindicated
      b) Tx w/NPO, IV Abx, nutrition
2. Reflux esophagitis  
   a) Elevate HOB  
   b) Omeprazole  
3. Tube displacement 10-20%  
4. Tumor overgrowth  
   a) Nd:YAG ablation  
   b) Replacement w/longer tube

I. Chemotherapy  
A. Single agents: 5-FU, cisplatin  15-20% response rate  
B. Multi-drug regimens (±/ RT)  33-50% and up to 77% respectively  
C. 44% life-threatening side effects

II. Brachytherapy  
A. Radioactive sources afterloaded into fluoroscopically placed PVC catheters  
B. 3500 cGy at surface of catheter, 1500cGy 1cm from center  
C. Benefits  
1. Cesium-137 and iridium 192 - more exact dosing  
2. Proximity to tumor minimizes radiation to normal tissues  
D. Patients with dysphagia due to extrinsic malignant compression more likely to fail  
E. 75% have improvement in dysphagia score  
F. 1-yr survival: 10% for SCC, 20% for adeno  
G. Complications = sore throat, esophagitis, epigastric pain  
H. Combined w/external beam (Flores)  complete restoration of swallowing in 62%  
   1. Radiation esophagitis common  
I. Compared to laser tx: shorter hospital stay and less likely to require re-treatment

III. Laser photoablation  
A. Nd:YAG is most common  
B. Works by tissue vaporization and thermal necrosis  
C. Authors recommend:  
1. Snare cautery debridement of exophytic tumor first  
2. Routine re-treatment 2-4 days post-procedure  
D. All tumor types, any location - exophytic more successful, extrinsic compression less successful  
E. Relatively safe, effective (80%), improves quality of life  
F. Complications (1-2.7% mortality)  
   1. Related to experience  
   2. Minor - 10-50%  
   3. Perforation - 5% (experienced operator), bleeding 4% (tx w/laser)

IV. Photodynamic therapy  
A. IV photosensitizing agents (hematoporphyrin derivatives & phthallocyanines)  
B. Dye lasers tuned to appropraite wavelength 2-3 days later - photochemical prrocess  
C. Mean survival 6.8 mo  
D. Complications
1. Photosensitivity
2. Failure of tx

V. Summary
A. Palliation reserved for:
   1. Medically unfit for resection
   2. Incurable disease on pre-op evaluation
   3. Unresectable at operation
   4. Refusal of surgical tx
Molecular Biology of Lung and Esophageal Cancer

Introduction
1. tobacco consumption is believed to be responsible for > 90% of lung cancers in men and 80% in women
2. tobacco has been implicated in the development of esophageal carcinoma acting synergistically with ethanol consumption
3. since only a minority of smokers develop lung cancer implies that there are other genetic and enviromental factors that contribute
4. epidemiologic studies have demonstrated familial risk of lung cancer in some patients who develop cancer at an earlier age (<50 Yrs)
5. in the U.S., the incidence of esophageal adenocarcinoma has risen faster than any other cancer
   a. tends to occur in young male patients with no history of tobacco or ethanol abuse
   b. chronic reflux, hiatal hernia, and Barrett’s esophagus are thought to be predisposing factors
   c. Barrett’s esophagus increases the risk of developing esophageal cancer 40-fold

Cell Cycle
1. cell proliferation normally proceeds in an orderly fashion (GO,G1,S,G2 and M phases)
2. multiple regulatory proteins known as cyclins (A,B etc) are involved in cell proliferation
3. perturbation of cell cycle integrity due to alterations in various cyclin levels due to mutations involving oncogenes or tumor suppressor genes induces genomic instability, DNA amplification, and malignant transformation

Dominant and Recessive Oncogenes
1. mutations associated with carcinogenesis may occur in dominant or recessive (tumor suppressor) genes
2. dominant oncogenes are genes in which mutation results in constitutive growth stimulation
3. tumor suppressor genes tend to control cell proliferation

Growth Factors and Growth Factor Receptors
1. lung and esophageal cancers have been associated with abnormal expression of a variety of growth factors and growth factor receptors
2. growth factors secreted by tumor cells may influence distant cells (endocrine stimulation)

Gastrin-Releasing Peptide
1. 27 amino acid homolog of bombesin
2. GRP receptors are found on small cell cancer cells but are absent on non-small cell cancer cells
3. in vitro proliferation of small cells can be inhibited by antibombesin monoclonal antibodies or antagonists

**Epidermal Growth Factor Receptor**
1. 170-kd tyrosine kinase glycoprotein
2. activation of EGFr ligand results in cell proliferation
3. overexpression of EGFr has been associated with 45% lung cancers and 80% of esophageal cancers
4. EGFr overexpression in patients with non-small cell cancers is associated with diminished survival

**ErbB2/Neu**
1. erbB2/neu gene encodes for a 185 kd transmembrane tyrosine kinase receptor molecule
2. structurally related to EGF
3. present on normal ciliated epithelium, mucus cells, and type II pneumocytes of the lung
4. overexpression had been associated with scca and adenoca of the lung

**Platelet-derived and Insulin-like Growth Factors** and Their Respective Receptors
1. both are important cell cycle progression in mammalian cells
2. PDGF, PDGFr expression have both been documented in association lung and esophageal cancers
3. normal lung tissue does not express PDGF ligand, but lung cancer cells do express PDGF
4. insulin growth factor ligands and receptors have been identified in lung and esophageal cancer cell lines
5. IGF-I, IGF-II or insulin stimulated mitogenesis in lung or esophageal cancer lines can be competitively inhibited by Mabs to the receptors or ligands

**Cyclin D**
1. the cyclin D gene appears to be amplified but not expressed in ~ 10% of large cell and squamous cell lung cancers
2. amplification and overexpression is seen in 32% of squamous cell esophageal cancers
3. overexpression of cyclin D disrupts G1 cell cycle kinetics resulting in damaged DNA and malignant transformation

**RAS**
1. H,K, and N-ras genes are members of a super gene family encoding for plasma membrane proteins that are important in signal transduction from cell surface receptors involved in mitogen-induced proliferation
2. Ras mutations are among the most common oncogene defects in human cancers
3. K-ras mutations are relatively common in pulmonary adenocarcinomas, esp. in patients with a smoking history
Myc
1. family of genes which are expressed during mammalian development and human carniogenesis
2. encode for DNA transcription factors that are critical for initiating movement of (G0) cells into and through the G1 phase of the cell cycle initiating DNA synthesis
3. aberrant C-myc expression has been primarily documented in small cell cancers
4. myc amplification occurs late in the process of carcinogenesis, enhancing tumor progression and metastasis

Tumor Suppressor Genes
3p
1. lung and esophageal cancers are associated with multiple genetic alterations
2. the majority of these neoplasms are aneuploid
3. deletions of 3p have been detected in nearly 100% of small cell lung cancers and >50% of non-small cell tumors and ~ 70% of esophageal cancers
The Mediastinum

1. Anatomy
   A. Compartments
      · Mediastinal borders: thoracic inlet (superior), diaphragm (inferior), sternum (anterior), spine (posterior), pleura (lateral)
      · Anterosuperior compartment is anterior to pericardium
      · Contents include thymus and great vessels
      · Middle, or visceral, compartment is between anterior and posterior pericardial reflections
      · Contents include heart, phrenic nerves, tracheal bifurcation, major bronchi, lymph nodes
      · Posterior, or paravertebral, compartment is posterior to posterior pericardial reflection
      · Contents include esophagus, vagus nerves, sympathetic chains, thoracic duct, descending aorta, and azygos/hemiazygos

2. Mediastinal Conditions
   A. Mediastinal Emphysema
      · Introduction of air from esophagus, tracheobronchial tree, neck, or abdomen
      · Causes include penetrating or blunt trauma, or spontaneous mediastinal emphysema
      · Presents as substernal chest pain, crepitation, and pericardial crunching sound
      · May result in tamponade
      · Treat underlying cause; may require chest tube placement for pneumothorax

   B. Mediastinitis
      · Occurs in about 1% of patients after median sternotomy
      · Risk factors include prolonged surgery or CPB, re-exploration, wound dehiscence, shock, and use of bilateral internal mammary artery grafts in patients who are older or have diabetes
      · Presents as fever, elevated WBC, and tachycardia
      · Best treatment results with wound debridement and tissue flaps

   C. Mediastinal Hemorrhage
      · Caused by trauma, aortic dissection, aneurysm rupture, or surgical procedures
      · May result in mediastinal tamponade, which is more insidious than pericardial tamponade
      · Meticulous hemostasis and adequate chest tube drainage will prevent this syndrome
      · Spontaneous mediastinal hemorrhage can result from mediastinal masses, altered coagulation status, and severe hypertension

   D. Superior Vena Cava Obstruction
      · Acute and chronic syndromes occur
      · See CTSN lecture on SVC Syndrome
Mediastinal Tumors

1. Location
   - Lesions are predictable to some degree predictable
   - Most common tumors are neurogenic (20%), thymomas (20%), primary cysts (20%), lymphomas (13%), and germ-cell tumors (10%)
   - Most are located in anterosuperior compartment (54%), followed by posterior (26%) and middle (20%) tumors

<table>
<thead>
<tr>
<th>Anterior</th>
<th>Middle</th>
<th>Posterior</th>
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<tbody>
<tr>
<td>Thymoma</td>
<td>Enterogenous cyst</td>
<td>Neurogenic origin</td>
</tr>
<tr>
<td>Germ cell tumor</td>
<td>Mesothelial cyst</td>
<td>Neurenteric cyst</td>
</tr>
<tr>
<td>Lymphoma</td>
<td>Lymphoma</td>
<td>Lymphoma</td>
</tr>
<tr>
<td>Hemangioma</td>
<td>Thoracic duct cyst</td>
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<tr>
<td>Parathyroid adenoma</td>
<td>Granuloma</td>
<td></td>
</tr>
<tr>
<td>Thymic cyst</td>
<td>Hamartoma</td>
<td></td>
</tr>
<tr>
<td>Lipoma</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aberrant thyroid</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lymphangioma</td>
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</tr>
</tbody>
</table>

- A significant portion (25-40%) of mediastinal tumors are malignant
- Anterosuperior tumors are more likely to be malignant, as are tumors of patients between the ages of 10 and 40
- Neurogenic tumors and non-Hodgkin's lymphomas are the most common tumors in children

2. Clinical Presentation
   - About two-thirds of patients will have symptoms at the time of diagnosis
   - The absence of symptoms is a reasonably good indicator that a diagnosed tumor is benign
   - Most common symptoms include chest pain, cough, and fever
   - Signs of mechanical compression or invasion of mediastinal structures are more common with malignant tumors
   - Paraneoplastic syndromes are not uncommon and include Cushing's syndrome, thyrotoxicosis, hypertension, hypercalcemia, hypoglycemia, diarrhea, and gynecomastia

3. Diagnosis
   - CXR will localize the tumor and give information on calcification and relative density of the tumor
   - CT scanning identifies chest wall invasion, multiple masses, and extension into spinal column
   - MRI is more accurate for vascular involvement and intracardiac pathology
   - Echocardiography is useful for patients with middle compartment tumors to localize between intracardiac and pericardial tumors
   - Guided needle biopsy can make a diagnosis of malignancy in 80-90% of patients
· Mediastinoscopy/mediastinotomy may be necessary to make a diagnosis and establish resectability

4. Thymoma
A. Features
· Represents 20% of all mediastinal masses in adults
· Peak incidence is in 3rd to 5th decades of life; rare in children
· About half are of mixed cell type, followed by epithelial (28%) and lymphocytic (20%) types
· Between 15 and 65% of thymomas are benign
· Frequently associated with paraneoplastic syndrome, most commonly myasthenia gravis
· Myasthenia gravis is diagnosed in 30-50% of patients with a thymoma, and 15% of myasthenia patients will have a thymoma
· Autoimmune reaction directed against the postsynaptic nicotinic receptors results in skeletal muscle fatigability and weakness, especially in axial muscles

B. Operative Technique
· Remove all anterior mediastinal tissue and any invasive disease, including involved lung, pleura, pericardium, and SVC/innominate vein
· Thymic blood supply arises from the internal mammary arteries
· Patients with stage IIa or higher disease should receive postoperative radiation
· Chemotherapy is indicated for stage III or IV disease
· Debulking may be appropriate for stage IV disease, although there is no evidence for increased survival · At 5 years after resection, 25-30% of patients will have complete resolution of myasthenia symptoms and 30-50% will be improved
· Prognosis is dependent on stage of tumor, not on presence of myasthenia gravis

5. Thymic Carcinoid
· Most occur in males and about two-thirds are symptomatic
· Originate from Kulchitsky cells in the thymus, but are not associated with myasthenia gravis or the carcinoid syndrome
· May cause other paraneoplastic syndromes, however, most commonly Cushing's syndrome (33%)
· Presence of such syndromes is a very poor prognostic factor
· Up to 75% will develop local recurrence or metastases
· Low overall cure rate and mean survival is 3 years

6. Lymphoma
· Between 40 and 70% of lymphoma patients will have mediastinal involvement during their disease course
· Only 5-10% of lymphoma patients will have isolated mediastinal disease, and are usually symptomatic
· Characteristic Hodgkin's lymphoma symptoms are chest pain after alcohol consumption and cyclic Pel-Ebstein fevers
· Nodular sclerosing and lymphocyte predominance forms of Hodgkin's lymphoma are the most common to cause mediastinal involvement
· Up to 40% of patients with lymphoblastic non-Hodgkin's lymphoma will have mediastinal disease
· Surgery is indicated if fine-needle aspiration is inconclusive or to evaluate residual mass after chemotherapy
· Surgical options include cervical mediastinoscopy, parasternal mediastinotomy, and thoracoscopy

7. Germ Cell Tumors
· Comprise 15-25% of anterior mediastinal masses
· Most common in children and young adults
· Includes teratomas, teratocarcinomas, seminomas, embryonal cell carcinomas, choriocarcinomas, and endodermal cell or yolk-sac tumors
· Identical to germ cell tumors originating in the gonads, but are not metastatic lesions from primary gonadal tumors
· About 60% are benign and 40% are malignant

A. Predominantly Benign Tumors
· Teratomas are complex, multiple tissue element tumors
· Symptoms are related to mechanical effects
· Simplest form is the dermoid cyst, which consists of mostly dermal and epidermal tissue
· More complex teratomas may have well-differentiated bone, cartilage, nerve, or glandular tissue
· Malignant tumors are differentiated upon histologic identification of embryonic tissue

B. Malignant Tumors
· Male predominance and most patients are symptomatic
· 40% are seminomas and 60% are nonseminomas (embryonal cell, choriocarcinoma, yolk-sac, and teratocarcinoma)

<table>
<thead>
<tr>
<th></th>
<th>Seminomas</th>
<th>Non-seminomas</th>
</tr>
</thead>
<tbody>
<tr>
<td>AFP/B-HCG</td>
<td>rare</td>
<td>90%</td>
</tr>
<tr>
<td>Associated syndromes</td>
<td>none</td>
<td>Klinefelter's, trisomy 8, 5q deletion</td>
</tr>
<tr>
<td>Radiosensitivity</td>
<td>High</td>
<td>Insensitive</td>
</tr>
<tr>
<td>Metastatic behavior</td>
<td>Remain intrathoracic</td>
<td>Frequently disseminated</td>
</tr>
<tr>
<td>Treatment</td>
<td>Radiation</td>
<td>Cis-platinum chemotherapy</td>
</tr>
<tr>
<td>Remission</td>
<td>Over 80%</td>
<td>CR in 55-60%, PR in 30-35%</td>
</tr>
<tr>
<td>5-year survival</td>
<td>50-80%</td>
<td>50-60%</td>
</tr>
<tr>
<td>Remission</td>
<td>CR=complete</td>
<td>PR=partial</td>
</tr>
</tbody>
</table>

· Initial surgical intervention typically only for diagnosis due to high radiosensitivity of seminomas and frequent metastatic disease in non-seminomas
· Surgical resection after induction of chemotherapy may have a role in non-seminomatous tumors

8. Endocrine Tumors
A. Intrathoracic Thyroid
· 80% are substernal extensions of a cervical goiter
· True intrathoracic thyroid (derives blood supply from thoracic vessels) comprises only 1% of all mediastinal tumors
· More common in women and in the 6th to 7th decades, most are adenomas
· Usually presents with tracheal or esophageal compression; thyrotoxicosis is uncommon
· I-131 scanning should be done to identify presence of functioning cervical thyroid tissue before resecting these tumors
· Resect substernal extensions through a cervical incision and true intrathoracic lesions through the chest

B. Parathyroid
· Most are adenomas and are found by the superior pole of the thymus due to common embryogenesis from the third branchial cleft
· Symptoms are usually due to hyperparathyroid syndrome
· Parathyroid cysts are not usually hormonally active

9. Primary Cysts
A. Bronchogenic Cysts
· Most common primary cysts in the mediastinum (5%)
· Arise from ventral foregut and are usually located in the subcarinal or right paratracheal region
· Two-thirds are asymptomatic; symptoms include tracheobronchial or esophageal compression and infection from tracheobronchial communication
· Complete excision is recommended, even if asymptomatic, to prevent late complications

B. Esophageal/Enteric Cysts
· Comprise 3-5% of mediastinal tumors
· More common in children and tend to occur in the lower third of the esophagus
· Dysphagia is the most common symptom
· CT scanning is essential in patients with vertebral anomalies to evaluate for possible spinal cord involvement (neuroenteric cyst)
· Avoid endoscopic biopsy, as this may cause cyst perforation and infection
· Complete excision is indicated; a thoracoscopic approach can be used for uninfected cysts

C. Pleuropericardial Cysts
· Uncommon, classically occur at the pericardiophrenic angles, 70-80% on the right side
· Usually asymptomatic and may communicate with the pericardium
Guided needle aspiration is the initial therapy of choice. Surgical excision is indicated if the cyst recurs or if the diagnosis is in doubt.

10. Neurogenic Tumors

A. Etiology and Diagnosis
- Most posterior mediastinal masses are of neurogenic origin
- 95% of these tumors in adults are benign and are usually asymptomatic
- In children, most neurogenic tumors are malignant
- Classified according to cell origin; most arise from intercostal nerve or sympathetic chain

<table>
<thead>
<tr>
<th>Intercostal nerve</th>
<th>Sympathetic ganglia</th>
<th>Paraganglia cells</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neurofibroma</td>
<td>Ganglioma</td>
<td>Paraganglioma (pheochromocytoma)</td>
</tr>
<tr>
<td>Neurilemoma</td>
<td>Ganglioneuroblastoma</td>
<td></td>
</tr>
<tr>
<td>Neurofibrosarcoma</td>
<td>Neuroblastoma</td>
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</tr>
</tbody>
</table>

- Neurilemmomas are the most common and originate from Schwann's cells
- These are encapsulated tumors which stain with S-100 protein immunostain
- Two primary types: Antoni A (organized pallisading pattern) and Antoni B (loose reticular pattern)
- Neurofibromas originate from peripheral nerve
- Form a pseudocapsule and have more variability with the S-100 stain
- Both types of tumors are associated with von Recklinghausen's disease, although more commonly neurofibromas
- Chest CT is sufficient for diagnosis of most of these tumors, and MRI should be used when an intraspinal component is present

B. Operative Indications
- Benign tumors (neurofibroma, neurilemoma, ganglioneuroma) can be effectively treated with local excision
- Combined thoracic and neurosurgical approach is indicated for tumors with intraspinal extension
- Recurrence is rare for benign tumors
- Local recurrence is common for malignant tumors and overall prognosis is poor

Selected Articles

Mediastinitis


Thymoma and Thymic Carcinoid


**Mediastinal Lymphoma**


**Germ Cell Tumors**


**Thyroid**


**Cysts**


**Neurogenic Tumors**


**Thoracoscopic Techniques**


**Superior Vena Cava Syndrome**

1. **SVC Obstruction and Collateral**
   a) Obstruction below azygous vein
      · Azygous - hemiazygous, lumbar veins to IVC
   b) Obstruction above azygous vein
      · **Venous collateral** in neck to azygous to SVC
   c) Obstruction includes azygous vein
      · Internal mammary, paraspinal, esophageal and subcutaneous vein to IVC
   d) Cerebral decompression through a single jugular vein via midline intracranial venous sinuses

2. **Pathogenesis**
   a) Extrinsic compression of SVC
   · Gradual SVC obstruction
   b) Invasion of SVC
   · Obstruction develops rapidly
   c) Thrombosis of SVC
   · Acute obstruction
   d) Venous hypertension and lymphatic obstruction - all empty into the subclavian veins

3. **Causes**
   a) Benign 10%
      · Inflammatory - histoplasmosis, idiopathic fibrosing mediastinitis
      · Iatrogenic - pacemaker electrode, hyperalimentation or other CV line
   b) Malignant 90%
      · Bronchogenic, epidermoid 65-80%
      · Small cell 12-30%
      · Lymphoma 12-20%

4. **Symptoms and Signs**
   · Swelling face, neck, arms
   · Shortness of breath, orthopnea, cough and chest pain suggest upper airway obstruction
   · Hoarseness, stridor, tongue swelling, nasal congestion
Headaches, syncope and lethargy are caused by cerebral edema from venous hypertension
- Symptoms worse lying down, bending forward
- Symptoms of cerebral or laryngeal edema is associated with a reduced life expectancy of about 6 weeks, demanding urgent intervention
- Caval obstruction may be the life-limiting problem of patients with underlying malignancy

5. Diagnosis
a) Chest x-ray
   - **Right hilar mass** - bronchogenic carcinoma
   - Anterior mediastinal mass - lymphoma
   - Calcification - histoplasmosis
b) Simultaneous bilateral arm venogram
   - Defines obstruction and collateral circulation
   - Identifies thrombus
c) **Computerized axial tomography**
   - Assessment of mediastinum
   - Determine patency of jugular veins
   - Directed needle biopsy

6. Radiation Therapy
   - Since most cases due to malignancy, nearly all patients receive radiation
   - 80-90% relieved of SVC Syndrome
   - 50% of patients relapse
   - Relapse occurs in benign disease as well; although collaterals develop, thrombosis will continue to propagate and occlude these collaterals over time

7. Medical Therapy
   - Chemotherapy for lymphomas and small cell carcinoma
   - Diuretics and corticosteroids reduce cerebral edema
   - Anticoagulants in selected cases to prevent clot propagation
   - Thrombolytic therapy for selected acute thrombosis

8. Surgery
   - Severe SVC Syndrome associated with thrombosis of caval tributaries and inadequate collateral circulation
   - SVC bypass with composite autogenous vein grafts or PTFE 6-12 months after onset in benign causes or for palliation in malignant causes with severe or acute onset SVC syndrome

**Selected Articles**

In this succinct article, the authors underscore the importance of having accurate tissue diagnosis prior to treating obstructing lesions. 1/3 of the patients had tumors best treated with chemotherapy (not radiation), and mediastinoscopy provides an effective way to obtain tissue for diagnosis.

Lochridge, SK; Knibbe, WP; and Doty, DB. Obstruction of the superior vena cava. Surgery 1979;85:14-24.

This early 10-year series of 66 patients covers a variety of therapeutic approaches, including venography. There is a thorough discussion at the end of the article to assist the reader in tailoring the approach to SVC obstruction.


18 out of 20 patients had a percutaneous intraluminal stent placed to relieve obstruction. The article also reviews the use of thrombolysis and anticoagulation in SVC syndrome.

Abner, A. Approach to the patient who presents with superior vena cava obstruction [review]. Chest 1993;103 (4 Suppl):394S-397S.

A brief review article with good references. Topics include pathophysiology, radiologic studies, biopsy procedures, and eventual management of these patients.

Sources for further reading

Textbook Chapters