The diagnostic methods in Pulmonology

Plan of the lecture

I. The respiratory system structure

II. Research methods in Pulmonology

1.Imagine studies:

- Roentgenoscopy
- Roentgenography (radiography)
- Fluorography
- Computed tomography
- Magnetic resonance imaging
- Scintigraphic imaging
- Bronchography
- Pulmonary angiography
- Ultrasound examination

Plan of the lecture

2.Technique for obtaining biological specimens

3. Instrumental methods

Thoracentesis

Bronchoscopy

Thoracoscopy

4. Methods for functional studies

Spirometry

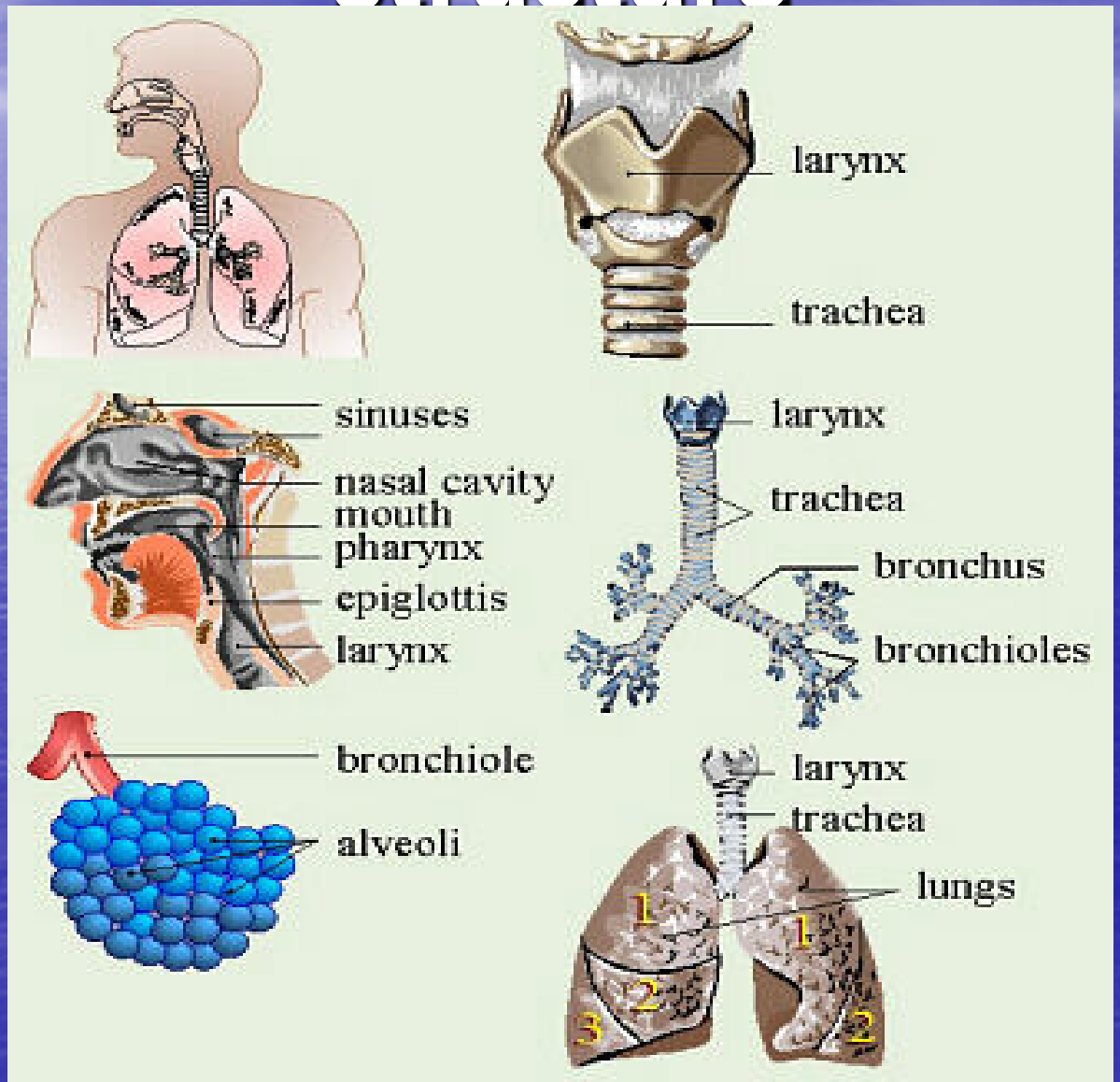
Spirography

Peak expiratory flow rate (PEFR)

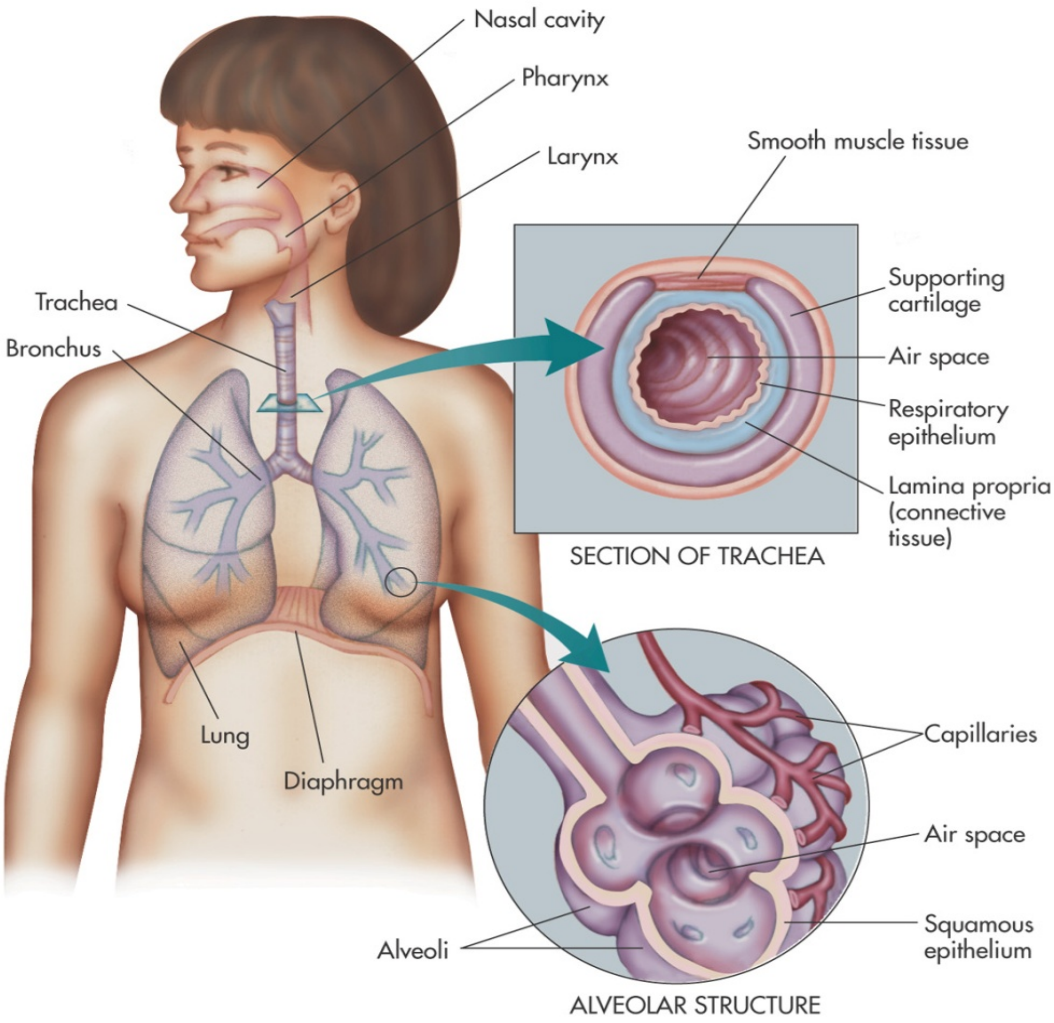
Pneumotachometry, pneumotachygraphy

Measurement of blood gases

I. The respiratory system structure



The respiratory system structure



II. Research methods in Pulmonology

- Diagnostic procedures for assessing the patients with suspected or known respiratory system disease include imagine studies, technique for obtaining biological specimens, and method used to characterize the functional changes developing as a result of disease.

II.1. Imagine studies

Imagine studies used to examine the patients with disorders of the respiratory system include:

- Roentgenoscopy
- Roentgenography (radiography)
- Fluorography
- Computed tomography
- Magnetic resonance imaging
- Scintigraphic imaging
- Bronchography
- Pulmonary angiography
- Ultrasound examination

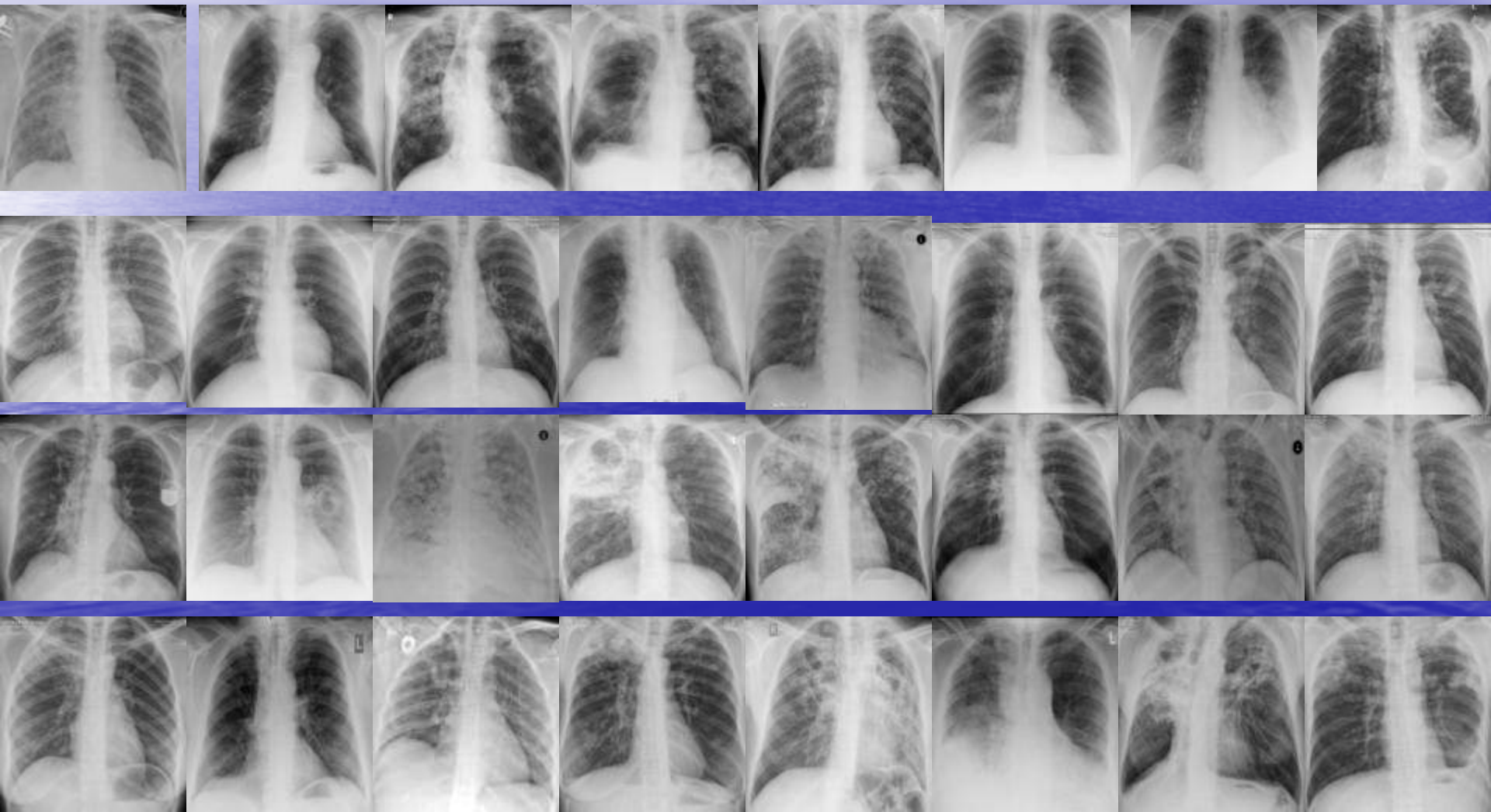
Roentgenoscopy

- is the most common method for assessing relative lungs translucency, and for the diagnostic evaluation of disease involving the pulmonary parenchyma (consolidation of the pulmonary tissue, pneumosclerosis, tumor), the pleura (pleural fluid or air, pleural adhesions), and, to a lesser extent, the airways. Presence of the cavity in the lungs can also be determined during roentgenoscopy.

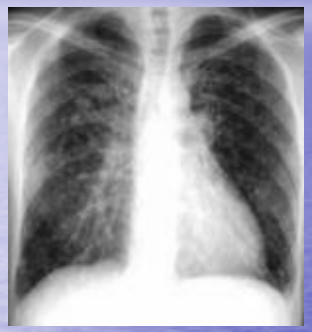
Roentgenography (radiography, x-rays)

- Routine chest radiography generally includes both posteroanterior and lateral views, and used for filmrecording - radiograph. The detail that can be seen on radiograph allows better recognition of parenchymal and airway diseases (indistinct focal consolidations, bronchovascular pattern, etc.).

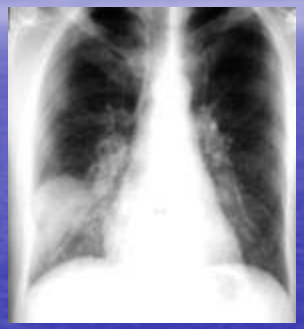
Roentgenography



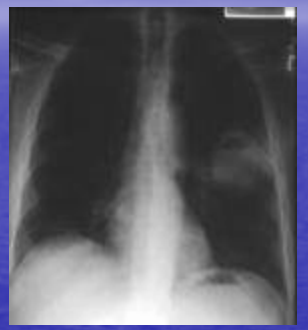
Roentgenography



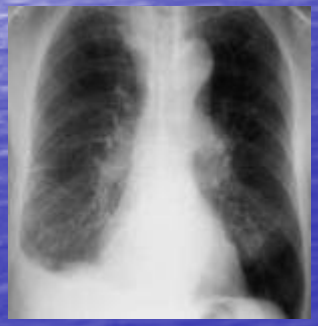
Diffuse infiltrates



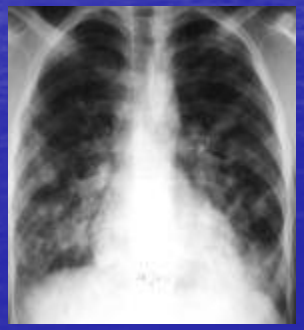
Focal infiltrates



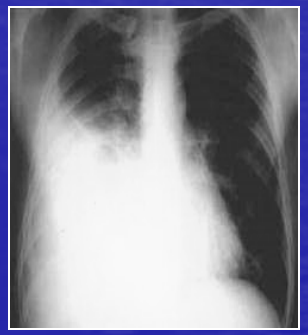
Cavitations



Pleural effusion



Nodular opacities

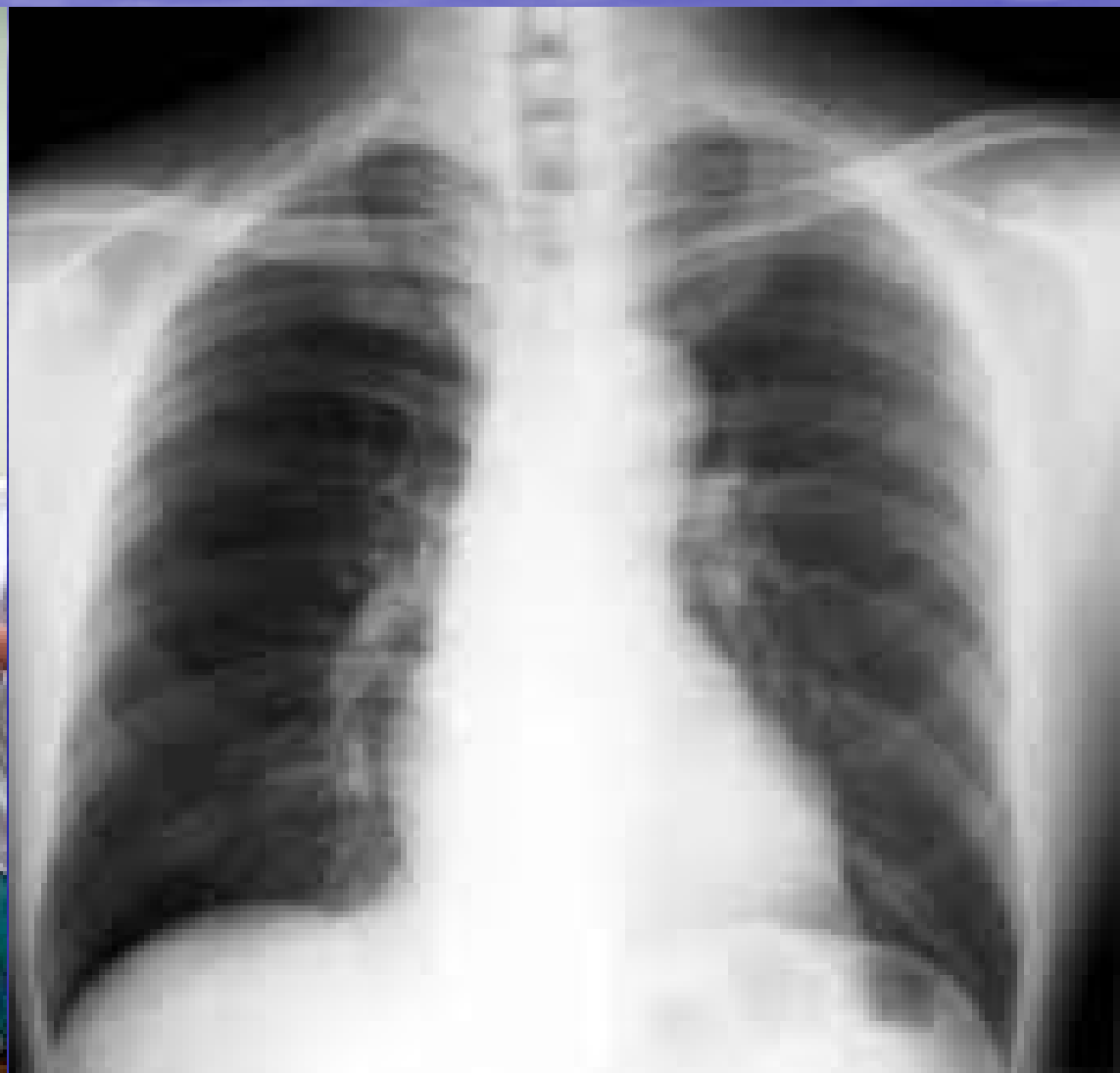


Malignancy

Fluorography

- a variant of radiography, is a convenient method for screening the population. The image in fluorography is made on a role film of a small size.

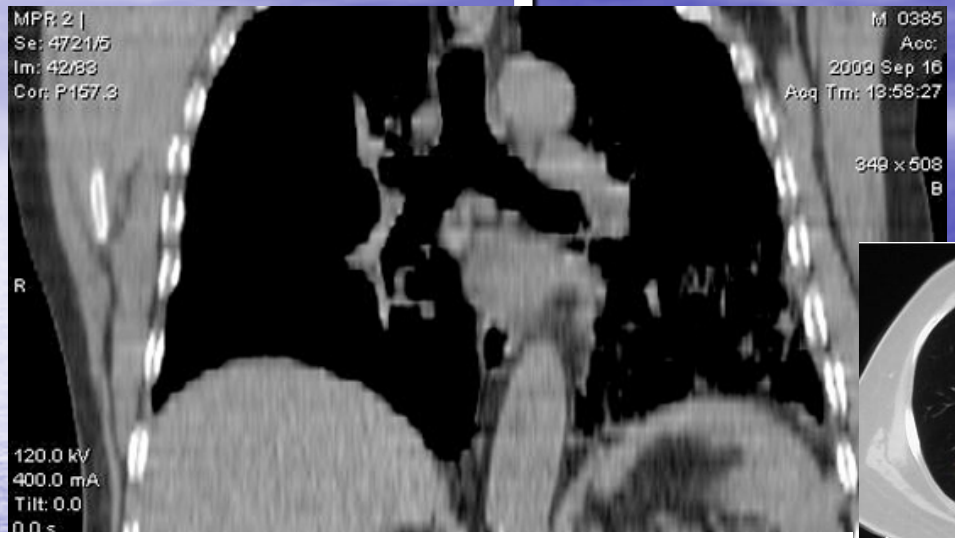
Fluorography

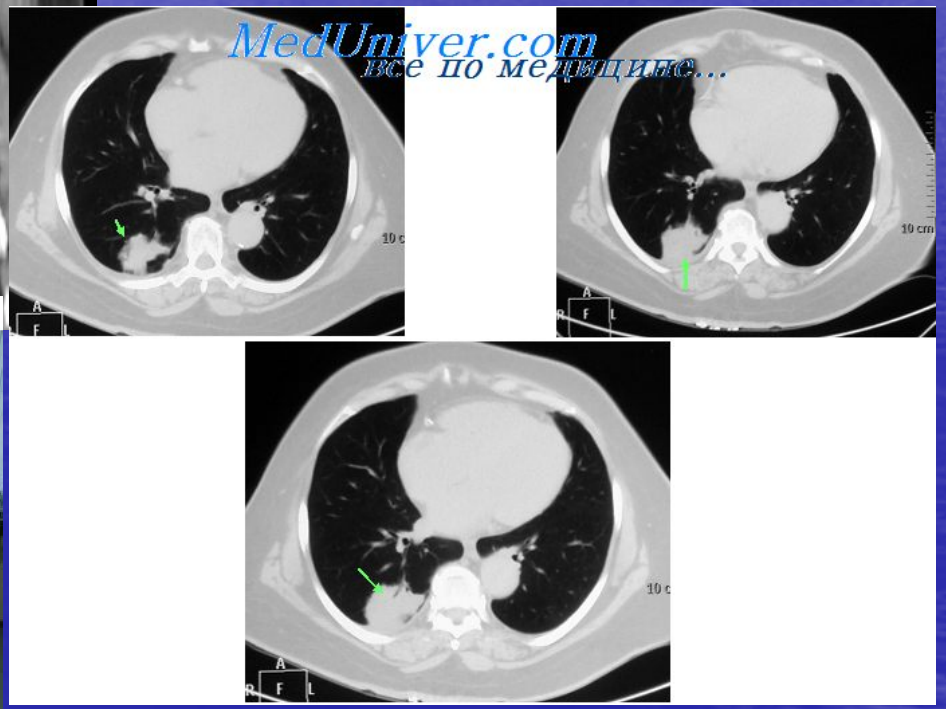


Computed tomography

- is cross-sectional scanning of the chest. This technique is more sensitive than plain radiography in detecting respiratory abnormalities. Computed tomography makes possible to distinguish more accurate tumors, small indurations, cavities and caverns in the lungs. This method is far better than radiographic studies at characterizing tissue density, distinguishing subtle differences in density between adjacent structures, and providing accurate size assessment of lesions. The use of computed tomographic scanning of the chest is very useful as a means of gathering quantitative information about specific radiographic findings.

Computed tomography





Magnetic resonance imaging

- provides a less detailed view of the pulmonary parenchyma as well as poor spatial resolution. However, magnetic resonance imaging offers several advantages over computed tomography in certain clinical settings: for imaging abnormalities near the lung apex, the spine, and the thoracoabdominal junction. Vascular structures can be distinguished from nonvascular without the need of contrast.

Magnetic resonance imaging

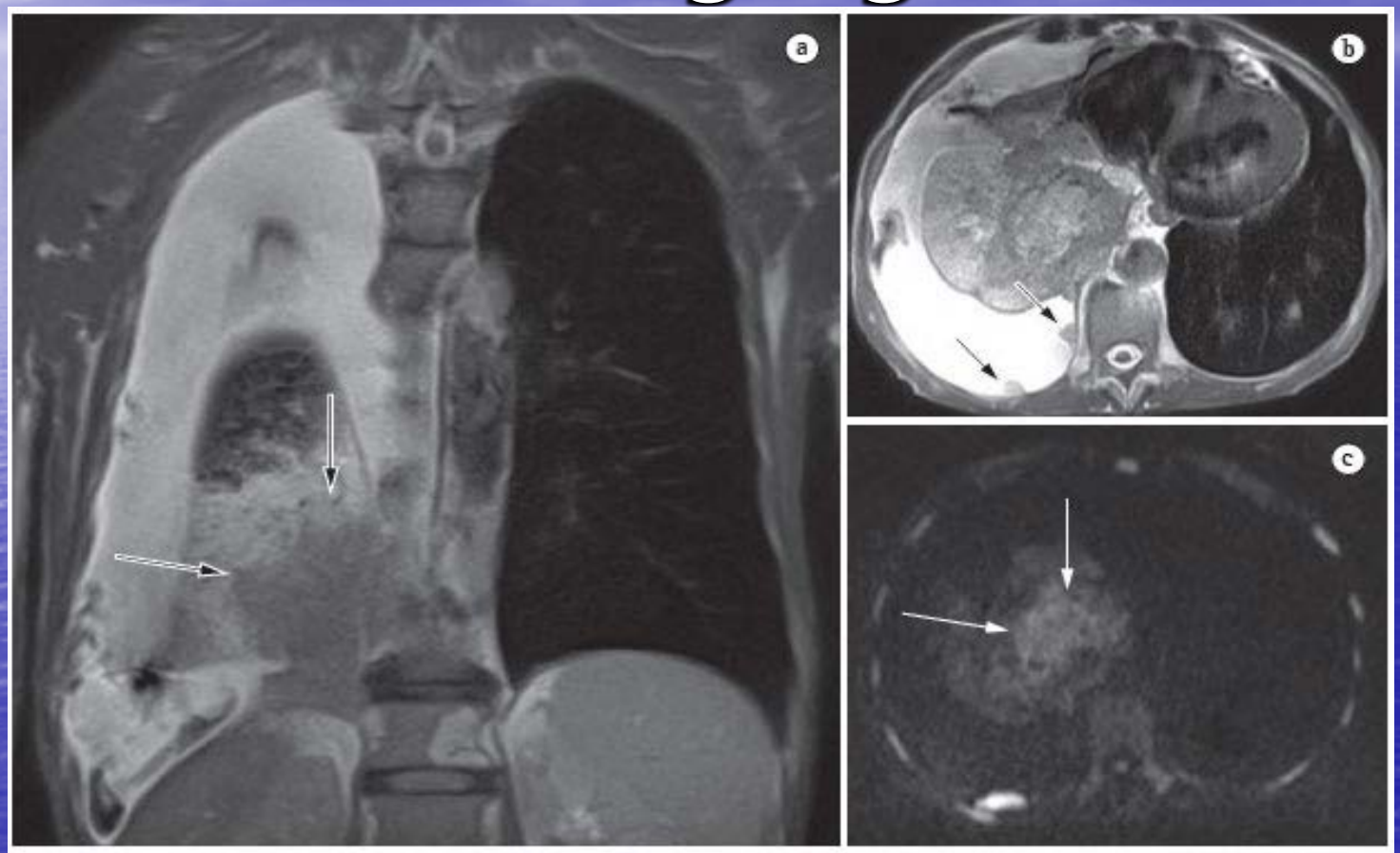


Figure 2 – In a, coronal T2-weighted magnetic resonance image showing a tumor with low signal intensity in the right lung and atelectasis with high signal intensity in the right lower lobe of the lung. Note the clear differentiation between the tumor and the atelectasis (arrows). In b, axial T2-weighted magnetic resonance image showing pleural thickening (arrows). In c, axial diffusion-weighted magnetic resonance image showing the tumor (arrows) and pleural thickening.

Magnetic resonance imaging

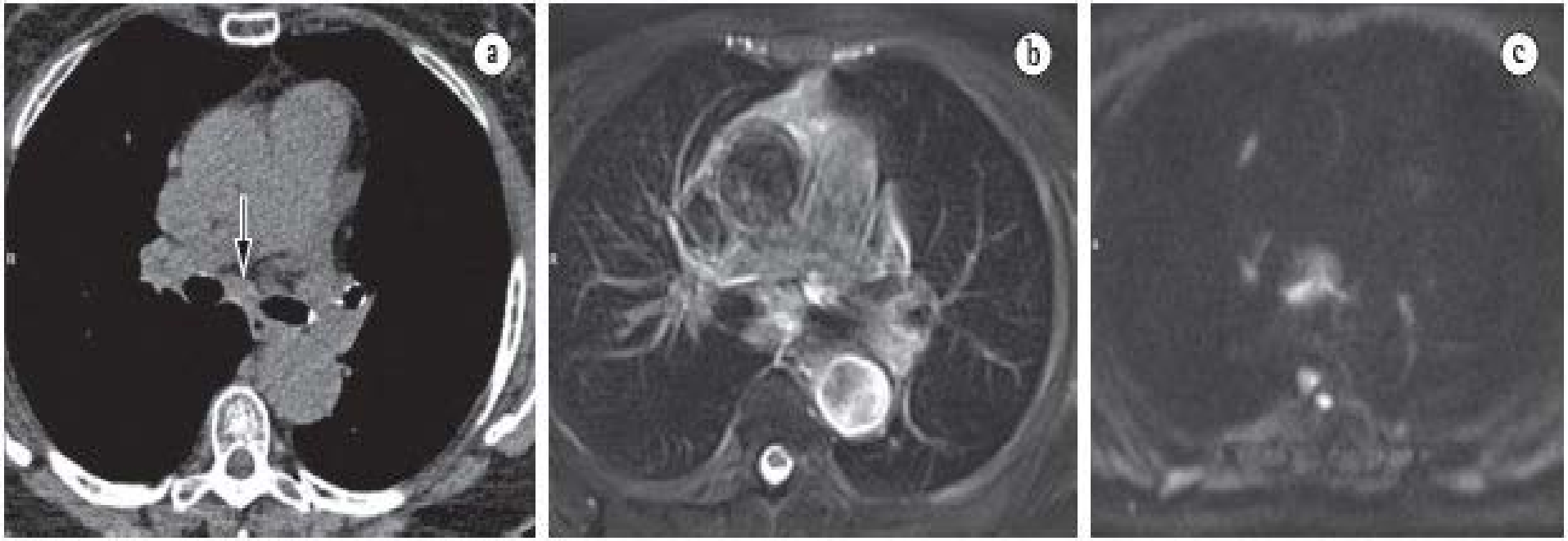
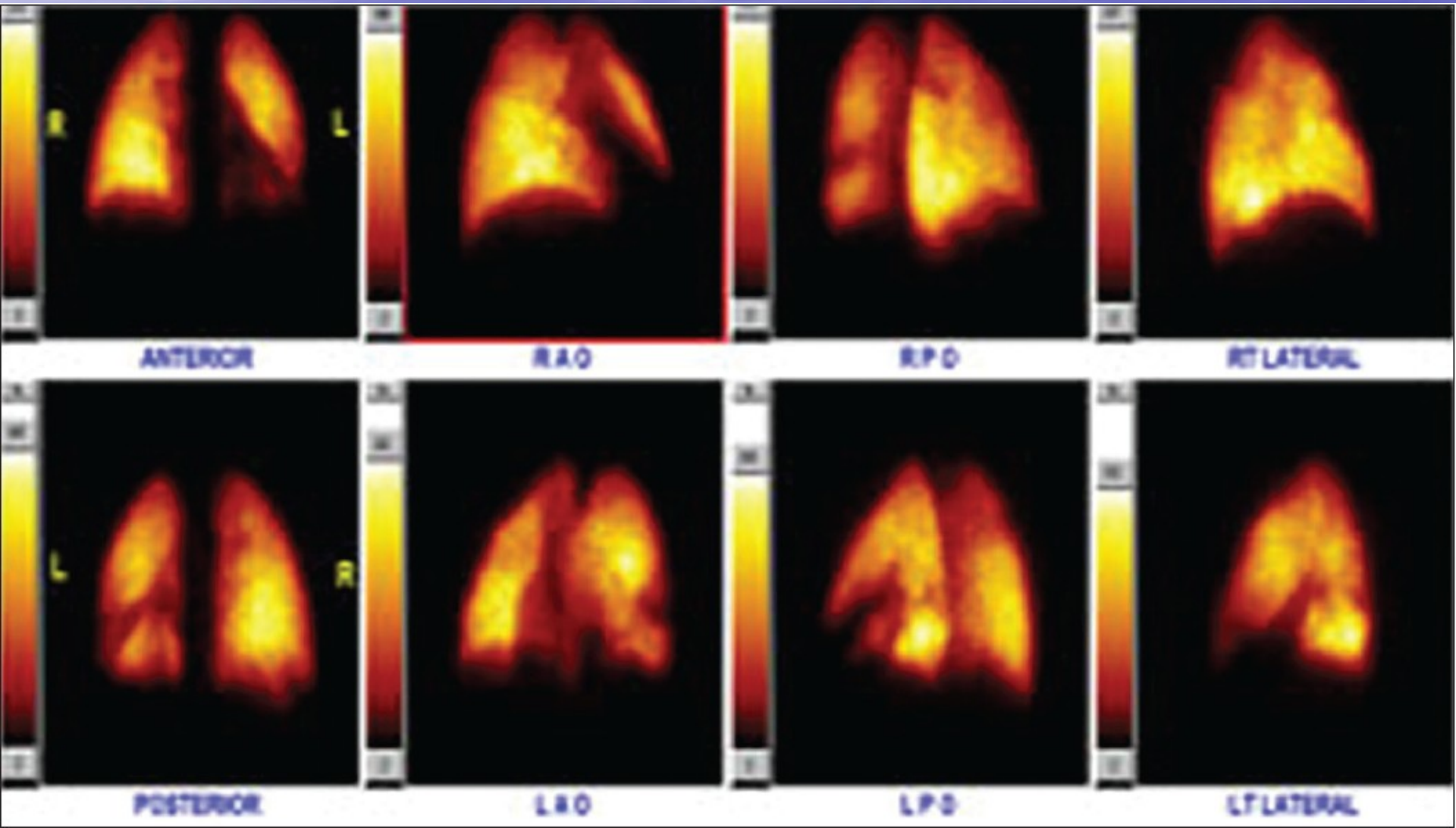


Figure 3 – In a, axial CT scan showing an 8-mm lymph node in the subcarinal chain (arrow). In b, axial T2-weighted magnetic resonance image with fat saturation, showing high signal intensity in the lymph node, suggesting metastatic disease. In c, axial diffusion-weighted magnetic resonance image showing the lymph node. Metastasis of small cell lung cancer was confirmed through biopsy.

Scintigraphic imaging

- Administered radioactive isotopes allow the lungs to be imaged with a gamma camera. The most common use of such method is ventilation-perfusion lung scanning performed for detection of pulmonary embolism. Radioactive isotopes can be injected intravenously; albumin macroaggregates labeled with technetium 99m is used for this purposes, or inhaled - radiolabeled xenon gas. When injected intravenously, the distribution of the trapped radioisotope follows the distribution of blood flow. When inhaled, radioisotopes can be used to demonstrate the distribution of ventilation.

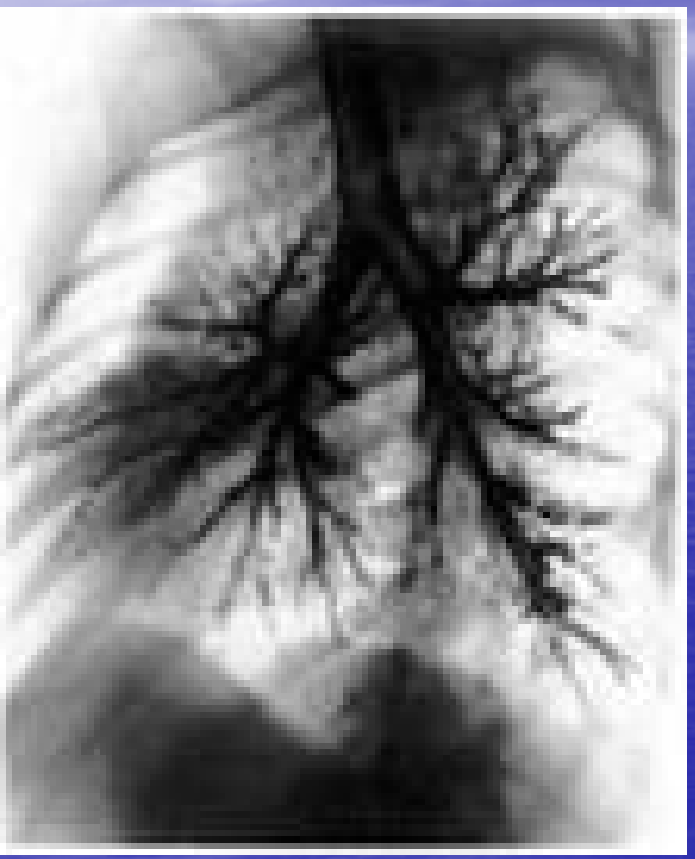
Scintigraphic imaging

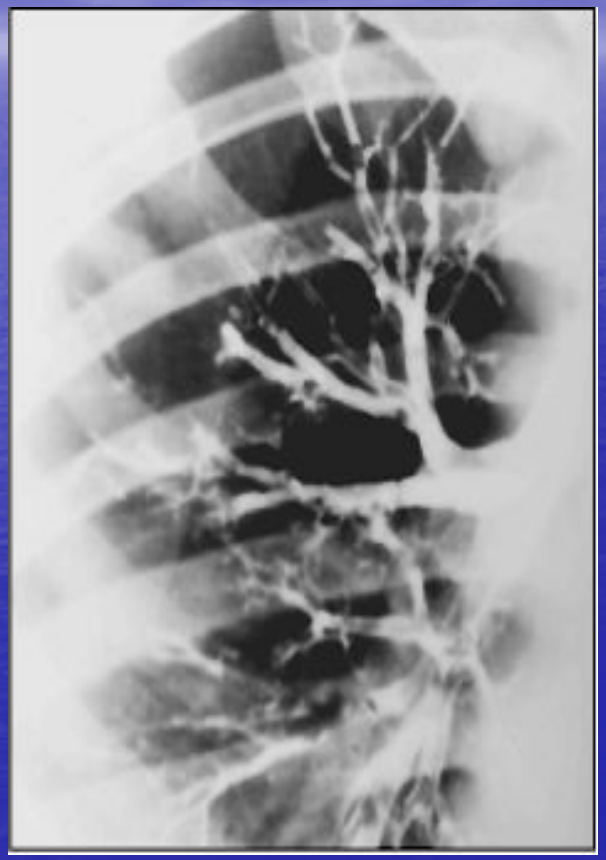


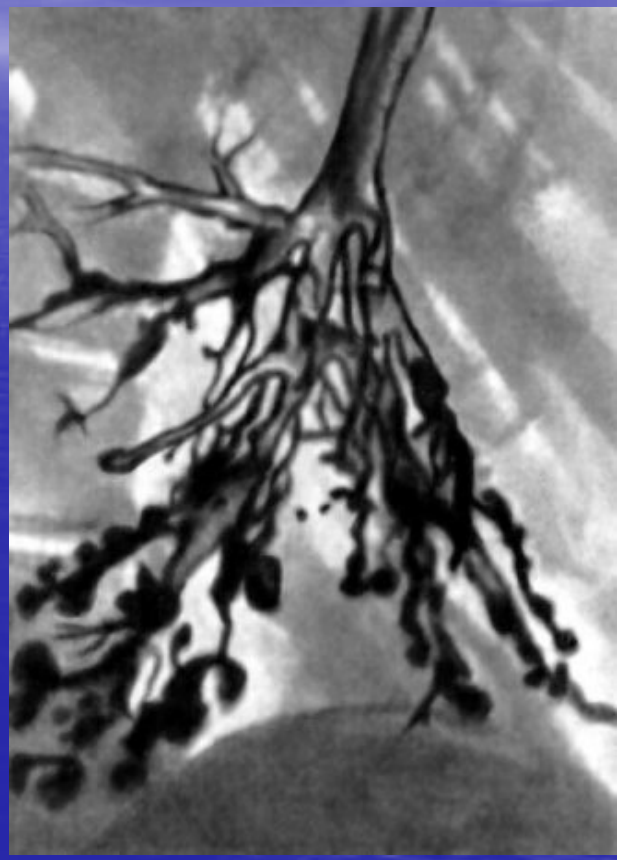
Bronchography

- is an integral part of the diagnosis evaluation of bronchi diseases. The standard technique requires the injection of contrast medium, usually iodolipol, into the bronchi lumen. This may be done through a catheter passed via the nose or mouth through the anaesthetized larynx. Then radiographs are taken, that give a distinct patterns of the bronchial tree. This procedure is of particular importance to the evaluation of bronchiectasis, abscesses, caverns in the lungs, and compression of the bronchi by tumor.

Bronchography



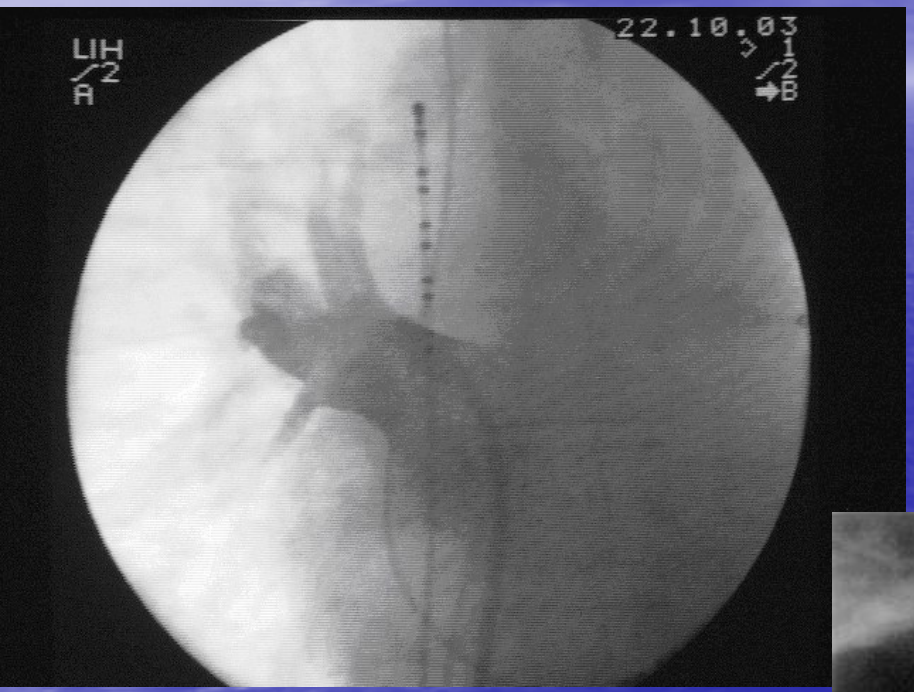


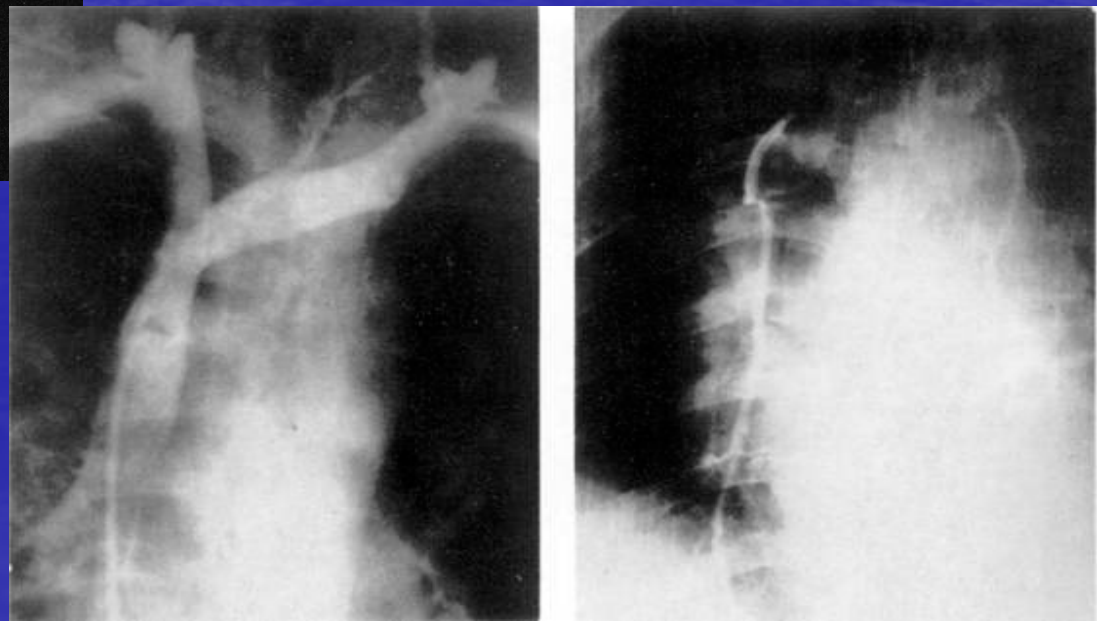


Pulmonary angiography

- The technique of the pulmonary angiography requires the injection of radiopaque contrast medium into the pulmonary artery through a previously threaded catheter. Radiographs are taken and the pulmonary arterial system can be visualized. Pulmonary angiography in pulmonary embolism demonstrates the consequences of an intravascular clot (a defect in the lumen of a vessel, or abrupt termination of the vessels). Suspected pulmonary arteriovenous malformation can be also visualized by this method.

Pulmonary angiography

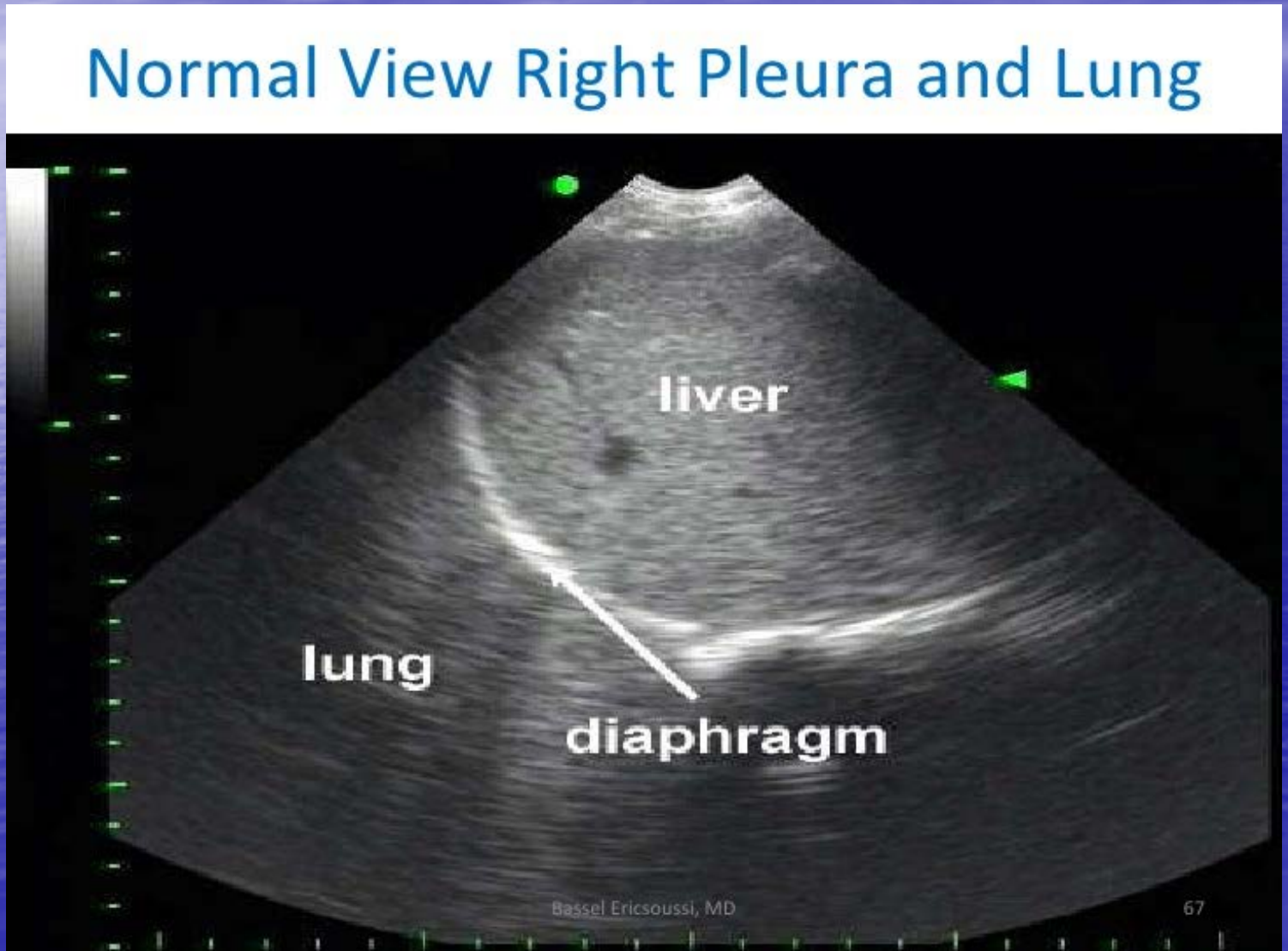




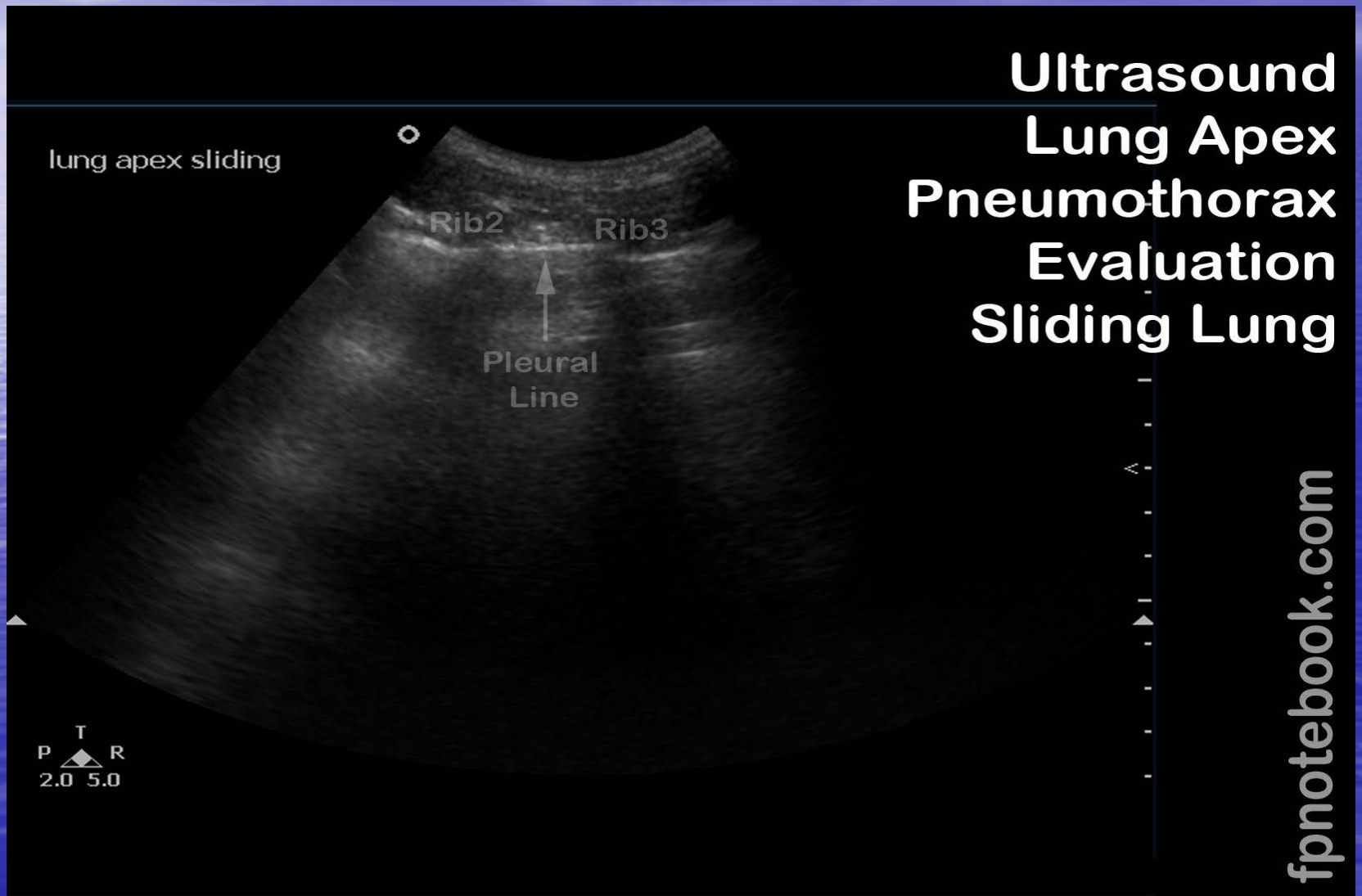
Ultrasound examination

- **Ultrasound** examination generally is not useful for evaluation of parenchyma of the lungs due to physical properties of the ultrasound waves: ultrasound energy is rapidly dissipated in air-containing pulmonary tissue. However, it is helpful in the detection and localization of pleural fluid and therefore is often used as a guide to placement of a needle for sampling of the liquid in thoracentesis.

Ultrasound examination



Ultrasound examination



II.2. Techniques for obtaining biologic specimens

Techniques for obtaining biologic specimens, some of which involve direct visualization of the part of the respiratory system, include

- ***Collection of the sputum***
- ***Thoracentesis***
- ***Bronchoscopy***

Collection of the sputum

- **Sputum** is pathological secretion expectorated from the respiratory tract. Sputum should be collected after thorough mouth and throat rinsing in the morning hours before breakfast. To collect sputum for more than 12 hours is not expedience because long-standing storage leads to rapid flora multiplying and autolysis of the formed elements.

Sputum Analysis

- Clinical sputum analysis includes: macroscopic,
- microscopic,
- bacterioscopic studies

Macroscopic study

In macroscopic study amount, character, color, consistence, and admixture in the sputum are assessed

- ***Amount of the sputum***
- Daily amount and amount of separate portions of the sputum depends on the character of the diseases from one side, and from the patient ability to expectorate from other one.
- *Scarce* amount of sputum observes in the patients with inflammation of the respiratory tract: in laryngitis, tracheitis, at initial stage of acute bronchitis, bronchial asthma out of attack, and in pneumonia.
- *Ample* amount of sputum (from 0.5 to 2 liters) secrete from the cavity in the lungs, in bronchus (bronchiectasis, pulmonary abscess), or in pulmonary edema due to significant transudate in bronchi.
- *Significant* amount of purulent sputum may forms layers on standing. Two-layers (pus and plasma) sputum is typical to pulmonary abscess, three-layers (pus, plasma, and upward mucus) - to bronchiectasis, pulmonary tuberculosis (in cavern presence).

Character of the sputum

- Character of the sputum is determined by its composition: mucus, pus, blood, and serous fluid.
- *Mucous sputum* consists of mucus - product of mucous glands. Such sputum is produced in acute bronchitis, at the peak of bronchial asthma attack.
- *Mucopurulent sputum* is mixture of mucus and pus, moreover mucus is predominant part, and pus in a form of traces or small bundles is observed. Mucopurulent sputum can be obtained in chronic bronchitis, trachitis, bronchopneumonia, and tuberculosis.
- *Puromucous sputum* contains pus and mucus; pus is predominant part of the sample. Such sputum arises in chronic bronchitis, bronchiectasis, pulmonary abscess, etc.
- *Purulent sputum without mucus admixture appears in opened to the bronchus pulmonary abscess, in* rupture of the pleural empyema to the bronchus lumen.
- *Mucous-bloody sputum* consists mainly of mucus with streaks of blood, and can be produced in inflammation of upper respiratory ducts, pneumonia, lung infarction, congestion in the pulmonary circulation, and bronchogenic tumor.
- *Mucopurulent bloody sputum* contains uniform mixed mucus, blood and pus. Such sputum arises in tuberculosis, bronchiectasis, actinomycosis of the lungs, and bronchogenic tumor. *Bloody sputum* observes in pulmonary hemorrhage: tuberculosis, wounds of the lungs, actinomycosis, and bronchogenic tumor).
- *Serous sputum* is plasma of the blood that passes to the bronchi in edema of the lungs.
- *Serous blood stained foamy sputum* is characteristic of pulmonary edema, when not only plasma, but also erythrocytes penetrate from pulmonary alveoli to the bronchi.

Color of the sputum

- Color of the sputum depends on its character, and also by inspirited particles. Predominance of one of substrates gives sputum corresponding hue.
- *Mucous* sputum is usually *colorless, transparent,* and *glass-like.*
- *Mucopurulent* sputum is *glass-like with yellow tint* as its main component is mucus, on the background of which pus traces is observed.
- *Puromucous* sputum is *yellow-greenish* due to predominance of pus.
- *Purulent* sputum is *greenish-yellow* due to the pus.
- *Mucous-bloody* sputum is *glass-like* (due to predominance of mucus) with pink or rusty tint (due to the presence of changed or unchanged blood pigment - hematin). *Rusty sputum* is characteristic of lobar pneumonia, when blood is not expectorated immediately from the respiratory tract and stays there for sometimes. The hemoglobin converts into hemosiderin to give a rusty hue to the sputum.
- *Mucopurulent bloody* sputum is *glass-like* (predominance of mucus), with *yellow traces* (pus), with *red* color *streaks* (fresh blood) or rusty hue (changed blood pigment).
- *Bloody* sputum is of *red* color. Peculiarity of the pulmonary hemorrhage is the presence foamy secretions due to the air bubbles.
- *Serous* sputum is transparent-yellow (color of penetrated blood plasma), and foamy.
- Sputum containing foreign admixtures has color of these admixtures: white in millers, black - in miners, blue in inspiration of ultramarine paint, etc.

Consistency of the sputum

- Consistency tightly connected with sputum character and may be tenacious, thick, and liquid.
- *Tenacity* of the sputum depends on the presence of mucus and amount of it. For example, in bronchial asthma, acute and chronic bronchitis, bronchopneumonia consistency of the sputum is tenacious
- *Thickness* of the sputum is caused by the presence of the large amount of the formed elements - leucocytes, various epithelium cells (bronchiectasis, chronic bronchitis, pulmonary abscess, and tuberculosis).
- *Liquid* sputum can be in large it amount, when the plasma is significant composing component (pulmonary hemorrhage, pulmonary edema).

Odor of the sputum

- Fresh sputum is usually odorless. Unpleasant smell can appears in protracted conservation of the sputum. Foul odor of freshly expectorated sputum can be caused by it retaining in bronchi and cavities in the lungs due to putrefactive decomposition of proteins. Unpleasant odor sputum can be had in chronic bronchitis with bad bronchi drainage, strong smell - in bronchiectasis, pulmonary abscess, sometimes in tuberculosis, in malignant tumor with necrosis, fetid (putrid) odor is characteristic of tissue decomposition - gangrene.

Admixture

The following elements can be seen in the sputum by an unaided eye:

- Curschmann spirals - has diagnostic significance in bronchial asthma;
- *Fibrin clots* -has significance in fibrinous bronchitis, and rarely in lobar pneumonia;
- *Lentil or rice-like bodies (Koch's lens)* - observe in sputum in cavernous tuberculosis;
- *Purulent plugs (Dittrich's plugs)* - occurring in bronchiectasis, gangrene, chronic abscess, and fetid bronchitis.
- *Diphtherias films;*
- *Necrotic pieces of the lungs* - observes in pulmonary gangrene and abscess;
- *Pieces of the pulmonary tumor,*
- *Actinomycete;*
- *Lime grains* - in decomposition of old tubercular foci;
- *Echinococcus bubbles* - observe in sputum in rupture of echinococcus cyst in the lung and expectoration of plentiful amount of colorless transparent fluid;
- Foreign bodies.

Microscopic study
Cellular elements

- *Squamous epithelium* - is epithelium of the oral cavity mucous membrane , nasopharynx, larynx, and vocal chords. Single cells of squamous epithelium are always observed in sputum, and have no diagnostic significance.
- *Columnar ciliated epithelium* - is epithelium of bronchi and trachea mucous membrane. It is contained in small quantity in any sputum, but its large amount is found in acute bronchitis, in bronchial asthma attack, and in acute infections of upper respiratory tract.
- *Alveolar macrophages.* Insignificant quantities of alveolar macrophages are present in any sputum, large amount —-in various inflammatory processes of bronchi and pulmonary tissue: pneumonia, bronchitis, and professional diseases of the lungs. Siderophages arise in the sputum of the patients with congestion in the pulmonary circulation, especially in mitral stenosis; in lung infarction, acute lobar pneumonia.
- *Leucocytes* observe in any sputum; in mucous - single, and in purulent - all microscope vision area. Their large amount is characteristic of inflammatory and especially purulent process. Sometimes among leucocytes eosinophils can be identified. *Eosinophils* are the large leucocytes with uniform large lustrous grains. Eosinophils presence in the sputum suggest bronchial asthma or chronic bronchitis with asthma component.
- *Erythrocytes* Single erythrocytes can be visible at any sputum; in large quantity observed in bloody sputum: pulmonary hemorrhage, lung infarction, congestion in the pulmonary circulation, etc.
- *Malignant tumor cells.* Sputum with such cells is underwent then special cytological study. Tumor cells are found in the sputum especially when tumor degrades or growth endobronchially.

Microscopic study
Fibrous elements

- *Curschmann spirals* - are found in the sputum of patients with respiratory pathology accompanied by bronchospasm: bronchial asthma, bronchitis with asthmatic component, bronchial tumor.
- *Elastic fibers* presence in the sputum indicates degradation of the pulmonary tissue: in tuberculosis, pulmonary abscess, and tumor.
- *Fibrin fibers* - are found in fibrinous bronchitis, tuberculosis, actinomycosis, and lobar pneumonia.

Microscopic study
Crystal elements

- *Charcot-Leyden crystals.* Presence of Charcot-Leyden crystals in the sputum is characteristic of the bronchial asthma even not in attack, and between attacks period. Less frequently they can be observed in the sputum of patients with eosinophilic bronchitis, lobar pneumonia, and bronchitis.
- *Hematoidin crystals.* These crystals are the product of hemoglobin degradation, and are formed in hemorrhage, and necrosis tissue.
- *Cholesterol crystals* - observed in the sputum of the patients with tuberculosis, tumor, pulmonary abscess, etc.
- *Fatty acid crystals* - are frequently found in purulent sputum (Dittrich's plugs), produced in sputum congestion in the cavity (abscess, bronchiectasis).

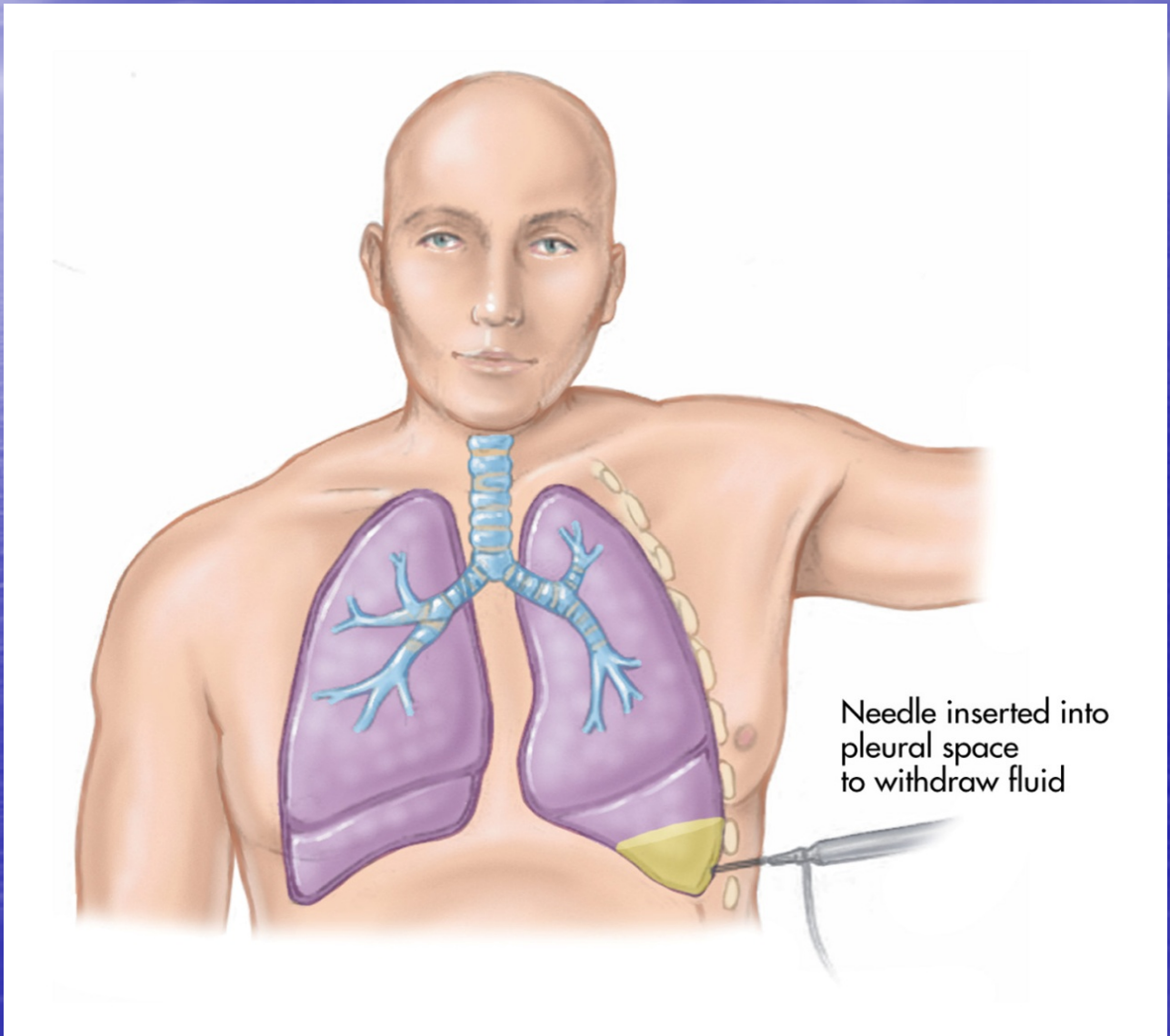
Bacterioscopic study

- *Tuberculosis mycobacteria* presence in the sputum indicates tuberculosis.
- Pneumococcus, streptococcus, staphylococcus, Pfeiffer's bacillus-all these microorganisms occur in small amount in the sputum of the respiratory ducts of healthy persons and only become pathogenic under the certain unfavorable condition to cause pneumonia, lung abscess, bronchitis.
- Microbes, their virulence and drug-resistance can be identifying by bacterioscopic study

II.3. Thoracentesis (pleurocentesis)

- is performed to sampling of pleural fluid for diagnostic purposes; in the case of a large effusion to remove fluid from the pleural cavity; and, whenever necessary, to administer drugs.
- *Technique.* The patient should sit facing the chair back with arms crossed on the chest. The puncture is done in posterior axillary line at the preliminary determined by percussion point of maximum dullness - usually 7th or 8th interspaces at the upper edge of the underlying rib (at the lower edge intercostals vessels are located). Previous the place of the puncture is treated with alcohol iodine and then anesthetized. Sampling is obtained by 10 ml syringe with a thick and long needle. For diagnostic purposes 50-150 ml of fluid is taken, and then puncture site after needle removing is treated with a
- 5 % iodine solution.

Thoracentesis (pleurocentesis)



Thoracentesis

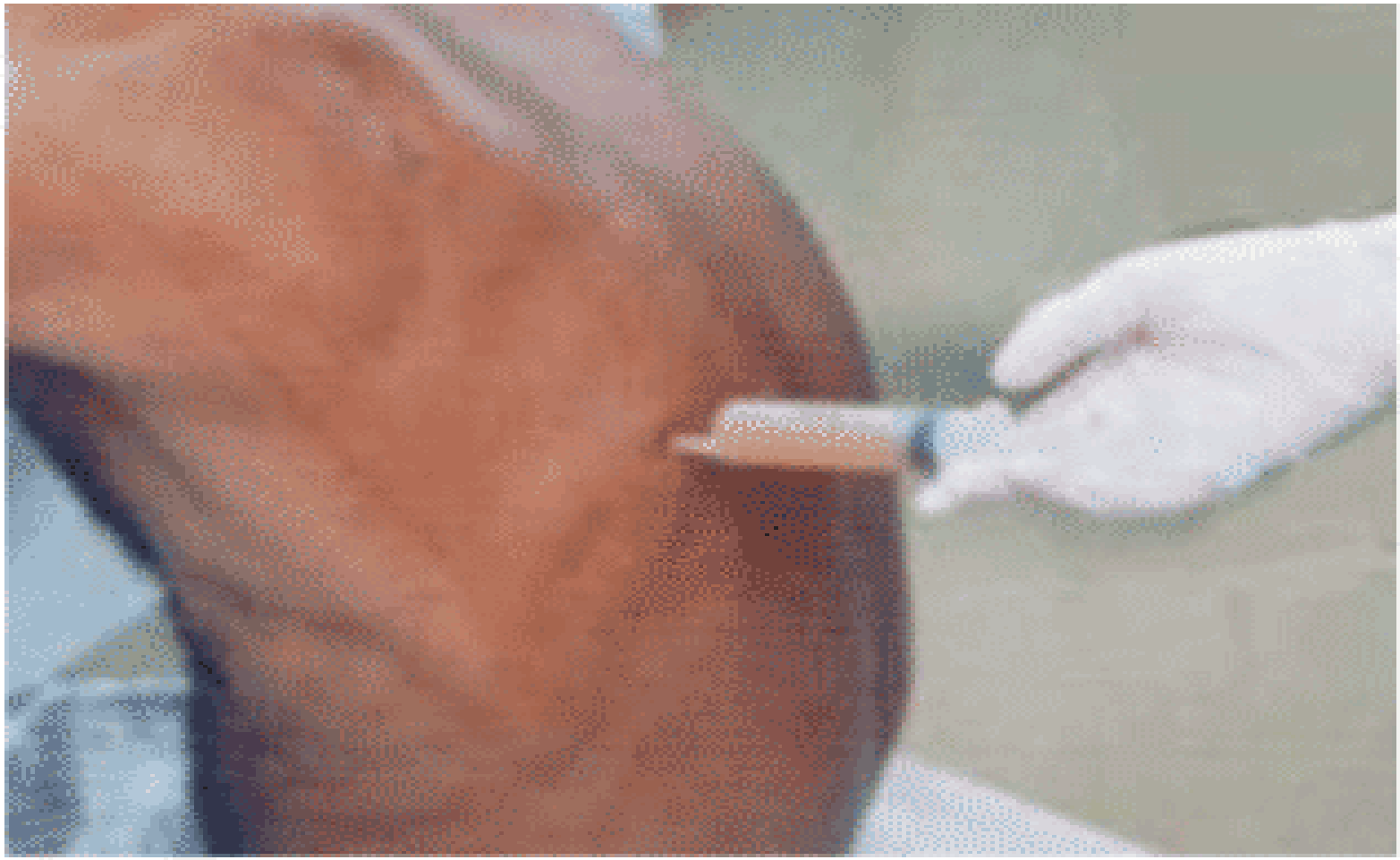


Figure 1. Diagnostic thoracocentesis producing purulent pleural fluid

Study of the Pleural Fluid
Macroscopic study

- Diagnostic sampling allows the collection of liquid for macroscopic, chemical, microscopic, and bacteriologic studies.
- **Macroscopic study**
- In macroscopic study character, color, consistency, and relative density of the pleural fluid are assessed.
- ***Character.*** The pleural fluid is divided into two large groups transudates and exudates.
- ***Transudates*** - are non-inflammatory fluid that occurs in disorders of lymph and blood circulation in the lungs (for example in heart failure).
- ***Exudates*** - are of inflammatory character, and occur in inflammatory affection of the pleura. Exudates can be:

  - *Serous* and *serofibrinous* in exudative pleurisy, rheumatic pleurisy;

  - *Seropurulent* and *purulent* in bacterial pleurisy;

  - *Hemorrhagic* more frequent in traumatic pleura affection, less frequently in infarction of the lungs, and tuberculosis;

  - *Chylous* in congestion of lymph or destruction of the thoracic duct by a tumor or an injury;

  - *Chylous like* in chronic inflammation of serous membrane as a result of cellular degradation with fatty degeneration;

  - *Putrefactive* in wounds associated with putrefactive flora.

Study of the Pleural Fluid
Macroscopic study

- ***Transparency*** of pleural fluid depends on its character. Transudates and serous exudates are transparent and slightly opalescent. Another exudates in most cases are turbid that can be caused by abundance of leucocytes (seropurulent, purulent), erythrocytes (hemorrhagic), fat drops (chylous), and cellular detritus (chylous-like)
- ***Color*** of the pleural fluid is also depends on its character. Transudates have pale yellow color, serous exudates - from pale to golden yellow, in jaundice - deep yellow. Purulent and putrefactive effusions are of grayish-white or greenish-yellow color; in blood admixture they can be reddish or more frequent - grayish-brown. The color of hemorrhagic exudates varies from pink to dark red or even brown depending on amount of blood in the fluid, and also on the time of its retention in pleural cavity. Chylous exudates resemble thin milk.

Study of the Pleural Fluid
Macroscopic study

- ***Consistency*** of pleural fluid in transudates and exudates is usually liquid. Only purulent exudates are thick and cream-like. In old encapsulated empyema the pus can be of puree consistency with grains and fibrin flakes.
- ***Odor.*** The pleural fluid as a rule odorless. Only putrefactive exudates have unpleasant, offensive smell due to decomposition of protein by anaerobic enzymes.
- ***Relative density*** of the pleural fluid is determined by urometer. Relative density of transudates is less than of exudates. Relative density of transudates varies from 1005 to 1015 g/cm2; relative density of exudates is usually higher than 1015 g/cm2 (1018-1022).

Study of the Pleural Fluid
Chemical study

- ***Protein*** level in the pleural fluid is assessed by refractometer. The relative density and protein contents are the main criteria that allow the effusion to be classified as either exudative or transudative. Protein content in transudates is 5-25 g/1 (0.5-2.5 %), in exudates - more than 30 g/1 (3-8 %). Qualitative protein content is also of great diagnostic significance for differentiation between transudates and exudates.
- Correlation of protein fractions of exudates is about the same as of blood serum; albumin-globulin ratio is 0.5:2; the fibrinogen contents is lower than that of blood (0.05-0.1 %) but its quantity is sufficient to clot spontaneously.
- In transudates albumin-globulin ratio is 2.5:4; albumin prevail while fibrinogen is absent or almost absent (therefore transudates does not clot).

Differentiation between *exudate* and *transudate*

Parameter	exudate	transudate
Total protein	<30	>30 g/L
Pleural/serum protein ratio	<0,5	>0,5
LDH	<200	>200 mcmol/L
Pleural/serum LDH ratio	<0,6	>0,6
Cholesterol	<45	>45 mg/dl

Study of the Pleural Fluid
Chemical study

- ***Rivalta's reaction*** was proposed for differentiation between transudates and exudates. In a cylinder filled with 100-150 ml of distillated water and 2-3 drops of acetic acid, 1-2 drops of the punctate are added. Exudates drop cause turbidity in a form of white cloud (or like cigarette smoke), which sinks to the bottom of a cylinder (positive reaction). Transudates drops or do not leave a cloudy trace, or it can be insignificant and quickly disappears (negative reaction).
- ***Lucaerini test.*** To 2 ml of 3 % hydrogen peroxide solution placed on a watch glass (against a black background) one drop of punctate is added. Exudates drop leaves opalescence turbidity (positive reaction); transudates drop cause no turbidity (negative reaction). In both reactions the cause of turbidity is the presence of seromucin - mucopolysaccharide complex in exudates. In transudates seromucin is absent.

Study of the Pleural Fluid
Microscopic study

- Microscopy allows study cellular composition of the pleural precipitate obtained by centrifuging. A native preparation before staining is recommended to study.
- **Native preparation**
- Study of the native preparation allows assessing quantity of cellular elements, qualitative content of precipitate, presence of suspected atypical cells, etc. In native preparation the following elements can be revealed.
- ***Erythrocytes*** in small quantity can be present in any pleural fluid because of puncturing of the tissues. In transudates and serous exudates insignificant amount of erythrocytes is detected; in hemorrhagic exudates in paticiilN with tumor, infarction of the lung, injuries, hemorrhagic diathesis llny usually covcred all vision area.
- ***Leucocytes*** in a small quantity (to 15 in vision field) are revealed in ti iinsiulutcs and in a large amount - in fluid of inflammatory genesis (especally in purulent exudates). Qualitative content of leucocytes are assessed.
- ***Mesothelium cells*** recognized by their large size (to 50 mcm). In canceromatosis, and sometimes in tuberculosis.
- ***Tumor cells*** In exudafes sometimes contain cells suspected for tumor. In absence of distinct cellular borders, polymorphism of their size etc. The nature of tumor cells is difficult to assess in native preparation.

Stained preparation

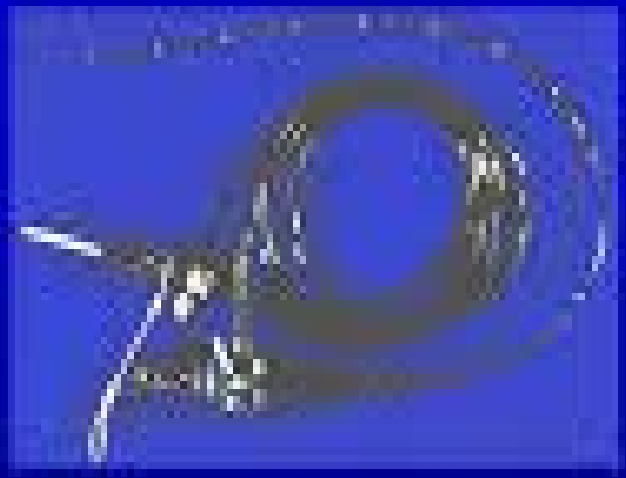
- Cytological picture of the pleural fluid is different and depend on character, etiology and duration of liquid presence. In stained preparation the following cellular elements are differentiated.
- ***Neutrophils*** are present in exudates of any etiology. In serous exudates of tubercular or rheumatic etiology they are found in significant amount at initial stage of exudates development (approximately during first 10 days), and then their amount gradually decreases - replaced by lymphocytes. Long-standing neutrophilia indicates grave course of disease; appearance of predominant amount of neutrophils is a sign of transition of serous exudates to purulent. In purulent exudates neutrophils are prevalent cells.
- ***Lymphocytes*** are obligatory elements of any exudates. They are predominant in cytological picture of serous exudates at a peak of clinical manifestation (80-90 % of all leucocytes).
- ***Eosinophils*** are contained sometimes in serous and hemorrhagic exudates of various etiology: in rheumatic, tubercular, tumor exudates, composing 20-80 % of all cellular elements.
- ***Macrophages*** resemble morphologically monocytes, but differ from they by the presence in the cytoplasm of phagocytosis products.
- ***Mesothelial cells*** are always present in transudates, at initial stage and at the period of reparation of exudates, in significant amount in canceroma- tosis of serous membrane. In long-standing and sometimes in acute pleural affections and also in transudates coarse vacuolized mesothelial cells acquire many properties of blastoma cells that can be lead to mistakes.
- ***Malignant cells.*** It is very difficult to differentiate between tumor and mesothelial cells. Luminescent microscopy helps in this situation: when stained with rhodamine, acridine orange or some other fluorochromes, tumor cells luminescence differently than normal cells.

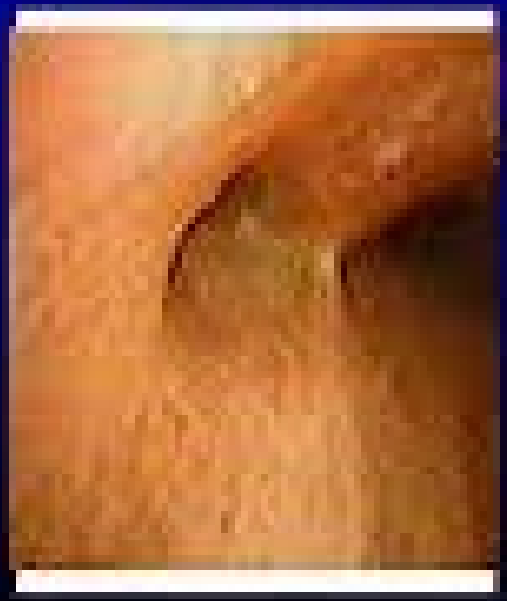
Bacterioscopic study

- *Transudates* as a rule are sterile in microbiological studies, but they can be infected during repeated thoracentesis.
- *Exudates* may be sterile, for example in rheumatic pneumonia, tumor of the lung, and lymphosarcoma. Bacterioscopy of serous exudates in tuberculosis rare gives positive results. More effective method for tuberculosis mycobacteria detection is inoculation to guinea pigs. In pleurisy caused by pyogenic flora the bacteria can be detected in Gram-stained smears. Pneumococcus, streptococcus, staphylococcus, enterococcus, Klebsiella organisms, Pfeiffer's bacillus, colibacillus can be found in bacterioscopic study. Microbes are tested for antibiotics sensitivity in order to prescribe a correct treatment.
- Characteristics of the pleural fluid obtained in thoracentesis

Endoscopic studies
Bronchoscopy

Bronchoscopy → For "live" procedures





video from bronchoscope

$I_t(x,y)$

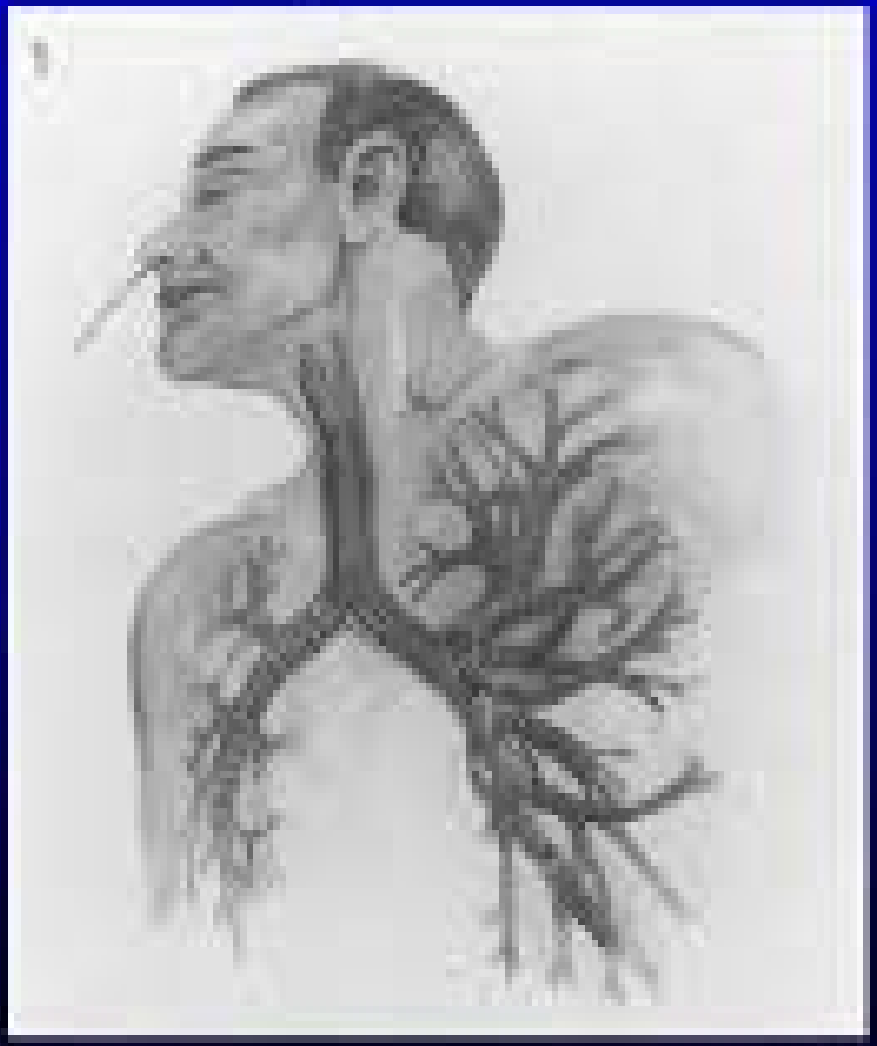
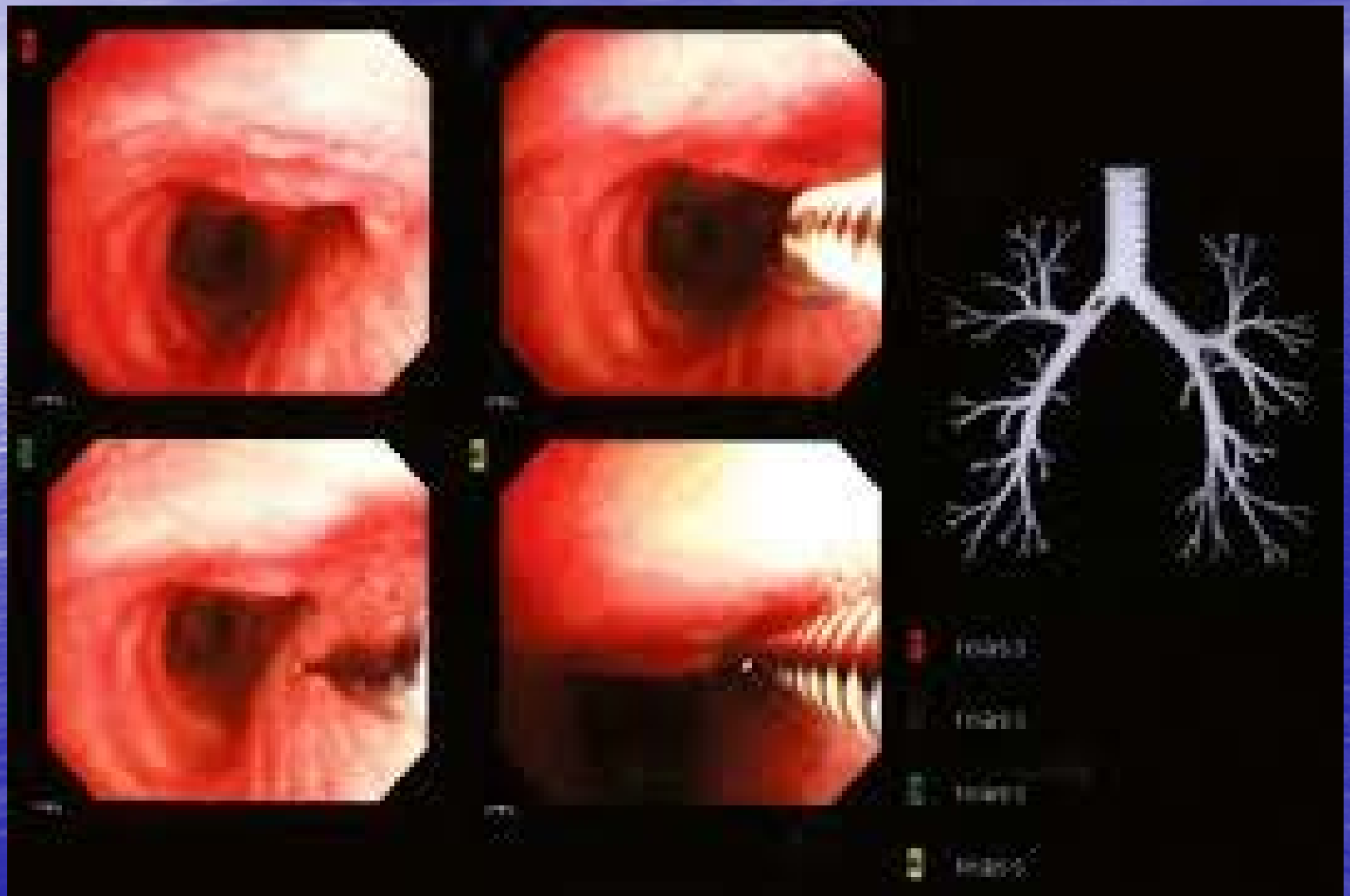


Figure 19.4, Wang/Mehta '93

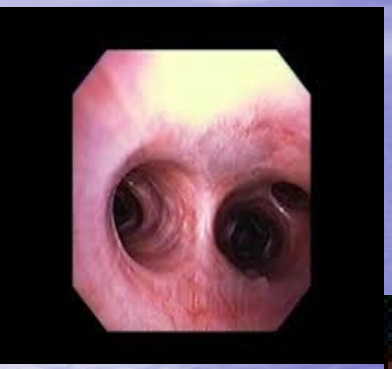
Endoscopic studies
Bronchoscopy

- **Endoscopic studies** include bronchoscopy and thoracoscop**y.**
- **Bronchoscopy** is used to direct visualization of the tracheobronchial tree. Bronchoscopy is now performed almost exclusively with flexible fiberoptic bronchoscope. The upper airways mucosa is preliminary anaesthetized by 1-3 % dicaine solution. The bronchoscope is passed through the nose, between the vocal cords, and into the trachea. The ability to flex the scope makes it possible to visualize virtually all airways to the level of subsegmental bronchi. Samples from airway lesions can be taken by biopsy. Using a small brush or biopsy forceps at the end of a long cable inserted through a channel of the bronchoscope, allows recovery of cellular material or tissue for analysis by standard cytological and histopathological methods. Photography can also be made whenever necessary. The bronchoscopist is able to identify endobronchial pathology including erosions and ulcers of the bronchial mucosa, tumors, granulomas, bronchitis, foreign bodies, and sites of bleeding. The bronchoscope may provide the opportunity for treatment as well as diagnosis. For example, an aspirated foreign body may be retrieved with an instrument passed through the scope, and bleeding may be controlled with a ballon catheter similarly introduced. Bronchoscopy is used for extracting polyps, treating bronchiectasis, and centrally located abscesses of the lungs.

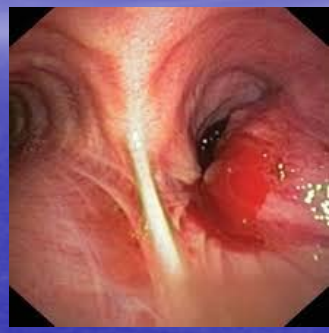
Bronchoscopy

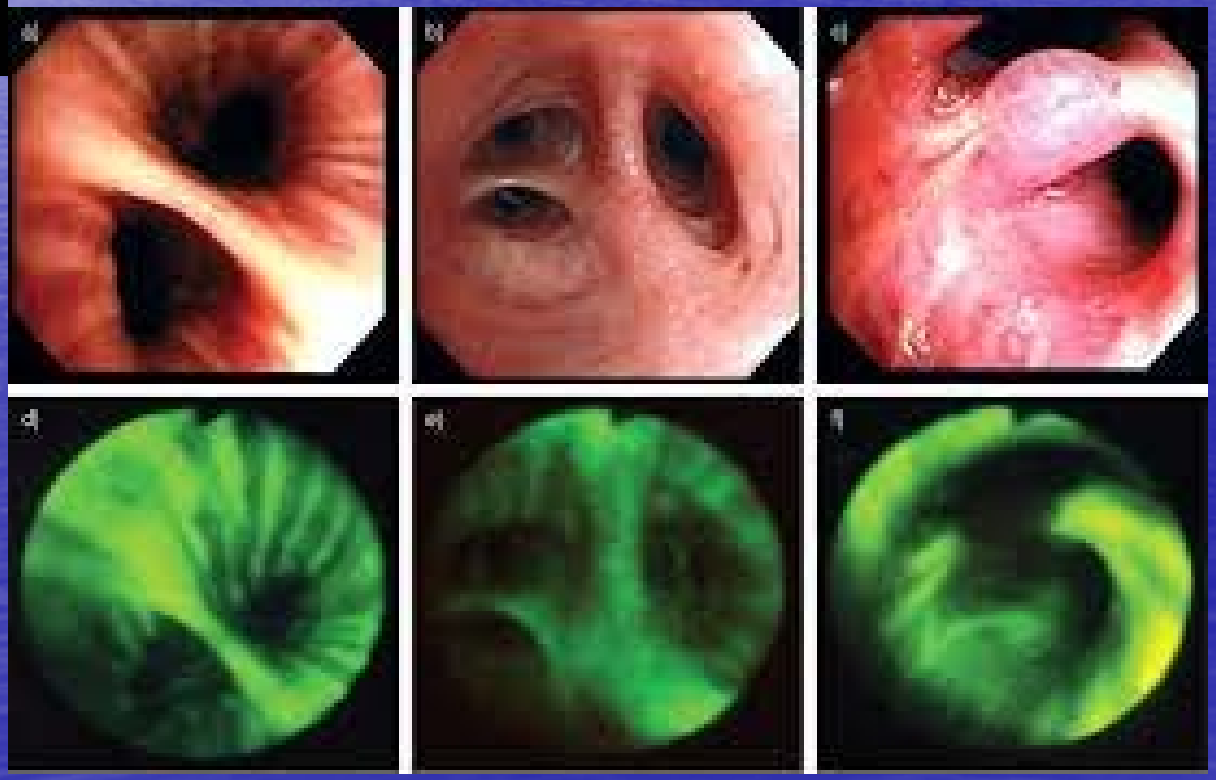


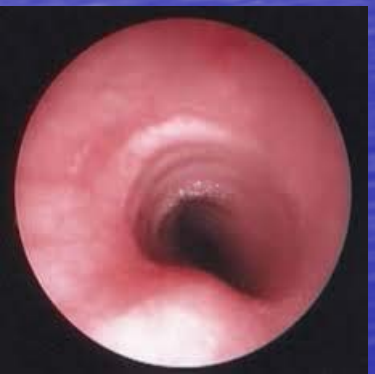
Bronchoscopy

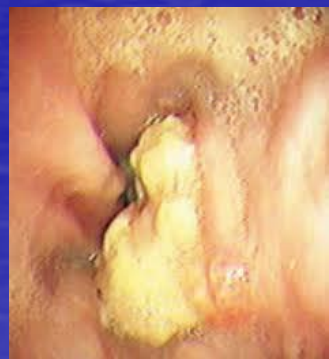


A comparison of video and autofluorescence bronchoscopy





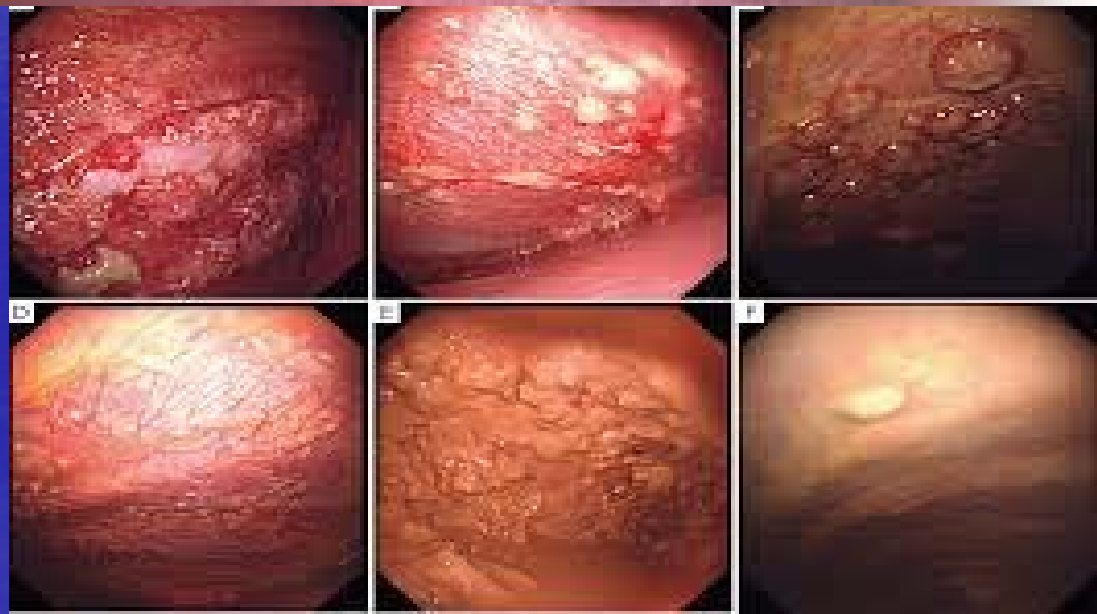




Endoscopic studies *thoracoscopy*

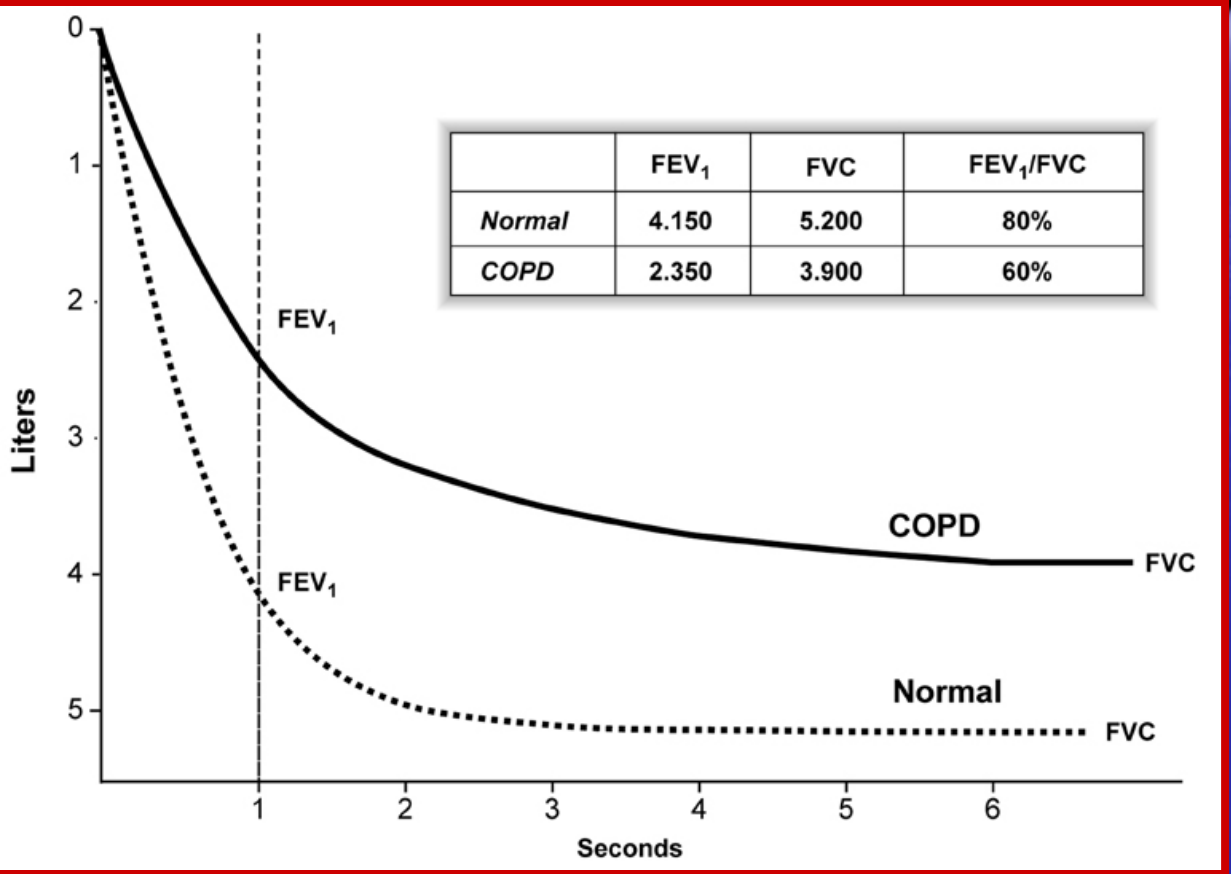
- **Thoracoscopy.** Recent advances in video technology have allowed the development of thoracoscopy for examination of the visceral and parietal pleura, and for severance of pleural adhesion bands that may interfere with placing artificial pneumothorax. This procedure, done under general anesthesia, involves the passage of a rigid scope with a distal lens through a trocar inserted into the pleural space through separate small intercostals incisions.

Thoracoscopy



II.4. Methods for functional studies

Tests of ventilatory function



	FEV_1	FVC	FEV_1/FVC
Normal	4.150	5.200	80%
COPD	2.350	3.900	60%

Tests of ventilatory function

- Various indices are used to assess lung ventilation. Their size and relationship to each other give clues to underlying functional disorder. How normal a volume is will depend on what we predict it should be for that person's height, weight, sex, and age.
- The total lung capacity is broken down into its various volumes.

Tests of ventilatory function

- The ***respiratory volume*** **(RV)** or tidal volume is the total air volume of cach normal resting breath (inspiration and expiration).
- RV varies from 300 to 900 ml; 500 ml on the average. It consists of two parts:
- ***Alveolar volume***: the volume of gas, which reaches the alveoli - the volume of alveolar ventilation;
- ***Dead space volume*** (about 150 ml): the volume of gas, which passes the lips and is present in the larynx, trachea, and bronchi, but does not take part in gas exchange. However, the air of the dead space is mixed with I lie inspired air to warm and moisten it, which makes it physiologically important.
- The ***expiratory reserve volume*** **(ERV)** is the volume of air that can be expired after normal expiration - 1500-2000 ml.
- The ***inspiratory reserve volume*** **(IRV**) is the volume of air that can be inspired after normal inspiration - 1500-2000 ml.
- The ***vital capacity*** **(VC)** is the largest volume that can be expired after full inspiration - 3700 ml on average.
- The ***residual air volume*** **(RAV**) is the volume of air that remains in the lungs after maximum expiration - 1000-1500 ml.
- The ***total lung capacity*** **(TLC)** can be derived by adding RV, ERV, IRV, and RAV. It is about 5000-6000 ml.

Spirometry

Spirography

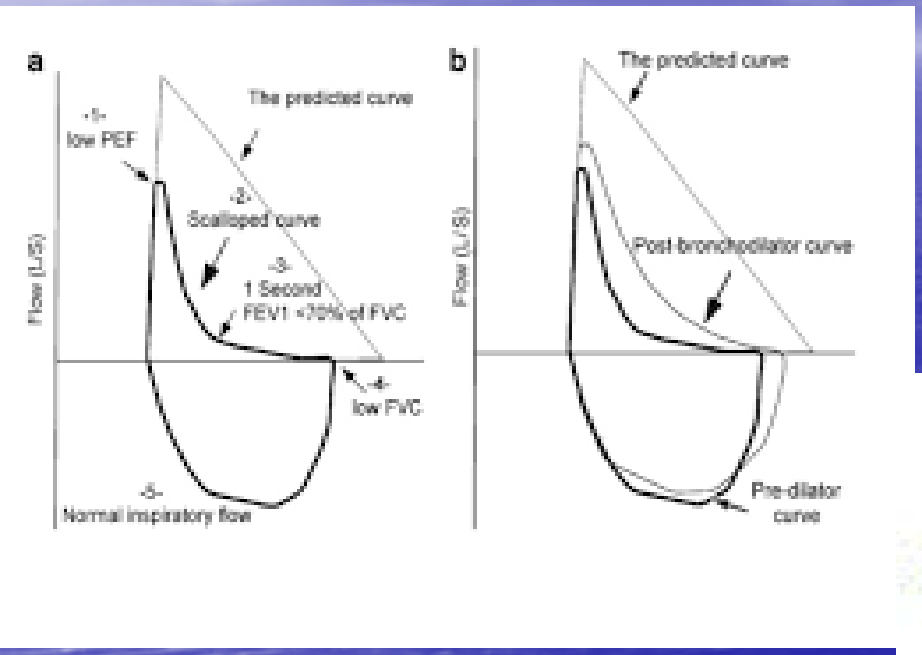
- Studies of the respiratory volumes allow assessing ability of the respiratory failure compensation at the expense of reserve inspiratory and expiratory volumes. All these volumes, apart from RV, can be measured by spirometer.
- Spirography gives more reliable information on respiratory volumes. It can be used to measure additional ventilation characteristics such as minute volume, maximum lung ventilation, respiratory reserve, and volume of lung ventilation.

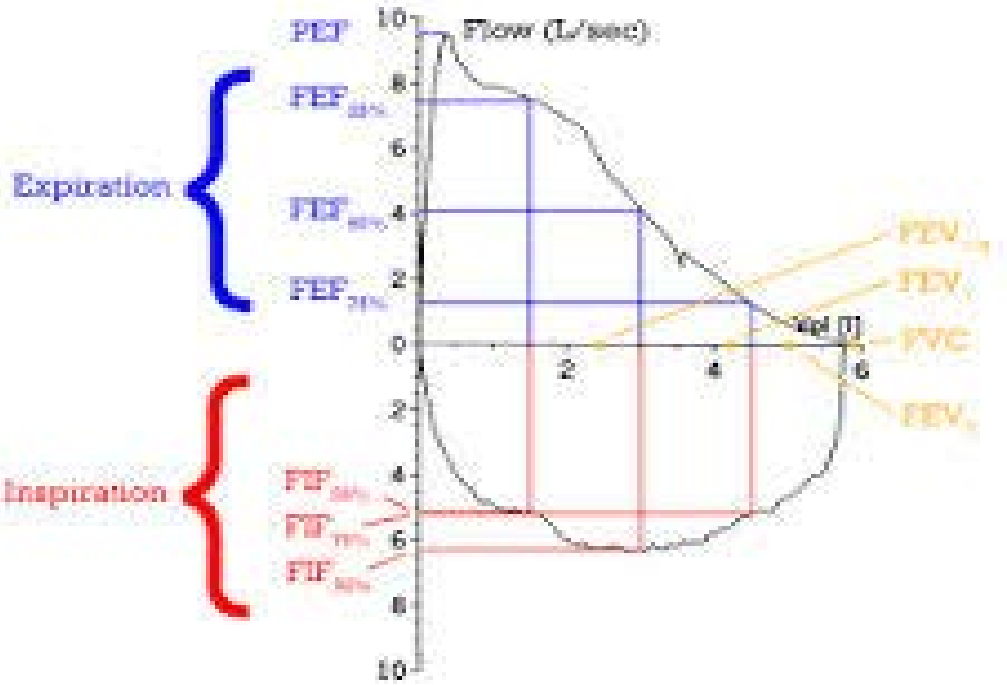
Spirography

Spirography

- The ***minute volume*** **(MV)** is the volume of gas, which passes the lips in one minute. It can be calculated by multiplying RV by the respiratory rate (frequency, f): MV = f x RV. It is about 5000 ml on the average.
- The ***maximum lung ventilation*** **(MLV)** is the amount of air that can be handed by the lungs by maximum efforts of the respiratory system. MLV is determined during deepest breathing at the rate of 50 per minute by spirometer; normally - 80-200 1/ml.
- The ***respiratory reserve*** **(RR)** may be calculated by the formula:
- RR = MLV - MV. Normally RR exceeds the MV by at least 15-20 times; RR is 85 % of MLV (in respiratory failure 60% and lower). This value reflects ability of healthy person in considerable load, or of patients with pathology of the respiratory system to compensate significant insufficiency by increasing of minute respiratory volume.

Spirography





disturbances in gas exchange. ***→For further discussion of disorders relating to CNS control of ventilation, see Chap. 246.***

DISTURBANCES IN VENTILATORY FUNCTION

Ventilation is the process whereby the lungs replenish the gas in the alveoli. Measurements of ventilatory function in common diagnostic use consist of quantification of the gas volume contained in the lungs under certain circumstances and the rate at which gas can be expelled from the lungs. The two measurements of lung volume commonly used for respiratory diagnosis are (1) total lung capacity (TLC), the volume of gas contained in the lungs after a maximal inspiration; and (2) residual volume (RV), the volume of gas remaining in the lungs at the end of a maximal expiration. The volume of gas that is exhaled from

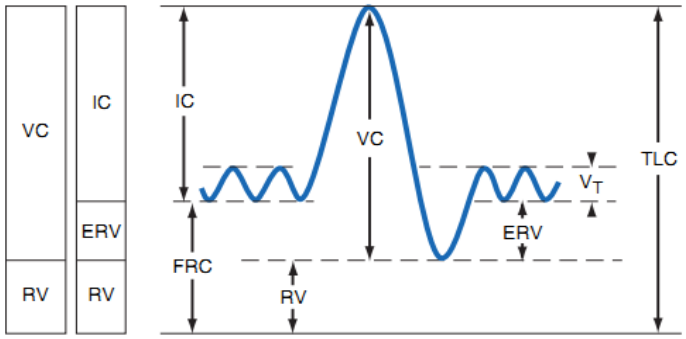


FIGURE 234-1 Lung volumes, shown by block diagrams *(left)* and by a spirographic tracing *(right)*. TLC, total lung capacity; VC, vital capacity; RV, residual volume; IC, inspiratory capacity; ERV, expiratory reserve volume; FRC, functional residual capacity; V_T, tidal volume. *(From Weinberger, with permission.)*

and 75% of the VC, or $FEF_{25-75\%}$, also called the maximal midexpiratory flow rate (MMFR)] (Fig. 234-2).

PHYSIOLOGIC FEATURES

The lungs are elastic structures, containing collagen and elastic fibers that resist expansion. For normal lungs to contain air, they must be distended either by a positive internal pressure—i.e., by a pressure in

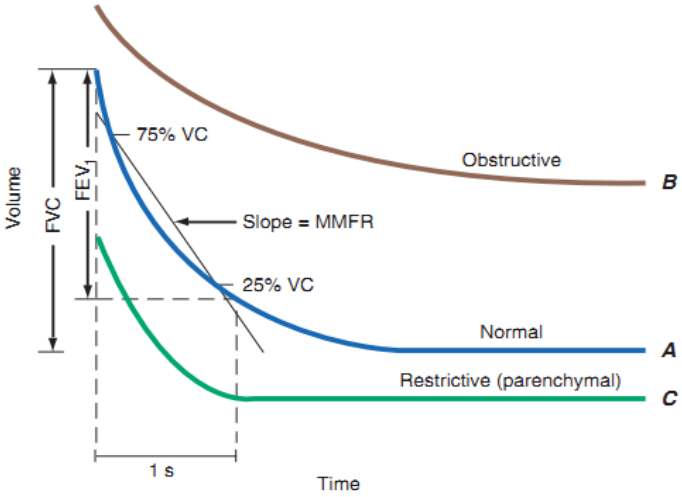


FIGURE 234-2 Spirographic tracings of forced expiration, comparing a normal tracing *(A)* and tracings in obstructive *(B)* and parenchymal restrictive *(C)* disease. Calculations of FVC, FEV_1, and $FEF_{25-75\%}$ are shown only for the normal tracing. Since there is no measure of absolute starting volume with spirometry, the curves are artificially positioned to show the relative starting lung volumes in the different conditions.

Spirography

- The study of mechanics of the respiratory act allows to evaluate changes in the inspiration and expiration correlation, breath efforts at various respiratory phases, etc.
- The ***forced expiratory vital capacity*** **(FEVC)** is determined according to Votchal-Tiffeneau during maximum fast, forced expiration. FEVC is 8-11 % (100-300 ml) lower than VC in healthy persons.
- The ***forced inspiratory vital capacity*** is assesses during maximum fast forced inspiration.

Types of ventilation deficiency according to spirographic examinations

Types of ventilation deficiency	Spirographic indicators
Obstructive	VC> FEV1> FEV1 / VC
	VC = FEV1> FEV1 / VC
Restrictive	VC<FEV1 <FEV1 / VC
Mixed	VC = FEV1 <FEV1 / VC
	VC> FEV1 <FEV1 / VC

Test	Predicted	Before bronchodilator	After Bronchodilator	Improvement
FVC	3.75	1.73	1.92	
FVC%		46%	51%	
FEV1	3.07	0.63	0.71	12%, 80ml
FEV1%		21%	23%	
FEV1/FVC		37%	37%	
PEFR	801	266	249	

Exercise 1: Spirometry of a 55 year old man, smoker with smoking index of 24 pack years and history of chronic airway obstruction showing obstructive abnormality with poor post bronchodilator reversibility.

Test	Predicted	Before bronchodilator	After Bronchodilator	Improvement
FVC	3.5	2.5	2.95	
FVC%		79%	93%	
FEV1	2.3	1.15	1.55	+34%, 300ml
FEV1%		54%	73%	
FEV1/FVC		50%	67.4%	
PEFR	476	280	320	

Exercise 2: Spirometry of a 60 year old man, chronic smoker with smoking index of 16 pack years presented with history of chronic airway obstruction showing obstructive abnormality with good bronchodilator reversibility.

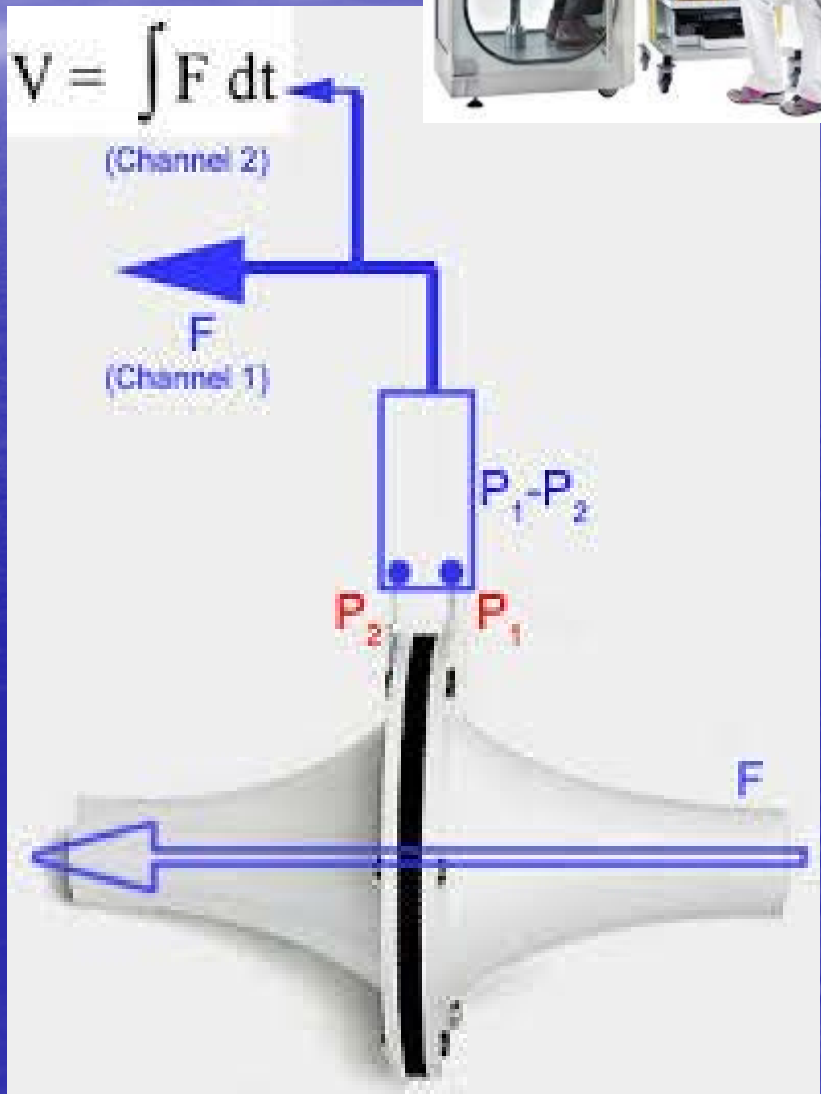
Peak expiratory flow rate (PEFR)

- This is an extremely simple and cheap test. Subjects are asked to take a full inspiration to total lung capacity and then blow out forcefully into the peak flow meter, which is held horizontally. The lips must be placed tightly around the mouthpiece. The best of three tests is recorded. Although reproducible, PEFR is not a good measure of airflow limitation since it measures the expiratory flow rate only in the first 2 ms of expiration and over estimates lung function in patients with moderate airflow limitation. PEFR is best used to monitor progression of disease and its treatment. Regular measurements of peak flow rates on waking, during the afternoon, and before bed demonstrate the wide diurnal variations in airflow limitation that characterize asthma and allow an objective assessment of treatment to be made.

Pneumotachometry, pneumotachygraphy

- methods of speed and pressure measuring at various phases of the breathing by pneumotachygraph. Pneumotachygraphy allows to determined volumetric rate of the airflow during inspiration and expiration (normally in rest breathing it is about 300-500 ml/s; in forced - 5000-8000 ml/s), duration of the respiratory cycle phases, MV, alveolar pressure, airways resistance, elasticity or distensibility or stiffness of the lungs and chest, and some other indices.


Transducer
Plastic tubing
Wire mesh inside
Disposable filter
Disposable mouthpiece


V = ∫ F dt
(Channel 2)
F
(Channel 1)
P1-P2
P2
P1
F

Tests for respiratory failure

- Determination of ***oxygen consumption*** *and* ***oxygen deficit*** is carried out by spirography with a closed $C0_2$ absorption system. Obtained spirogram compared then with spirogram that records with apparatus filled with 0_2.
- ***Ergospirography*** is the method, which allow assessing reserves of the respiratory system. Oxygen consumption and deficit is detected by spirography in the patient at rest and during exercise on ergometer.

II.5. Measurement of blood gases

Measurement of blood gases

- Gas composition of blood samples obtained from warmed up finger is measured on a Van-Slike apparatus. The following is determined:
- 0_2 content in units of volume;
- oxygen capacity of the blood (the amount of 0_2 that can bound by a blood unit);
- percentage of 0_2 saturation of the blood (95 % in norm);
- partial pressure of 0_2 in the blood (90-100 mm Hg in norm);
- $C0_2$ content in arterial blood (about 48 % in norm);
- partial pressure of $C0_2$ (about 40 mm Hg in norm).

Thank you for your attention!