

Ministry of Health of Ukraine
Kharkiv National Medical University

**AUSCULTATION OF THE LUNGS: ADDITIONAL
RESPIRATORY SOUNDS (RALES, CREPITATION, PLEURAL
FRICTION SOUND). LABORATORY SPUTUM AND PLEURAL
FLUID ANALYSIS. INSTRUMENTAL METHODS OF
RESPIRATORY ORGANS EXAMINATION**

Methodical instructions for students

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AUSCULTATION OF THE LUNGS

Adventitious (added) sounds

Three types of adventitious sounds can be heard in pulmonary pathology: rales, crepitation, and pleural friction sound.

Rales are generated in bronchi and bronchioles. Dry and moist rales are distinguished.

Dry rales can be caused by narrowing of airways, or by presence of viscous sputum in them (Fig. 1).

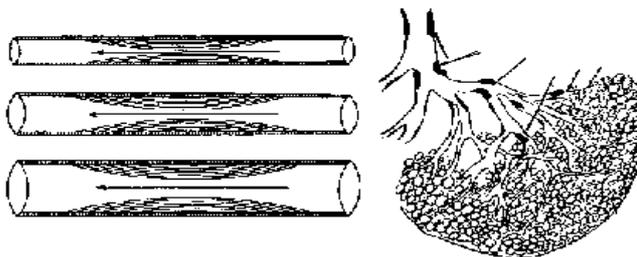


Fig. 1. Mechanism and site of dry rales generation

Dry rales are continuous musical sounds, persist throughout the respiratory cycle, and vary greatly in their character, pitch, and intensity. Depending on character and pitch, dry rales are divided into sibilant and sonorous rales. *Sibilant rales (wheezes)* are relatively high pitched, whistling sounds (Fig. 2).



Fig. 2. Sibilant rales.

Sibilant rales signify obstruction in small bronchi in:

- *bronchial asthma* (total bronchospasm during attack);
- *bronchitis* (non-uniform swelling of the bronchial mucosa due to inflammation, or viscous sputum narrows the lumen of bronchi);
- *tuberculosis or tumor of bronchus* (localized constriction of the bronchus. Limited dry rales over apex of the lung can suggest early symptom of tuberculosis).

Sonorous rales (rhonchi) are relatively low pitched, sonoring sounds (Fig. 3).



Fig. 3. Sonorous rales.

Sonorous rales are generated by vibration of the viscous secretions or in widespread obstruction of medium and large bronchus. The most common cause of sonorous rales is bronchitis. They may be also heard in bronchial asthma, tuberculosis, and bronchocarcinoma.

Intensity and transmission of the dry rales depends on the size and depth of the affected bronchi. In localized affection of medium and large bronchus insignificant amount of low pitched and soft rales is heard. Widespread bronchi inflammation or bronchospasm in asthma attack both sibilant and sonorous rales of different tone and intensity are heard. Such rales can be heard at a distance during expiration. If dry rales are caused by accumulation of the viscous secretions in the lumen of bronchi, they can be altered by coughing or deep inspiration to shift mucus.

Moist rales (clackles) are generated in bronchi and cavities in the lungs in the presence of liquid secretions (sputum, congestive fluid, blood).

Airflow in liquid-containing bronchi causes formation of air bubbles, which break to produce specific cracking sound. Similar sound can be heard when bubbling air through the water using small tube. Such sounds are called bubbling or moist rales.

Moist rales are discontinuous sounds, intermittent, nonmusical, and brief. Moist rales are heard throughout the respiratory cycle, but as speed of airflow in inspiration is higher, rales are somewhat louder during inspiration.

Moist rales are subdivided into fine, medium, and coarse bubbling rales depend on the caliber of bronchi where they are originated.

Fine bubbling rales (.) generate in small bronchi and bronchioles. These rales are soft, high-pitched, and very brief.

Medium bubbling rales (■ ■ ■ ■) originate in bronchi of medium caliber. They are somewhat louder, and not so brief.

Coarse bubbling rales (■ ■ ■ ■) produce in bronchi of large caliber, large bronchiectasis, and also in fluid-containing lung cavity communicated with large bronchus (Fig. 4). Coarse bubbling rales are loud, low-pitched, and longer.

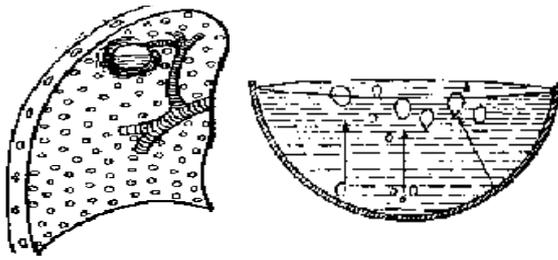


Fig. 4. Mechanism of the coarse bubbling rales generation over the cavity.

Moist rales are classified into consonating and non-consonating rales.

Consonating rales are heard when liquid-containing bronchi or cavity are surrounded by solid lung tissue. The cavity itself act as resonator to intensify loudness of rales.

Non-consonating rales are heard in bronchitis or acute pulmonary edema caused by left ventricular failure, when intensity of rales produced are dampened by air-containing lung tissue.

The most common causes of the moist rales include:

- *acute and chronic bronchitis* (bilateral, symmetrical, of various caliber, non-consonating rales);
- *bronchopneumonia* (consonating rales);
- *bronchiectasis* (of various caliber, over limited area, non-consonating rales);
- *cavity in the lungs* (coarse bubbling, over limited area, as rule over lung apices, consonating rales);
- *pulmonary edema* due to the left ventricular failure (bilateral symmetrical, of different caliber, non-consonating rales).

Creptitation is generated in alveoli, when they contain small amount of liquid secretion. During expiration alveoli stick together as a result of fluid presence. During inspiration alveolar walls separate with difficulty only at the end of inspiration to produce late inspiratory slight cracking sound (Fig. 5). Creptitation somewhat resembles sound produced by rubbing a lock of hair near the ear.



Fig. 5. Mechanism of creptitation.

Temporary creptitation in first deep inspiration can be heard in the patients with grave cardiovascular and infectious diseases, in aged persons, especially so if the patient was in lying posture before auscultation.

Relatively constant creptitation can be due to:

- *acute lobar pneumonia* at the *initial* and *final* stages (insignificant amount of exudates at the initial stage causes so-called *indux creptitation* – quit, remote sound. During next stage of disease alveoli are overfilled with inflammatory fluid and creptitation therefore disappears. At the final stage due to resolution of exudates, loud, as near the ear, crackling sound – *redux creptitation* is heard again);
- *pulmonary tuberculosis* (in small amount of inflammatory fluid in alveoli);
- *lung infarction* (in small amount of blood in alveoli);

- *congestive heart failure* (in small amount of congestive fluid in alveoli);
- *compressive atelectasis* (alveoli are compressed by pleural air or fluid, and separate therefore with difficulty).

Pleural friction sound (pleural rub, friction rub) is diagnostic added sound of pleurisy.

The smooth surfaces of visceral and parietal pleura lubricated by pleural fluid, allow pleura to move easily and noiseless during breathing.

Adventitious sound known as pleural friction sound, generates as a result of *decreased amount of pleural fluid* in dry pleurisy due to dehydrotation:

- intestinal infections (cholera, dysentery);
- profuse bleeding;
- profuse diarrhea;
- profuse vomiting;

or cicatrices, commissures, bands between pleural layers at the focus of inflammation, or when fibrin deposits on inflamed *pleura* to make it *surface rough* in:

- pleuropneumonia;
- rheumatic pleurisy;
- pleural tuberculosis;
- tumor;
- effusive pleurisy at the period of rapid resorption of exudates.

Pleural friction rub is heard throughout inspiration and expiration, and is differentiated by intensity, location and duration.

A soft friction rub in early dry pleurisy may be mistaken for crepitation or fine bubbling rales but is not altered by coughing as rales; it can be louder by pressure with stethoscope. During rapid resorption of pleural effusion, pleural rub becomes louder, and more intense. Such sound is so rough that can be felt even during palpation.

Pleural friction sound is best heard at the lung bases due to better respiratory mobility, and rarely at the lung apices (tuberculosis with involvement of the pleura, for example).

Duration of the friction rub varies in different diseases. Periodic pleural friction sound is typical to rheumatic pleurisy. It is heard a few hours, temporary disappears, and then appears again. In dry pleurisy of tuberculosis etiology and pleurisy with effusion at resorption stage, pleural rub is heard for a week and over. Longstanding, for years after pleurisy, friction rub can be sometimes heard due to significant roughness of the pleural surfaces.

Characteristics of adventitious sounds are summarized in Tab. 1.

Tab. 1. Differential diagnosis of adventitious sounds.

Signs	Dry rales	Moist rales	Crepitation	Pleural friction sound
Relation to the respiratory phases	Best heard during expiration	Best heard during inspiration	Heard at the end of inspiration	Heard throughout respiratory cycle
Change during cough	Decrease or change character	Decrease or disappears	Without changes	Without changes
Pressure with the stethoscope	Without changes	Without changes	Without changes	Increase
Breathing movement with close nose and mouth	Absent	Absent	Absent	Only this sound is heard

INSRUMENTAL AND LABORATORY METHODS

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.

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 roentgenoscopy.

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

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.

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.

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.

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.

Bronchography is an integral part of the diagnosis evaluation of diseases of bronchi. 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.

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, on which 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.

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.

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, and 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, trachitis, at initial stage of acute bronchitis, bronchial asthma out of attack, and in bronchopneumonia.

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 bloodstained 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 acute 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*;
- *Actinomyceae*;
- *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*.

Physical properties of the sputum revealed in macroscopic examination are summarized in Tab. 2.

Tab. 2. Physical properties of the sputum

Character	Consistency	Color	Odor	Layerness	Disease
Mucous	Tenacious	Glass-like	Odorless	Absent	Acute bronchitis, at the peak of the bronchial asthma attack
Mucopurulent	Tenacious thick	Glass-like with yellow traces	Odorless	Absent	Chronic bronchitis, trachitis, bronchopneumonia, tuberculosis
Purulent-mucous	Thick, tenacious	Yellow-greenish	Unpleasant	Three layers	Chronic bronchitis, bronchiectasis,

					pulmonary abscess
Purulent	Thick	Greenish-yellow	Sharp unpleasant	Two layers	Pulmonary abscess, gangrene of the lungs
Mucous bloody	Viscous, tenacious	Rusty, glass-like, reddish	Odorless or without unpleasant odor	Absent	Inflammation of the upper respiratory ducts, pneumonia, bronchogenic tumor, lung infarction, congestion in the lesser circulation
Mucopurulent bloody	Tenacious thick	Glass-like, reddish with purulent traces	Unpleasant, putrefactive	In large amount three layers	Tuberculosis, bronchiectasis, bronchogenic tumor
Bloody	Liquid, foamy	Red	Odorless	Absent	Pulmonary hemorrhage: in tuberculosis, wounds, lung tumor
Serous	Foamy, liquid, sticky	Transparent yellowish	Odorless	Absent	Pulmonary edema

Microscopic study

Sputum elements revealed in microscopic study can be divided into three main groups: cellular, fibrous, and crystal formations (Tab. 3).

Tab.3. Sputum elements in microscopic study

Cellular elements	Fibrous elements	Crystal elements
<ul style="list-style-type: none"> • Epithelium cells (squamous, columnar) • Macrophages • Leucocytes, (eosinophils) • Erythrocytes • Tumor cells 	<ul style="list-style-type: none"> • Curschmann spirals • Elastic fibers • Fibrin fibers 	<ul style="list-style-type: none"> • Charcot-Leyden crystals • Crystals of hematin • Crystals of cholesterol • Crystals of fatty acid

Cellular elements

Squamous epithelium – is epithelium of mucous membrane of mouth cavity, 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.

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.

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.

Sputum analysis in selected respiratory pathology is represented in Tab. 4.

Tab. 4. Sputum analysis in selected respiratory pathology

Disease	Sputum amount	Sputum character	Macroscopic study	Microscopic study
Acute bronchitis	Scarce, in later stages – large amount	Mucous, mucous-purulent	---	Columnar epithelium, leucocytes-moderate amount, in long-standing course - macrophages
Chronic bronchitis	Various	Mucous-purulent, mucous-purulent bloody	---	Leucocytes – large amount; erythrocytes, macrophages
Bronchiectasis	Ample (morning)	Puro-mucous three-layers	Dittrich's plugs	Leucocytes – many; fatty acids, hematoidin, cholesterol

				crystals
Bronchial asthma	Scarcely	Mucous	Curschmann spirals	Columnar epithelium, Charcot-Leyden crystals, eosinophils,
Lobar pneumonia	Scarcely initially, ample – later	Sticky, rusty initially, later mucous-purulent	Fibrin clots, changed blood	Macrophages, leucocytes, erythrocytes, hematoidin crystals, pneumococcus
Pulmonary abscess	Ample in secretions to bronchus	Purulent with foul odor	Necrotic pieces of the lung tissue	Leucocytes, elastic fibers, fatty acid, hematoidin, cholesterol, crystals,
Pulmonary tuberculosis	Various	Mucous-purulent, sometimes with blood	“Koch’s lens” in cavern presence	Tuberculosis mycobacteria; elastic fibers, and various crystals
Bronchopulmonary tumor	Various	Mucous-bloody, mucous-purulent bloody	Tissue pieces in ample sputum in tumor degradation	Atypical cells

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 intercostal 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.

STUDY OF THE PLEURAL FLUID

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.

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.

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 is 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/cm³; relative density of exudates is usually higher than 1015 g/cm³ (1018-1022).

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/l (0.5-2.5%), in exudates – more than 30 g/l (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).

Rivalta's reaction was proposed for differentiation between transudates and exudates. In a cylinder filled with 100-150 ml of distilled 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.

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 patients with tumor, infarction of the lung, injuries, hemorrhagic diathesis they usually covered all vision area.

Leucocytes in a small quantity (to 15 in vision field) are revealed in transudates and in a large amount – in fluid of inflammatory genesis (especially in purulent exudates). Qualitative content of leucocytes are assessed in stained preparations.

Mesothelium cells are recognized by their large size (to 50 mcm). Transudates contain significant amount of mesothelium cells. They also can be determined in exudates in canceromatosis, and sometimes in tuberculosis.

Tumor cells. Exudates sometimes contain cells suspected for tumor according to absence of distinct cellular borders, polymorphism of their size and shape. 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 canceromatosis 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.

Methods for functional studies

Methods used to characterize the functional changes developing as a result of disease are very important for an integrated examination of the patients. It is unusual for a specific lung function test to diagnose a disease. At best, a series of tests may place a lung disorder into one of several categories and when other features such as history, physical examination, radiology and pathology are added to the equation, a possible diagnosis is considered.

The main uses of lung function testing are to help define more clearly the type, character and degree of respiratory failure, and to measure serially natural progression (or regression with therapy) of functional disorder.

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.

Figure 6 shows how the total lung capacity is broken down into its various volumes.

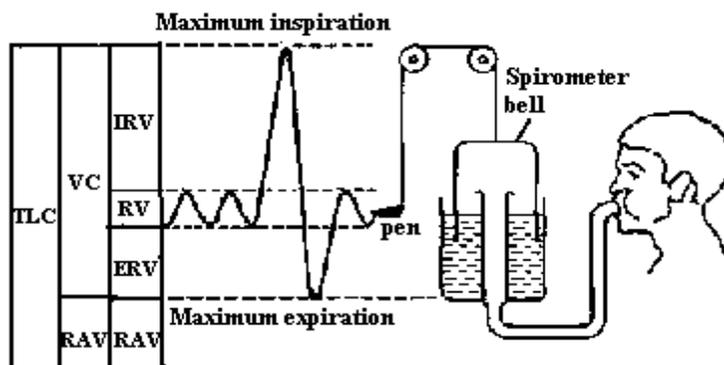


Fig. 6. The subdivision of the total lung capacity (TLC) with spirometric recording.

RV – respiratory volume, ERV – expiratory reserve volume, IRV – inspiratory reserve volume, RAV – residual air volume, VC – vital capacity.

The *respiratory volume* (RV) or tidal volume is the total air volume of each normal resting breath (inspiration and expiration). RV varies from 300 to 900 ml; 500 ml on the average. It consists of two parts:

1. Alveolar volume: the volume of gas, which reaches the alveoli – the volume of alveolar ventilation;
2. 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 the 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.

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.

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): $MV = f \cdot RV$. It is about 5000 ml on the average.

The *maximum lung ventilation* (MLV) is the amount of air that can be handled 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 l/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.

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 assessed during maximum fast forced inspiration.

Pneumotachymetry, 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.

Tests for respiratory failure.

Determination of *oxygen consumption and oxygen deficit* is carried out by spirometry with a closed CO₂ absorption system. Obtained spirogram compared then with spirogram that records with apparatus filled with O₂.

Ergospirometry is the method, which allow assessing reserves of the respiratory system. Oxygen consumption and deficit is detected by spirometry in the patient at rest and during exercise on ergometer.

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:

1. O₂ content in units of volume;
2. oxygen capacity of the blood (the amount of O₂ that can bound by a blood unit);
3. percentage of O₂ saturation of the blood (95% in norm);
4. partial pressure of O₂ in the blood (90-100 mm Hg in norm);
5. CO₂ content in arterial blood (about 48% v/v);
6. partial pressure of CO₂ (about 40 mm Hg in norm).

Tests

1. The patient's position is forced, he is sitting resting his hands against the edge of the chair. There are numerous whistling rales against vesiculotympanic resonance and weak vesicular respiration all over the lungs. What diagnosis can be supposed?
 - A. Lung cancer
 - B. Bronchitis
 - C. Pulmonary emphysema
 - D. Bronchial asthma
 - E. Lung abscess
 2. In the right subscapular area from the 7th to the 10th ribs there is dull percussion sound, bronchial respiration. What diagnosis can be supposed?
 - A. Height of lobar pneumonia
 - B. Lung cancer
 - C. Lung abscess
 - D. Pneumosclerosis
 - E. Exudation pleurisy
 3. Solitary coarse moist rales are heard over the left apex of the lung against a background of tympanic sound and amphoric respiration. What diagnosis can be supposed?
 - A. Bronchial asthma
 - B. Lung cancer
 - C. Pneumonia
 - D. Bronchitis
 - E. Cavity in the lung
 4. The patient complains of pain in the left hemithorax, which becomes worse on breathing in. Lung sound is heard on percussion of the chest. Auscultation demonstrates weak vesicular respiration, pleura friction rub in the left axillary area. What diagnosis can be supposed?
 - A. Pneumothorax
 - B. Exudation pleurisy
 - C. Pleuropneumonia
 - D. Dry pleurisy
 - E. Lung emphysema
 5. Dull tympanic sound, weak vesicular respiration and crepitation are heard over the left hemithorax at the level of 4th-10th interspace. What diagnosis can be supposed?
 - A. Lung abscess
 - B. Focal pneumonia
 - C. Initial stage of lobar pneumonia
 - D. Lung edema
 - E. Pneumothorax
6. The patient complains of dyspnea on moderate exercise. Acrocyanosis. The ratio of anteroposterior to transverse size of the chest is 0.92; the voice resonance is weak; the chest is rigid. The resonance is vesiculotympanic, the respiration is weak vesicular. ERF investigation demonstrates a "shark's tooth" curve and abrupt reduction of the ERF parameters. What diagnosis can be supposed?
- A. Emphysema
 - B. Chronic obstructive lung disease.
 - C. Bronchial asthma
 - D. Lung cancer
 - E. Pneumonia
7. The patient complains of attacks of difficult breathing especially on breathing out, morning cough with some mucous sputum. Microscopy of the sputum demonstrates bronchial epithelium, eosinophils, and Charcot-Leiden crystals. What diagnosis can be supposed?
- A. Emphysema
 - B. Chronic obstructive lung disease.
 - C. Bronchial asthma
 - D. Lung cancer
 - E. Pneumonia
8. A smoker complains of cough with moderate sputum discharge. The sound over the lungs is clear, rigid, vesicular. The rales are disseminated buzzing. Investigation of the sputum demonstrates bronchial epithelium separately and in aggregates, leukocytes in moderate amounts, Churchman's spirals. X-ray demonstrates increased lung picture. Fibrobronchoscopy shows hyperemia and edema of the bronchial mucosa. ERF has not reveal any ventilation abnormality. What diagnosis can be supposed?
- A. Emphysema
 - B. Chronic obstructive lung disease.
 - C. Bronchial asthma
 - D. Lung cancer
 - E. Pneumonia
9. The patient has tympanic sound on the left of the 2nd and 3rd interspace. X-ray demonstrate a cavity with horizontal fluid level. Laboratory study demonstrates elastic fibers in the sputum. What diagnosis can be suggested?
- A. Lung cancer
 - B. Bronchial asthma
 - C. Pneumonia
 - D. Chronic bronchitis
 - E. Lung abscess
10. The patient with chronic obstructive lung disease has dyspnea at rest, acrocyanosis. RR at rest is 28/min. Computer spirometry demonstrates considerably pronounced disorders of a mixed type (vital lung capacity 55%, forced expiration volume₁ 50%, Tiffno's index 60%). What diagnosis can be supposed?
- A. Stage 1 respiratory failure.
 - B. Stage 2 respiratory failure.
 - C. Stage 3 respiratory failure.
 - D. Pulmonary emphysema
 - E. Pneumosclerosis
- Keys: Keys: 1D, 2A, 3E, 4D, 5C, 6A, 7C, 8D, 9E, 10B

Methodical instructions

RESPIRATORY SYSTEM EXAMINATION. LUNGS PERCUSSION. TECHNIQUE OF COMPARATIVE AND TOPOGRAPHIC PERCUSSION.

Methodical instructions for students

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