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METHODS OF DIAGNOSTICS AND MAJOR CLINICAL SYMPTOMS OF DISEASES OF RESPIRATORY SYSTEM IN CHILDREN

Methodical recommendation
for students of 3rd course of medical faculty

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МЕТОДИ ДІАГНОСТИКИ ТА ОСНОВНІ КЛІНІЧНІ СИМПТОМИ ЗАХВОРЮВАНЬ ДИХАЛЬНОЇ СИСТЕМИ У ДІТЕЙ

Методичні рекомендації

(Англ. мовою)

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CONTENTS

LIST OF ABBREVIATIONS

ALI – acute lung injury
ARDS – acute respiratory distress syndrome
BCG – Bacillus Calmette–Guérin
CHF – chronic heart failure
CNS – central nervous system
COPD – chronic obstructive pulmonary disease
CT – Computer tomography
FEF – forced expiratory flow
FEV1 – forced expired volume in the first second
FVC – forced vital capacity
Hb – hemoglobin
MRI – Magnetic resonance imaging
PA – posteroanterior
PEFR – peak expiratory flow rate
TLC – total lung capacity

INTRODUCTION

The disease of respiratory system is common pathology in childhood, and one of the most frequent reasons for hospitalization of infants and children. The complete examination of respiratory system includes three components: history taking, physical examination and diagnostic investigations. Taking a careful clinical history is always the first diagnostic step and is an essential approach to the patient. Often, the clinical history provides – or at least suggests – the diagnosis prior to investigation. Physical examination classically follows a sequence: inspection, palpation (feeling with the hands), percussion and auscultation (listening with a stethoscope). The clinical history and physical examination provide the essential clues towards the possible underlying respiratory disease, guiding selection of the appropriate diagnostic investigations: laboratory tests, respiratory function tests, imaging techniques and/or biopsy procedures.

Basic knowledge of the methods of diagnostics and major clinical symptoms of respiratory system diseases is essential to providing appropriate diagnosis and effective therapy of respiratory tract diseases.

SUBJECTIVE EXAMINATION OF RESPIRATORY SYSTEM IN CHILDREN

General and specific complaints

The most often complaints: cough, nasal discharge, dyspnea, chest pain, change of voice, non-specific complaints (fewer, weakness, decrease of appetite).

Cough is a common respiratory complaint. Cough means a forceful expiration that can clear the airways of debris and secretions, this is important in protecting the lungs. Cough may be voluntary or generated by reflex irritation of the nose, sinus, pharynx, larynx, trachea, bronchi, and bronchioles. The loss of the ability to cough results in poor secretion clearance and predisposes to atelectasis and pneumonia.

Acute cough generally is associated with respiratory infections (rhinitis, bronchitis, pneumonia, sinusitis) or irritant exposure (smoke) and subsides as the infection resolves or exposure is eliminated. Sudden onset of coughing after a choking episode suggests foreign body aspiration. Morning cough usually is associated with excess production of secretions and may be seen with asthma, bronchitis, bronchiectasis, or cardiac failure. Nocturnal cough suggests asthma, allergy, gastroesophageal reflux, or sinusitis. Coughing with exercise often is caused by exercise-induced asthma. Paroxysmal cough suggests pertussis or foreign body aspiration. A repetitive, staccato cough is heard in chlamydial infections in infants. A harsh, brassy, or "seal-like", barking cough suggests croup, tracheomalacia.

Cough that persists longer than 4 to 6 weeks in a child (and even shorter than that in an infant) warrants more attention.

Chronic cough is a daily cough lasting longer than 6 weeks. It occurs for diverse reasons, including allergy (asthma, postnasal drip, rhinitis), anatomic abnormalities (tracheoesophageal fistula, gastroesophageal reflux, swallowing dysfunction), chronic infection, environmental exposure to irritants (tobacco smoke, wood stove smoke), foreign body aspiration, psychogenic causes (habit cough, cough tic, Tourette syndrome), and neurologic dysfunction. Coughs should be characterized: time of day, is it productive or nonproductive of sputum.

Sputum production may result in external stimuli (irritant) or from acute and chronic bronchial infection or a lung abscess (rare cause in children). Very impartment information about amount of

sputum, color, smell. Excess production of sputum that separates into layers may indicate bronchiectasis. Foul smelling sputum may result from an anaerobic infection, such as an abscess. Blood tinged or rust color sputum may result from trauma caused by coughing or from such underlying pathology as pulmonary infection or tuberculosis, and tumors. Hemoptysis (coughing up blood) must be distinguished from hematemesis (vomiting blood).

A color change from white to yellow or green indicates bacterial infection.

Dyspnea

– Inspiratory dyspnea is the result of block of upper and media airways (stenotic laryngotracheitis, diphtheria, foreign body in trachea).

– Expiratory dyspnea – block in lower part of airways (bronchiolitis, obstructive bronchitis, bronchial asthma).

– Mix dyspnea (pneumonia).

Onset of dyspnea may be slow or abrupt. For example, a child with asthma may experience acute dyspnea intermittently. Ask about factors, that provoke and relieve the attack of dyspnea. Paroxysmal nocturnal dyspnea and orthopnea are commonly associated with chronic lung disease, but may be related to cardiac dysfunction. Dyspnea from activities suggests poor ventilation or profusion, or insufficient breathing mechanisms. Dyspnea can accompany by external sounds, such as wheezing or stridor. Wheezing sounds result from small airway obstructions (for example, from aspirated foreign body, a tumor, asthma, or congestive heart failure). Stridor results from tracheal compression or laryngoedema.

Chest pain: may be associated with cardiovascular disorders, but respiratory disorders usually cause musculoskeletal chest pain (the lungs have no pain-sensitive nerves). However, the parietal pleura and the tracheal bronchial tree are sensitive to pain.

Anamnesis of disease

Considering the fact that in different age periods certain features of life are of greater importance, the collection of an anamnesis of life is of great importance. The questions that doctor should carefully study will be discussed further on.

Anamnesis of a life of child

1. Pregnancy and childbirth: if pregnancy is not the first, how previous pregnancies have been and how they ended (miscarriages, stillbirths and premature babies, abortions, the alleged reasons for this).

2. How did the pregnancy take place in the mother (toxicosis of the first, second half – nausea, vomiting, swelling, hypertension, nephropathy, eclampsia, the transferred diseases, especially viral, occupational hazards during this period). Whether was treated in a hospital during pregnancy, what medicines used.

3. The regime and features of eating pregnant. Is maternity leave used?

4. How the childbirth was taking place (duration, benefits, complications). Immediately the child shouted (loud, weak cry). Weight and length of the body at birth. When the child was attached to the chest, how he took the breast, actively sucked, how often the child was put to the chest. When the remainder of the umbilical cord fell off, the umbilical wound was healed. On which day and with what weight were discharged the child from the hospital.

5. Diseases during the newborn period (intensity and duration of jaundice, hemolytic disease of the newborn, birth trauma, skin and navel diseases, septic diseases, diseases of the respiratory system, digestion, etc.).

6. Physical development of the child in the first, second and third years of life (weight gain and body length).

7. Development of motor skills and statics: when he began to hold his head turn on his side, from back to stomach, sit, crawl, stand, walk, run.

8. Mental development: when he began to smile, walk, say syllables, pronounce words, phrases. Spare words by 1 year, 2 and 3 years.

9. Behavior of the child at home and in the team. Attitude to other children and adults. Dream, its features and duration.

10. Type of feeding in the first year of life: natural, artificial, mixed. At natural feeding – time of feeding by a breast, activity of sucking. With mixed feeding – the kind of supplementary feeding, from what age is introduced the supplement, the amount. At artificial feeding – age of transfer on artificial feeding, a kind of food. A mode of feeding of the child. Terms of introduction of lures, consistency, tolerability.

11. When the first teeth appeared, the order and nature of their eruption. The number of teeth by the end of the first year of life.

12. Postponed diseases: rickets, diathesis, anemia, respiratory diseases, infectious diseases (features of the course, complications), helminthic invasions, surgical interventions (when, which ones).

13. Prophylactic vaccinations: against hepatitis, tuberculosis (BCG, BCG-M), poliomyelitis, whooping cough, diphtheria, tetanus, measles, mumps, rubella. Reactions to vaccinations. Tuberculin samples, when conducted, their result.

14. Allergic reactions (as expressed, the kind of allergen: household, food, medicinal).

15. Contact with infectious patients (in the family, in an apartment, in a children's institution).

OBJECTIVE EXAMINATION OF RESPIRATORY SYSTEM IN CHILDREN

Inspection

Before doing the examination of the respiratory system, a general examination relevant to the respiratory system should be carried out.

Appearance extrapulmonary manifestations of pulmonary disease include growth failure, altered mental status (from hypoxemia or hypercapnia), pallor or cyanosis, and clubbing (excessive curvature of the nail). Elevated neck veins can be an evidence of cor pulmonale.

Cyanosis. Usually cyanosis is observed when the amount of deoxyhemoglobin is more than 5 g/100 ml of blood in patient with normal Hb and more in patient has low Hb.

Central cyanosis is observed in the face, lips, tongue. Results from systemic hypoxia due to poor perfusion or ventilation in the lungs. Peripheral cyanosis may be found in extremities, ears, cheeks, etc. Can be caused by cold-induced vasoconstriction (Raynaud's phenomenon) or poor circulation (shock, CHF).

Digital clubbing is a sign of chronic hypoxia due to cardiac failure or chronic pulmonary diseases. However, it may also be present in non-pulmonary chronic diseases (endocarditis, celiac disease, inflammatory bowel disease, chronic active hepatitis) or, rarely, as a familial trait.

Position of patient can be active, passive, compelled position on sick side and may indicate the severity of the disease. Patients with

asthma attack often have tripod position. Forward position is seen in children with epiglottitis.

Inspection of nasal breath includes inspection of nasal discharge, nasal flaring.

Inspection of pharynx, tonsils (includes assessment of color, size and sings of inflammation of tonsils).

Thorax inspection (shape, deformity, symmetry of chest wall movement, respiratory effort, using of accessory muscles, retractions).

The normal chest is bilaterally symmetrical and elliptical in cross section, the transverse diameter exceeds the anteroposterior diameter.

Common abnormalities of shape includes: kyphosis – forward bending of vertebral column; scoliosis – lateral bending of vertebral column; flattening; barrel shaped chest – increase in anteroposterior diameter in compare to lateral diameter. Seen in hyperinflation and it is normal for newborn.

Pigeon chest (*pectus carinatum*): outwards bowing of the sternum and costal cartilages. May be a sign of childhood respiratory disease. Also seen as an isolated anomaly or familial or with Noonan syndrome, Marfan.

Funnel chest (*pectus excavatum*): localized depression of the lower end of the sternum. Causes similar to carinatum. Harrison's sulcus: linear depression of the lower ribs just above the costal margins at the site of the diaphragm attachment. May be seen in severe asthma in children and in rickets.

Assessment of breathing

Types of respiration (breathing pattern) in the children.

• In the normal neonate, respiratory movements are predominantly diaphragmatic (abdominal type), because young children use the diaphragm as the primary breathing muscle.

• Abdominal-chest respiration (thoraco-abdominal type) appears after the child stands up and walks (above 2 years).

• Thoracic type of breathing is noticed in children of 3–7 years of age and is characterized by well-developed muscles of the thoracic girdle, the function of which during breathing considerably prevails diaphragmatic muscles.

• From 8–14 years, the type of breathing depends on the sex: predominantly abdominal type in boys, and thoracic type in girls.

Evaluation of respirations:

1) respiratory rate (number per minute);
2) rhythm (regular, irregular or periodic);
3) depth (deep or shallow);
4) type (thoracic, abdominal, mix or pathologic);
5) quality (automatic, difficult, or labored).

It is especially important to look at and listen to the child's breathing only when the child is quiet and calm. It is not possible to count the breathing rate accurately or assess other signs of difficult breathing in a child who is frightened, crying or angry. To calm the child, give the child something to play with, ask the mother to breast-feed the child, or suggest they wait in another room until the child calms down.

The respiratory rate is an important indicator of respiratory status. Then younger the child, the respiration is more rapid. The metabolism and oxygen requirement of infants are high, but respiratory volume is limited, that causes to increase frequency of respiration for metabolic requirement. Young children are also unable to increase the depth of respirations because not all the alveoli are developed.

The respiratory rhythm is extremely unstable at infants of the first months, especially in preterm babies. Count the respiratory rate for 30 seconds or one minute. Look for breathing movement anywhere on the child's chest or abdomen or use stethoscope.

Normal respiratory rate (breaths per 1 min) in children:

- newborn – 40–60;
- till 1 year – 30–35;
- 5 years old – 20–25;
- more than 12 years old – 16–20.

Disorders of the respiratory rate.

Tachypnea is the increase of the respiratory rate (more than 10 % from normal range). Fast breathing: 40 breaths per minute or more if the child is aged 12 months up to 5 years; 50 breaths per minute or more if the child is aged 2 months up to 12 months; 60 breaths per minute or more if the child is aged less than 2 months. Any factor that impairs respiratory mechanics is likely to increase the respiratory rate. However, nonrespiratory causes of tachypnea include fever, pain, and anxiety. Remember: a child's respiratory rate may double in response to exercise, illness, or emotion, but an elevated respiratory rate in young children may be an initial and main indicator of pneumonia or hypoxemia!!!

Bradypnea is the decrease of the respiratory rate (less than 10 % from normal range).

Apnea is a period of breathing absence lasting twenty seconds or more, or a shorter time if the child develops a bluish or pale color or the heart rate drops.

Many infants have periods of rapid breathing alternating with periods of slow rate, or they may not breathe for periods up to fifteen seconds. This is normal if the color and heart rate do not change considerably and the infant starts to breathe spontaneously. Pauses longer than 20 seconds are abnormal and should be monitored.

Apnea is caused by respiratory, central nervous system, metabolic and obstructive abnormalities. Common causes are when the child is exhausted, has pneumonia or a pneumothorax, has aspirated some solid or fluid, or has had the vagus nerve stimulated in the pharynx such as when passing a naso-gastric feeding tube or over-suctioning the pharynx/trachea. Central causes of apnea in children are due to an immature/underdeveloped respiratory control center or when they have a seizure.

Dyspnea is the distress during breathing.

Disorders of the respiratory depth:

- hyperpnea is an increased depth;
- hypoventilation is a decreased depth and irregular rhythm;
- hyperventilation is an increased rate and depth.

Signs of difficulty breathing (respiratory distress syndrome):

- nasal flaring: widening of the nose as the childbreathes in. It is a sign of severe pneumonia;
- use of accessory muscles;
- chest retractions: sign that the child is trying to move air into the lungs, but the air movement is impaired by increased resistance. It can be supraclavicular, subclavicular, intercostal, subcostal, suprasternum, and substernum;
- head bobbing;
- prolonged inspiratory or expiratory times;
- open mouth breathing;
- abnormal respiratory patterns (rates, effort, tidal volume, gasping);
- abnormal sounds:

o *grunting*: deep, short sounds, forced expiration against a partially closed glottis. It suggests respiratory distress, sign of severe pneumonia, but it may also be a manifestation of pain;

o *stridor*: high-pitched sound occurring with inspiration. Stridor or snoring sound suggests an upper airway obstruction. It occurs when there is a narrowing of the larynx, trachea or epiglottis (croup, epiglotitis or a foreign body);

o *wheeze*: high-pitched musical breath sound usually heard on expiration. It may be caused by swelling and narrowing of the small airways of the lung or by contraction of the smooth muscles surrounding the airways in the lung.

Pathological respiration.

Cheyne-Stokes respiration: gradually increasing tidial volume (depth and frequency) up to maximum, then the amplitude and frequency of respiration decreases followed by apnea 20–30 sec, and then cycle repeats. It result of CNS injury, meningitis, severe cardiac insufficiency, during significant intoxication (uremia) or prematurity.

Kussmaul's breathing is hyperventilation, increased rate, increased tidal volume, regular deep respiration, usually seen in diabetic coma or respiratory (metabolic) acidosis;

Biot's respiration: increasing of the rate and depth with abrupt pauses. After some 2–5 respiratory movements of identical amplitude with a respiratory effort, there comes apnea 5–30 sec. It in result of considerable damage of brain hemorrhage, tumor (located near the respiratory center), and in result meningitis.

See-saw (paradoxic, Grocco-Frougoni) respirations: the chest falls on inspiration and rises on expiration. It is usually observed in respiratory failure of third degree.

Chaotic respiration (Gasping): arrhythmic, slow rate, different in depth. Consider hypoxia, shock, sepsis, or asphyxia.

Palpation of chest

Before making a systemic examination palpate any part of the chest where the patient complains of pain or where there is a swelling. Palpation of the chest can detect of terdeness or pain, edema, palpable ronchi, pleural friction rib, crepitation du to subcuteneus emphysema. Crepitation is felt as a coarse, cracking sensation as the hand presses over the affected area. It is the result of the escape of air from the lungs into the subcutaneous tissues from an injury or surgical intervention. Both pleural friction rubs and crepitation can usually be heard as well as felt. Palpation of chest can be superficial and deep.

Assess of *an angle of the chest* (shape): asthenic (angle less than 90^0), normosthenic (angle 90^0), and hypersthenic (angle more than 90^0).

Resistance of thorax: the chest is squeezed simultaneously with both hands in symmetrical sides from front and behind along the median line and each side, notice the resistance arising at it. The resistance of the thorax is reduced at the insufficiency of process of ossification. The resistance increases at the disorders of metabolism with the increased ossification at the accumulation of the liquid in the thorax in case of inflammatory pleural effusion.

Respiratory movements (chest expansion, chest excursion) are felt by placing hands around the lower ribs posteriorly and oppose the thumbs on either side in midline along the lower costal margin. On inspiration, both thumbs should move equal distances from their original positions. Normally in older children the posterior base of the lungs descends 5 to 6 cm during a deep inspiration.

Tracheal position. In normal the trachea is in the midline and can be palpated in the suprasternal notch. Displacement of the trachea indicates that the position of the mediastinum has been altered. This may be due to pneumothorax or significant atelectasis. The trachea may be deviated toward the normal side in conditions such as neck tumors, thyroid enlargement, enlarged lymph nodes, and pleural effusion.

Tactile or *vocal fremitus* (vocal tremor, vibration with vocalization), the conduction of voice sounds through the respiratory tract. Vocal fremitus is the vibration detected by palpation with the palm of the hand on the chest, when the patient is asked to repeat "ninety-nine", "one-one-one", "one, two, three", "eee-eee", Mickey Mouse or ice cream, etc. Vibrations are felt as the hands move symmetrically on either side of the sternum and vertebral column. In a normal healthy child, the vibrations felt in the corresponding areas on the two sides of the chest are equal in intensity. Usually vocal fremitus is the most intense in the regions of the thorax where the trachea and bronchi are the closest to the surface, particularly along the sternum between the first and second ribs and posteriorly between the scapulae. In young children vocal fremitus can be felt when the child cries. It may change with the presence of consolidation or air in the pleural space.

Vocal fremitus is increased when consolidation of lung tissue (pneumonia, lung abscess), atelectasis, a large cavern present. Vocal fremitus also increases at hypotrophy and emaciation.

Decreased vocal fremitus (weakening of vocal tremor or its absence) can be:

a) physiological (silent voice, thick chest wall, paratrophy and obesity);

b) pathological (compressed/closed bronchus and tissue is non-aerial, emphysema, cavern, pneumothorax, hydrothorax, thickened pleura, pyothorax, hemothorax).

Percussion of lungs

Percussion is the tapping of an object to set underlying structures in motion and thus produce a sound called a percussion note and a palpable vibration. Percussion penetrates to a depth of approximately 5 to 7 cm into the chest. This technique is used in the thoracic examination to determine the relative amounts of air, liquid, or solid material in the underlying lung and to determine the positions and boundaries of organs.

Lung percussion has limited value in small infants because it cannot discriminate between noises originating from tissues that are close to each other.

There are direct and indirect percussion.

Direct percussion is more often used in infant, and under-nourished child of early age. Direct percussion is known as Yanovsky's method. The doctor taps with his plexor – finger on the chest of the child. Next method of direct percussion is called as Obraztsov's method. The tapping on the body spent pulp right index finger, slide down to the radial surface adjacent middle finger (in the form of clicks).

Usually *indirect percussion* is used, when the doctor taps with a half-bent finger (plexor) on the finger placed on the chest (pleximeter).

The lungs are percussed in order to evaluate the densities of the underlying organs.

The main types of sounds obtained by percussion: normal resonance, increase of resonance – hyperresonance (tympanic) and decrease of resonance – dullness (dull, flatness, flat, stone dull).

Normal resonance is heard over all the lobes of the lungs that are not adjacent to other organs.

Dullness is heard beginning at the fifth interspace in the right midclavicular line. Percussing downward to the end of the liver, a flat sound is heard because the liver no longer overlies the air-filled lung. Cardiac dullness is felt over the left sternal border from the second to the fifth interspace medially to the midclavicular line.

Below the fifth interspace on the left side, tympany results from the air-filled stomach. Deviations from these expected sounds are always recorded and reported.

The pathological dullness is heard in cause of pneumonia, hydro-, hemothorax, pulmonary edema, lung or mediastinal tumor.

The bandbox (tympanic or hyperresonance) is heard in cause of: emphysema of lungs, cavern of lung, abscess of lung, pneumothorax, bronchial asthma, asthmatic bronchitis.

There are 2 type of percussion depending on the aim: comparative and topographic.

Comparative percussion is percussion of the symmetrical points of the chest for determination of character of percutory sound, its symmetry. In comparative percussing the chest, the anterior lung is percussed from apex to base, usually with the child in the supine or sitting position. Each side of the chest is percussed in sequence in order to compare the sounds. At normally the sounds should be same.

Topographical percussion of lungs uses for determination of the lungs' borders in the main lines, the location of the apex of the lung and width of Crenig's areas.

The upper margin of the lung (the location of the apex of the lung) is determined by percussions from the clavicle to the neck. The apex of each lung rises about 2 to 4 cm above the inner third oi the clavicles in front of the body. At the back we examine the location of the apex of the lung by percussions from the scapula axis to the seventh cervical vertebra. Normally, the upper border of the lung is in the seventh cervical vertebra at the back.

The width of Krenig's area is a width of vesicular resonance over the surface of the lung occupying the area from the clavicle to the scapular spine. Normally it is about 3–5 cm.

The Damoiseau-Ellis line is a semeiotic sign of exudative pleural effusion that delimits to the percussion on the back. It is a curved line with a concavity pointing downwards, the lower limit of which starts from the vertebral column. It is directed upwards and sideways until reaching the maximum point in correspondence with the posterior and middle axillary line and then begins to descend again.

It delimits the pleural effusion to the percussion, which provides a dull sound below the line, since there is liquid that prevents the transmission of the tympanic sound due to the air contained in the alveoli, and a clear tympanic sound above.

The Damoiseau-Ellis line also delimits two triangular areas:

• the Garland triangle, a hyperresonance area located between the vertebral column and the ascending portion of the line;

• the opposite paravertebral triangle Grocco-Rauchfuss, a triangular area with an upper vertex, located along the spinal column on the opposite side of the back relative to the Garland triangle, caused by a displacement of the mediastinum.

The inferior border of the lungs in children

Line	The side	Age of the child	
		Till 10 years	After 10 years
Midclavicular	Right	VI rib	VI rib
	Left	–	–
Middle axillary	Right	VII–VIII ribs	VIII rib
	Left	IX rib	VIII rib
Scapular	Right	IX–X ribs	X rib
	Left	X rib	X rib

Auscultation of lungs

Use the diaphragm of the stethoscope to auscultate breath sounds.

Rules of auscultation are:

1. Auscultate from side to side and top to bottom.
2. Compare one side to the other looking for asymmetry.
3. Note the location and quality of the sounds you hear.

Breath sounds are produced by turbulent air flow. They are categorized by the size of the airways that transmit them to the chest wall (and your stethoscope). The general rule is, the larger the airway, the louder and higher pitched the sound. Vesicular breath sounds are low pitched and normally heard over most lung fields. Tracheal breath sounds are heard over the trachea. Bronchovesicular and bronchial sounds are heard in between. Inspiration is normally longer than expiration.

Auscultation involves using the stethoscope to evaluate breath and voice sounds. Breath sounds are best heard if the child inspires deeply. The child can be encouraged to "take a big breath" by following a demonstration of "breathing in through the nose and out through the mouth." Younger children respond well to games such as blowing out the light from a cigarette lighter or the light of the otoscope.

During auscultation a doctor should be evaluate:

- the quality of breath sounds;
- detect the presence of abnormal sounds: localization, amount, kind, communication with the phase of breathing;
- determination of bronchophony.

Breath sounds are classified as vesicular or bronchovesicular and bronchial.

Vesicular breath sounds are produced by the passage of air in and out of normal lung tissue, and are normally heard over the entire surface of the lungs, with the exception of the upper intrascapular area and the area beneath the manubrium. Inspiration is louder, longer, and higher-pitched than expiration. Sometimes the expiratory phase seems nearly absent in comparison to the long inspiratory phase. It is a soft, low pitched rustling sound. There is no gap between inspiration and expiration.

Bronchovesicular breath sounds are normally heard over the manibrum and in the upper intrascapular regions where there are bifurcations of large airways. Inspiration is louder and higher in pitch than that heard is vesicular breathing.

Puerile breath sounds are one of normal types of breathing in children from 6 month till 3 or 7 (if asthenic) years old. Puerile breath sounds have short inspiration and louder, a hollow expiratory phase, blowing character.

Another type of breathing than is normal only over the trachea near the suprasternal notch is *bronchial* breath sounds. These are produced by the passage of air in the trachea and larger bronchi. The inspiratory phase is short and the expiratory phase is longer, louder and of higher pitch. There is a gap between inspiration and expiration.

In disease, bronchial breathing may be heard over the area of lung that is affected (lung collapse, fibrosis or when there is a cavity).

Rough breath sounds have short inspiration and louder phase. Rough breath has hollow and blowing character.

Absent or diminished breath sounds are always an abnormal finding warranting investigation. Fluid, air, or solid masses in the pleural space all interfere with the conduction of breath sounds (pneumonia pneumo-, hydro-, hemothorax, tumor of lung or mediastinal, emphysema of lungs, atelectasis, airways obstruction, a forcing body in the bronchus).

Diminished breath sounds in certain segments of the lung can alert the doctor to pulmonary areas that may benefit from postural

drainage and percussion. Increased breath sounds following pulmonary therapy indicate improved passage of air through the respiratory tract.

The main abnormal sounds includes following:

- crackles;
- wheezing;
- rhonchi;
- pleural rub.

Crackles are small clicking, bubbling, or rattling sounds in the lungs. Rales result from the passage of air through fluid or moisture. They are more pronounced when the child takes a deep breath. Even though the sound may seem continuous, it is actually composed of several discrete sounds, each originating from the rupture of a small bubble. The type of rales is determined by the size of the passageway and the type of exudate the air passes through. They are roughly divided into three categories: fine, medium, and coarse.

Fine crackles can be simulated by rubbing a few strands of hair between the thumb and index finger close to the ear or by slowly separating the thumb and index finger after they have been moistened with saliva. The result is a series of fine crackling sounds. They are believed to occur when air opens closed air spaces. Fine rales are most prominent at the end of inspiration and are not cleared by coughing. They occur in the smallest passageways, the alveoli and bronchioles.

Crepitation is a fine bubbling or crackling sound heard on auscultation, produced by the presence of a very thin secretion in the alveolus, pathognomonic sing of pneumonia. Heard over the lungs at peak of inspiration, when air reaches alveolus, expands and the wall of alveolus separate.

Medium crackles are not as delicate as fine rales and can be simulated by listening to the "fizz" from recently opened carbonated drinks or by rolling a dry cigar between the fingers. They are prominent earlier during inspiration and occur in the larger passages of the bronchioles and small bronchi.

Coarse crackles are relatively loud, coarse, bubbling, gurgling sounds that occur in the large airways of the trachea, bronchi, and smaller bronchi. Often, they clear partially during coughing.

Rhonchi are sounds that resemble snoring. Rhonchi are continuous, since sound being forced past an obstruction. They occur when air is blocked or becomes rough through the large airways.

Sibilant rhonchi are high pitched, musical, wheezing, and squeaking in character. The wheezing quality is often more pronoun

forced expiration. Sibilant rhonchi are produced in the smaller bronchi and bronchioles.

Sonorous rhonchi are low pitched and often snoring or moaning in character. They are produced in the large passages of the trachea and bronchi. Like coarse rales, they can be partly cleared by coughing.

Wheezes are continuous, high-pitched, musical, predominantly expiratory sounds that are produced by air flowing through narrowed bronchi, causing fluttering and resonance of the bronchial walls. Thus, they are caused by pathology leading to the narrowing of bronchi, most commonly COPD, asthma, and bronchitis.

A pleural friction rub is a loud, dry, creaking or grating sound indicative of pleural irritation. It is produced by the rubbing together of inflamed and roughened pleural surfaces during respiration (e.g., in pleurisy). Therefore, it is heard best during the latter part of inspiration and the beginning of expiration. Because thoracic expansion is greatest in the lower anterolateral thorax, pleural friction rubs are most often heard there.

Bronchophony are also part of auscultation of the lungs. The resonant sound that is heard with the stethoscope when the patient is asked to repeat "ninety-nine" or "one-one-one". Normally voice sounds or vocal resonance is heard, but the syllables are indistinct. Sound depends on the loudness and the depth of the patients voice and the conductivity of the lungs. Consolidation of the lung tissue produces three types of abnormal voice sounds – whispers pectoriloquy, bronchophony and egophony. Egophony is present when *e* sounds like *a*. Whispering pectoriloquy produces clearer sounding whispered words.

ADDITIONAL METHODS OF INVESTIGATION OF RESPIRATORY SYSTEM IN CHILDREN

Instrumental investigations

Chest radiographs are useful in assessing respiratory disease in children. In addition to determining lung abnormalities, they provide information about the bony thorax (rib or vertebral abnormalities), the heart (cardiomegaly, pericardial effusion), and the great vessels (right aortic arch/vascular rings, rib notching). Chest radiographs should be obtained in both the posteroanterior (PA) and lateral projections and, if possible, following a full inspiration. Estimation of

lung hyperinflation based on a single PA view is unreliable; flattened diaphragms and an increased PA diameter on lateral projection is a better indicator of hyperinflation. Crowding of the blood vessels with poor inspiration can be misinterpreted as increased markings or infiltrates. External skin folds, rotation, and motion may produce distorted or unclear images. Expiratory views and fluoroscopy may detect partial bronchial obstruction due to an aspirated foreign body that results in regional hyperinflation, because the affected lung or lobe does not deflate on exhalation. Fluoroscopy can also be used to evaluate diaphragm movement.

Barium esophagram may be valuable in diagnosing disorders of swallowing (dysphagia) and esophageal motility, vascular rings (esophageal compression), tracheoesophageal fistulas, and, to a lesser extent, gastroesophageal reflux. When evaluating for a tracheoesophageal fistula, contrast material must be instilled under pressure via a catheter with the distal tip situated in the esophagus.

Computer tomography (CT) scan of the chest is the imaging test of choice for evaluating pleural masses, bronchiectasis, and mediastinal lesions as well as delineating pleural from parenchymal lesions. CT scans with intravenous contrast provide excellent information about the pulmonary vasculature and great vessels and can detect pulmonary embolism. High-resolution CT scans are used to assess lung parenchyma (congenital pulmonary malformations, interstitial lung disease) and the airways (bronchiectasis). The speed of current CT scanners makes it possible to scan most children without sedating them. However, sedation may be required in infants and toddlers to decrease motion artifact.

Magnetic resonance imaging (MRI) useful in visualizing cardiac and great vessel anatomy, is less useful for evaluation of pulmonary parenchymal lesions.

Ultrasonography can be used to delineate some intrathoracic masses and is the imaging procedure of choice for assessing parapneumonic effusion/empyema. It is useful for assessing diaphragmatic motion in small children.

Pulse oximetry measures the O2 saturation of hemoglobin by measuring the blood absorption of two or more wavelengths of light. It is noninvasive, easy to use, and reliable. Because of the shape of the oxyhemoglobin dissociation curve, O2 saturation does not decrease much until the Po2 reaches approximately 60 mm Hg. Pulse oximetry may not accurately reflect true O2 saturation when abnormal

hemoglobin is present (carboxyhemoglobin, methemoglobin), when perfusion is poor, or if no light passes through to the photodetector (nail polish). The measurement of Pco2 is accomplished most reliably by blood gas analysis. However, there are noninvasive monitors that record exhaled Pco2 (end-tidal CO2), which is representative of alveolar Pco2. End-tidal Pco2 measurements are most commonly used in intubated and mechanically ventilated patients, but some devices can measure Pco2 at the nares. Transcutaneous electrodes can be used to monitor Pco2 and Po2 at the skin surface, but are less accurate. Noninvasive techniques of CO2 measurement are best suited for detecting trends rather than for providing absolute values.

Pulmonary function testing. Measurement of lung volumes and airflow rates using spirometry are important in assessing pulmonary disease. The patient inhales to TLC and then forcibly exhales until no more air can be expelled. During the forced expiratory maneuver, forced vital capacity (FVC), forced expired volume in the first second (FEV1), and forced expiratory flow (FEF) rates are measured. These are compared to predicted values based on patient age, gender, and race, but rely mostly on height. Most children above 6 years of age can perform spirometry. Infant pulmonary function testing is possible, using sedation and sophisticated equipment. Airway resistance, FRC, and RV cannot be measured with spirometry and require other techniques, such as body plethysmography. Helium dilution can also measure TLC and RV by determining the magnitude of dilution of inhaled helium in the air within the lung, but may underestimate air trapping. Abnormal results on pulmonary function testing can be used to categorize obstructive airway disease (low flow rates and increased RV or FRC) or a restrictive defect (low FVC and TLC, with relative preservation of flow rates and FRC). When the FEV1 and flow rates are decreased to a greater extent than the FVC, then airway obstruction is likely; however, a proportional decrease in FVC, FEV1, and flow rates suggests a restrictive lung defect. The mean midexpiratory flow rate (FEF 25–75 %) is a more sensitive measure of small airways disease than the FEV1, but is also more variable. Pulmonary function testing can detect reversible airway obstruction characteristic of asthma with a significant improvement in FEV1 (>12–15 %) or in FEF 25–75 % (>25 %) following inhalation of a bronchodilator. Spirometry is also useful for longitudinal patient management.

The peak expiratory flow rate (PEFR) can be obtained with a simple handheld device and may be useful for home monitoring

of older children with asthma. However, it is highly dependent on patient effort, and values must be interpreted with caution. Inhalation challenge tests using methacholine, histamine, or cold, dry air are used to assess airway hyperreactivity, but require sophisticated equipment and special expertise and should be performed only in a pulmonary function laboratory with experienced technicians.

Endoscopic evaluation of the airways. Endoscopic evaluation of the upper airways (nasopharyngoscopy) is performed with a flexible fiberoptic nasopharyngoscope to assess adenoid size, patency of the nasal passages, and abnormalities of the glottis. It is especially useful in evaluating stridor and assessing vocal cord motion/function, and it does not require sedation. Endoscopic evaluation of the subglottic space and intrathoracic airways can be done with either a flexible or rigid bronchoscope under anesthesia. Bronchoscopy is useful in identifying airway abnormalities (stenosis, malacia, endobronchial lesions, excessive secretions) and in obtaining airway samples for culture (bronchoalveolar lavage), especially in immunocompromised patients. Rigid bronchoscopy is the method of choice for removing foreign bodies from the airways and performing other interventions, and flexible bronchoscopy is most useful as a diagnostic tool and for obtaining lower airway cultures. Transbronchial biopsies are rarely performed in children. There are few absolute contraindications to bronchoscopy. Relative contraindications include bleeding diatheses, thrombocytopenia (<50,000/cm3), and clinical conditions when the patient is too unstable to tolerate the procedure.

Laboratory investigations

Examination of sputum. Sputum specimens may be useful in evaluating lower respiratory tract infections, but they are difficult to obtain in young children. In addition, an expectorated specimen may not provide a representative sample of lower airway secretions. Specimens containing large numbers of squamous epithelial cells either are not from the lower airways or are heavily contaminated with upper airway secretions and may yield misleading results. Sputum in patients with lower respiratory tract bacterial infections often contains polymorphonucleated leukocytes and one predominant organism on culture, crystals of Charco – Leyden (formed from destruction of eosinophils, sing of bronchial asthma), spirals of Curschman (the formations of mucous character), elastic filaments –

are found out at tuberculosis, abscesses (destruction of pulmonary tissue). If sputum cannot be obtained, then bronchoalveolar lavage specimens may be used for microbiologic diagnosis in selected situations. In patients with CF who cannot produce sputum, specially processed throat cultures are often used as surrogates for lower airway cultures.

Lung biopsy. When less invasive methods fail to provide diagnoses in patients with pulmonary disease, a lung biopsy may be required. Concern for childhood interstitial lung disease, atypical infection (especially in an immunocompromised host), and evaluation of a mass/malformation are the most common indications for biopsy. CT-guided needle biopsy performed by an interventional radiologist is an option if limited histology is needed and the lesion is amenable to percutaneous approach (e. g., fungal nodules). Either a thoracoscopic procedure or a thoracotomy is preferred if thorough histologic evaluation is desired. Thoracotomy allows the surgeon to inspect and palpate the lung, which aids in choosing the best site for biopsy, but it is more invasive than thoracoscopy. In most cases, infants and children tolerate lung biopsy well.

DISORDERS OF RESPIRATORY SYSTEM IN CHILDREN

Upper respiratory diseases.

Rhinitis – inflammation of the nasal mucosa

Rhinosinusitis or sinusitis – inflammation of the nares and paranasal sinuses, including frontal, ethmoid, maxillary, and sphenoid.

Nasopharyngitis (rhinopharyngitis or the common cold) – inflammation of the nares, pharynx, hypopharynx, uvula, and tonsils.

Pharyngitis – inflammation of the pharynx, hypopharynx, uvula, and tonsils.

Epiglottitis (supraglottitis) – inflammation of the superior portion of the larynx and supraglottic area.

Laryngitis – inflammation of the larynx.

Laryngotracheitis – inflammation of the larynx, trachea, and subglottic area.

Tracheitis – inflammation of the trachea and subglottic area.

Lower respiratory diseases.

Bronchitis.

Bronchiolitis.

Pneumonia.

Bronchial asthma.

The main symptoms of *colds:* nasal congestion, runny nose, sneezing, sore throat, mild to moderate hacking cough, possible low-grade fever for the first day or two.

Croup – the common early childhood ailment known as croup (tracheolaryngobronchitis) involves inflammation of the trachea (windpipe), the larynx (voice box) and the bronchioles (tiny airways leading to the lungs). It is recognized by a distinctive "barking cough" that usually starts suddenly and at night. Children ages 3 months to 3 years are most susceptible to croup. Signs and symptoms: dry, barking (brassy) cough, stridor – noisy, labored breathing, high-pitched noise when inhaling, hoarseness, tight throat.

Sinusitis – viral infections and allergies affect sinuses the same way they affect the nasal passages, causing swelling and producing extra mucus. This makes it difficult for the sinuses to drain properly and as mucus accumulates, the sinuses become a safe haven for germs to grow. The resulting infection can cause sinus pressure and pain. Signs and symptoms: upper respiratory tract infection symptoms lasting more than 10 days without improvement, nasal congestion or discharge any color, cough at day and night, facial pain or headache, fatigue and irritability, low-grade fever.

Bronchitis are divided on acute (simple, obstructive, bronchiolitis) and chronic bronchitis. Main symptoms of acute bronchitis: cough – dry and rough at the beginning of disease, gradually becoming productive; symptoms of intoxication are not expressed greatly and quickly disappear; symptoms of respiratory insufficiency are absent; rough respiration during auscultation, wheezes become coarse crackles.

Obstructive bronchitis – is a variant of acute bronchitis, which proceeds with respiratory tract obstruction because of bronchospasm, mucous edema, hypersecretion and pressure from without. Signs of respiratory tract obstruction: persistent "spastic" cough, expiratory dyspnea, wheezing, oral crepitations, tympanic percussion sounds, wheezes (whistling) and crackles. On chest X-ray picture – strengthened lung figure, at the same time absence of focal shadow; rarefied lung pattern in lateral divisions of the lungs and its thickening in the medial divisions (occult emphysema).

Bronchial asthma – is one of the most common causes of hospital admission and visits to healthcare providers in this age group. Children with asthma have sensitive, easily irritated airways in their lungs. When exposed to certain triggers – like viruses, allergens, secondhand smoke, chemical irritants, cold air or pollution – the airways become more inflamed, producing increased mucus, mucosal swelling and muscle contraction. This results in airway obstruction, chest tightness, coughing, shortness of breath and wheezing. The main symptoms: coughing on expiration (breathing out), especially at night, wheezing on expiration, difficulty breathing, shortness of breath when exercising or playing, rapid heart rate, during percussion is heard tympanic sound, during auscultation – diffuse whistling wheezes. On chest X-ray picture – Barrel chest, emphysema.

Bronchiolitis – is an acute viral lower respiratory tract infection that results in an inflammatory obstruction of the peripheral airways. It is characterized by obstructive respiratory insufficiency and cyclic course. Bronchiolitis is mainly a disease of the first months of life. The main clinical symptoms: cyanosis nasolabial triangle, tachypnea with usually shallow respirations, dyspnea (increased expiratory phase), asphyxial paroxysms are possible for infants of the first months of the life, persistent spastic cough, tachycardia: especially when hypoxemia present, mild fever usually, vomiting (post tussive). During examination: intercostal retractions of flexible parts of breast (subcostal / intercostal recession), percussion of the chest: hyperresonance (high tympanic resonance), auscultation: prolonged breathing out, diffuse wheezes and crackles throughout the breathing cycle on the both sides of lungs and a lot of fine bubbling rales, hypoxia is common in severely affected patients. X-ray showing the typical bilateral perihilar fullness of bronchiolitis.

Pneumonia is inflammatory process in respiratory pulmonary parts with intraalveolar exudation. The main clinical symptoms: fever, cough (dry or moist), tachypnea, decreased activity and poor eating, grunting sound when your child exhales, pallor skin, perioral cyanosis, retractions – drawing in of muscles and skin around neck and chest with each breath. During examination: palpation – there can be voice trembling, percussion – located decrease is resonance, auscultation of the lungs – local diminished breath sound, fine crackles, crepitation. X-ray – infiltration is certain area of lung.

Pleurisy – is the inflammation of the pleura, divide on dry (fibrous) and exudative. Dry pleurisy – usually as complication of

pneumonia, clinical symptoms: dry painful cough, pain in the thorax on the affected side. During examination: pain on palpation at the affected side, auscultation – diminished breath sound, pleural friction rub. Exudative pleurisy is characterized by accumulation of considerable amount exudates (serous, serofibrinous, purulent, hemorrhagical). Clinical symptoms: cough (dry, painful), tachypnea, cyanosis, asymmetric of thorax, less active of breathing, protrusion of intercostals space in ill side. During examination: percussion dull sound on affected side, line of Damoiseau is present, decreases of excursion of lung, auscultation – diminished breath sound, pleural rub only at the beginning of pleural effusion. Chest X-ray indistinct contour, deformation costo-diaphragmal sinus, presence of effusion in the pleural cavity (an intense homogenous obscuration with an oblique upper border going down and inside is found, the mediastinum shifts to a healthy side.

Acute respiratory failure occurs when the pulmonary system is unable to maintain adequate gas exchange to meet metabolic demands. The resulting failure can be classified as hypercarbic (Paco2 >50 mm Hg in previously healthy children), hypoxemic (Pao2 <60 mm Hg in previously healthy children without an intracardiac shunt), or both. Hypoxemic respiratory failure is frequently caused by ventilation-perfusion mismatch (perfusion of lung that is not adequately ventilated) and shunting (deoxygenated blood bypasses ventilated alveoli). Hypercarbic respiratory failure results from inadequate alveolar ventilation secondary to decreased minute ventilation (tidal volume × respiratory rate) or an increase in dead space ventilation (ventilation of areas receiving no perfusion). Respiratory failure may occur with acute lung injury (ALI) or acute respiratory distress syndrome (ARDS). Early signs of hypoxic respiratory failure include tachypnea and tachycardia in attempt to improve minute ventilation and cardiac output and to maintain delivery of oxygenated blood to the tissues. Further progression of disease may result in dyspnea, nasal flaring, grunting, use of accessory muscles of respiration, and diaphoresis. Late signs of inadequate oxygen delivery include cyanosis and altered mental status (initially confusion and agitation). Signs and symptoms of hypercarbic respiratory failure include attempts to increase minute ventilation (tachypnea and increased depth of breathing) and altered mental status (somnolence). A chest radiograph may show evidence of the etiology of respiratory failure. The detection of atelectasis, hyperinflation, infiltrates, or pneumothoraxes assists with ongoing management. Diffuse infiltrates or pulmonary edema may suggest ARDS. The chest

radiograph may be normal when upper airway obstruction or impaired respiratory controls are the etiology. In patients presenting with stridor or other evidence of upper airway obstruction, a lateral neck film or computed tomography (CT) may delineate anatomic defects. Direct visualization through flexible bronchoscopy allows identification of dynamic abnormalities of the anatomic airway. Helical CT helps diagnose a pulmonary embolus. Pulse oximetry allows noninvasive, continuous assessment of oxygenation but is unable to provide information about ventilation abnormalities. Determination of CO2 levels requires a blood gas measurement (arterial, venous, or capillary). An arterial blood gas allows measurement of CO2 levels and analysis of the severity of oxygenation defect through calculation of an alveolar-arterial oxygen difference. A normal Pco2 in a patient who is hyperventilating should heighten concern about the risk of further deterioration.

QUESTIONS FOR SELF-CONTROL

The tests for self-control

1. What average respiration rate is typical for 1 year infant in the rest?

A. 40–60 per min.
B. 30–35 per min.
C. 20–25 per min.
D. 16–18 per min.
E. 10–15 per min.

2. Inspiratory dyspnea may be present in such diseases except:

A. Constrictive laryngotracheitis.
B. Diphtheria.
C. Foreign body in the larynx of trachea.
D. Bronchiolitis.

3. In each inhalation gradual increase in its depth and frequency up to maximum, then the amplitude and frequency of respiration decreases (10–12 r. m.), then apnea 20–30 sec. Then cycle repeats. What kind of pathological respiration is described?

A. Cheyne-Stokes respiration.
B. Kussmul's respiration.

C. Biot's respiration.
D. Chaotic respiration.

4. What clinical method can you use to vocal fremitus estimation?
A. Palpation.
B. Percussion.
C. Auscultation.
D. Visual inspection.
E. All listed above.

5. Dull sound is present during percussion in such area except:
A. In area over heart and liver.
B. Over large infiltration at pneumonia.
C. Over accumulation the fluid in the pleural cavity in lower part of lung.
D. Over significant tumor.
E. Over large empty cavern.

6. Tympanic resonance is present in such diseases except
A. Obstructive bronchitis.
B. Pneumonia (over infiltration's area).
C. Bronchial asthma.
D. Pneumothorax.
E. Emphysema.

7. What the additional breath sounds do you know in children?
A. Ronchi and crackles.
B. Pectoral fremitus.
C. Bronchial breathing.
D. Vesicular breathing.
E. All listed above.

8. Coarse crackles are indication on
A. Fluid in the large airways.
B. Fluid in the smaller airway.
C. Obstruction of one airway.
D. Generalized obstruction of small airways.
E. Fluid in alveoli.

9. Fine crackles are indication on:
A. Fluid in the large airways.
B. Fluid in the small airways.
C. Obstruction of one airway.
D. Generalized obstruction of small airways.
E. Fluid in alveoli.

10. Crepitation is heard in case of:
A. Obstructive bronchitis.
B. Laryngotracheitis.
C. Pneumonia.
D. Cavern.
E. Emphysema.

11. The most common X-ray abnormality in a child with asthma:
A. Bronchiectasis.
B. Generalized hyperrairness.
C. Lower lobe infiltrates.
D. Pneumomediastinum.
E. Right middle lobe atelectasis.

12. What indexes can be estimated by peakflowmetry in children.n?
A. Peak velocity of exhalation (L/min).
B. Tidal volume, ml.
C. Expiratory reserve volume, ml.
D. Vital capacity, l.

13. What parameter of peak flow meter is corresponding to the airways are open:
A. >80 %.
B. 50–80 %.
C. 50 %.
D. 30 %.

14. You want to receive the pleural fluid to further analysis. What method you must use?
A. Thoracocentesis.
B. Lung biopsy.
C. Bronchoscopy.
D. Laparoscopy.

15. Bronchoscopy may be used for following:
A. Diagnose cancer, tuberculosis, lung infection, or other lung disease.
B. Examine an inherited deformity of the lungs.
C. Remove a foreign body in the lungs.
D. Provide biopsy, to test for cancer cells.
E. All mentioned.

Answers:

1 – B, 2 – D, 3 – A, 4 – A, 5 – E, 6 – B, 7 – A, 8 – A, 9 – B, 10 – C, 11 – B, 12 – A, 13 – A, 14 – A, 15 – E.

Situational tasks. A 15-year-old patient presents to the emergency room with shortness of breath. Objective data: chest is inflated, distended in anteroposterior part, respiratory rate is 34, tympanic resonance, at auscultation – dry whistling rales and prolonged expiration. What is the most likely diagnosis?

Answer: Bronchial asthma.

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