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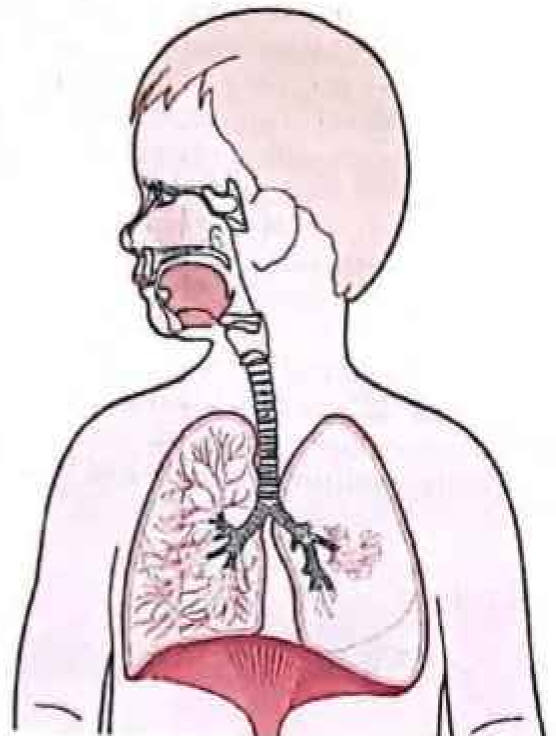
ANATOMICAL AND PHYSIOLOGICAL FEATURES OF RESPIRATORY ORGANS IN CHILDREN

Methodical handbook for students of medical institutions and clinical residents



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The study of the anatomical and physiological features of the respiratory system in children is one of the most important directions in modern pediatrics. This is especially important given the high incidence of respiratory diseases in children at the present time, including such common pathologies .These disease have a significant impact on the health and well being of children and require a comprehensive approach to their diagnosis, treatment and prevention. Therefore, understanding the peculiarities of the development and functioning of the respiratory system in children is a key aspect of modern pediatric practice, contributing to the development of effective strategies for the treatment and prevention of respiratory diseases, as well as improving the quality of life of children.

The methodological manual "Anatomical and physiological features of the respiratory organs in children" is a valuable source of knowledge not only for students, both for future doctors and specialists in the field of pulmonology, but also for pediatricians, pediatric pulmonologists and health care organizers.

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Abbreviations

APF- anatomical and physiological features
Po_2- partial pressure of oxygen
VEL -vital capacity of the lungs
IRV- inspiratory reserve volume
ERV- expiratory reserve volume
FRC- functional residual capacity
RV-residual volume
MVL- maximum ventilation of the lungs
CO_2 -carbon dioxide
RV-respiratory volume
FVC- forced vital capacity
MVL-maximum lung ventilation
MVB-minute volume of breathing
O2UC- oxygen utilization coefficient
O2A -the amount of oxygen absorbed
HbF- fetal hemoglobin
H_2CO_3- фcidum carbonicum
$NaNCO_3$- sodium bicarbonate
CT scan- computed tomography scan
RF-Respiratory failure
ARF-acute respiratory failure
RDS-respiratory distress syndrome
CNS-central nervous system
ASLT-acute stenosing laryngotracheitis
ARI-acute respiratory infection
RD-Respiratory deficiencies
HF-heart failure
ECG- electrocardiogram
BOS-bronchial obstruction syndrome
LDH-lactate dehydrogenase

CONTENTS

INTRODUCTION

Respiratory pathology in children occupies one of the first places in the overall morbidity of children (about 2/3 of those who go to a children's polyclinic) and among the causes of child mortality. Timely diagnosis, effective treatment and prevention of respiratory diseases are impossible without knowledge of the anatomical and physiological features of the respiratory system and a thorough examination of the child.

Objective: To master the knowledge of anatomical and physiological features of respiratory organs, semiotics and syndromes of their damage; methods of clinical, laboratory and instrumental examination of the child.

As a result of studying the APF of respiratory organs in children, methods of study and semiotics and the main syndromes of respiratory system **the student should know:**

1. Age-related anatomical and physiological features of the respiratory system;
2. Modern methods of clinical, laboratory and instrumental diagnostics used in pediatric practice to assess the state of the respiratory system in children and adolescents;
3. Semiotics and the main syndromes of respiratory damage in children and adolescents;
4. Features of laboratory parameters and data of instrumental research methods in children of different ages, their diagnostic significance

The student must be able to:

1. Analyze and evaluate the health status of the child population, the impact of lifestyle, environmental, social and biological factors on it;
2. Establish psychological and verbal contact with healthy and sick children and their parents;
3. Collect anamnesis of the child's life and illness by interviewing him, his parents or relatives, and make a conclusion based on the anamnesis.
4. Conduct a physical (clinical) examination of a patient of various ages (complaints, medical history, examination, palpation, percussion, auscultation, measurement of respiratory rate, etc.), make a conclusion based on the results of the examination;
5. Identify the main symptoms and syndromes of respiratory damage in a sick child and assess the severity of his condition;
6. Send children and adolescents for laboratory and instrumental examination, for consultation with specialists;

is present, their fate depends on the time of diagnosis and the speed of providing the necessary medical care. A newborn with such a developmental defect in the first hours looks quite normal and breathes freely. However, at the first attempt at feeding, due to the ingestion of milk from the esophagus into the trachea, asphyxia occurs – the child turns blue, a large number of wheezes are heard in the lungs, and infection quickly joins. Treatment of such a malformation is only operative and should be carried out immediately after diagnosis. Delayed treatment causes severe, sometimes irreversible, organic changes in the lung tissue due to the constant ingress of food and gastric contents into the trachea.

It is customary to distinguish *between the upper* (nose, pharynx), *middle* (larynx, trachea, lobular, segmental bronchi) and *lower* (bronchioles and alveoli) airways (Fig. 2). Knowledge of the structure and function of various parts of the respiratory system is of great importance for understanding the features of respiratory damage in children.

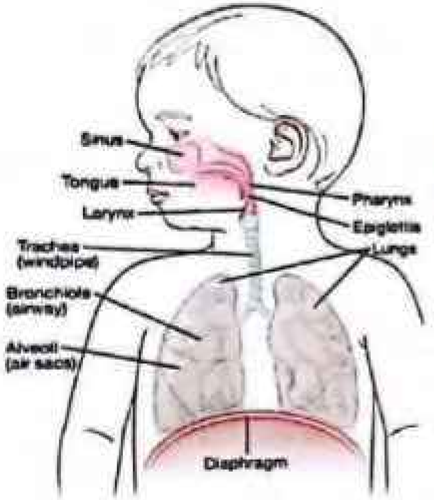


Fig 2. Respiratory organs in children https://www.drboonathi.com/medical-problems/bronchiolitis/

Upper respiratory tract. *The nose* of a newborn is relatively small, its bones are poorly developed, and the nasal passages are narrow (up to 1 mm). The lower nasal passage is missing. The nasal cartilage is very soft. The nasal mucosa is tender, rich in blood and lymphatic vessels. By the age of 4, the lower nasal passage is formed. As the facial bones (upper jaw) increase and the teeth erode, the length and width of the nasal passages increase. In newborns, the cavernous part of the nasal mucosa is insufficiently developed, which develops only by 8-9 years. This explains the relative rarity of nosebleeds in 1-year-olds. Due to insufficient development of the cavernous tissue in young children, the inhaled air is poorly warmed, and therefore children should not be taken outside at temperatures below -10° C. A wide nasolacrimal duct with underdeveloped valves contributes to the transition of inflammation from the nose to the eye mucosa. Due to the narrowness of

the nasal passages and the abundant blood supply to the nasal mucosa, even a slight inflammation of the nasal mucosa causes difficulty breathing through the nose in young children. Breathing through the mouth in children of the first half of life is almost impossible, since the large tongue pushes the epiglottis posteriorly.

Although the paranasal sinuses begin to form in the prenatal period, they are not sufficiently developed at birth (Chart 1).

Chart 1

Development of the paranasal sinuses (sinuses) of the nose

Name of the sine	Term of intrauterine development, mass	Size at birth, mm	Fastest development period	Term of detection during X-ray examination
Latticed	5-6	5x2x3	By the age of 7-12 years	3 months
Maxillary	3	8x4x6	2 to 7 years old	From 3 months
Frontal	No	0	Slowly up to 7 years, fully developed by 15-20 years	6 years
Wedge-shaped	3	1-2	Slowly up to 7 let, fully developed by the age of 15	6 years

These features explain the rarity of diseases such as gaimorit, frontitis, etmoiditis, polysinusitis (disease of all sinuses) in early childhood. When breathing through the nose, air passes with greaterresistance than when breathing through the mouth, so when nasal breathing, the work of the respiratory muscles increases and the breath becomes deeper. Atmospheric air, passing through the nose, is warmed, moistened and purified. The warmer the air is, the lower the outside temperature. So, for example, the air temperature when passing through the nose at the level of the gortni is only 2...3° C lower than the body temperature. The inhaled air is purified in the nose, and foreign bodies larger than 5-6 microns are captured in the nasal cavity (smaller particles penetrate into the underlying parts). 0.5–1 l of mucus is released into the nasal cavity per day, which moves in the posterior 2/3 of the nasal cavity at a rate of 8-10 mm / min, and in the anterior third – 1-2 mm / min. Every 10 minutes, a new layer of mucus passes through, which contains bactericidal substances (lysozyme, complement, etc.), secretory immunoglobulin A.

The pharynx of a newborn is narrow and small. The lymph pharyngeal ring is poorly developed. Both palatine tonsils in newborns normally do not go out of the arches of the soft palate into the pharyngeal cavity. In the second year of life, hyperplasia of the lymphoid tissue is observed, and the tonsils come out from behind the anterior arches. Crypts in the tonsils are poorly developed, so angina in children under one year old, although there are, but less often than in older children. By the age of 4-10, the tonsils are already well developed and can easily become hypertrophied. The tonsils are similar in structure and function to the lymph nodes.

The tonsils act as a filter for microorganisms, but with frequent inflammatory processes, a focus of chronic infection can form in them. At the same time, they gradually increase, hypertrophy — chronic tonsillitis develops, which can occur with general intoxication and cause sensitization of the body.

Nasopharyngeal tonsils can grow-these are so-called adenoid vegetations, which disrupt normal nasal breathing, and also, being a significant receptor field, can cause allergy, intoxication of the body, etc. Children with adenoids are not very attentive, which affects their school performance. In addition, adenoids contribute to the formation of malocclusion.

Among the lesions of the upper respiratory tract in children, rhinitis and sore throats are most often observed (Chart 2).

Chart 2

Anatomical and physiological features of the respiratory system

Anatomical structure	Anatomical and physiological features	Possible clinical consequences
Nose	Narrow nasal passages, thick nasal shells, and the lower nasal passage are formed by the age of 4. The mucous membrane is delicate, richly vascularized. Cavernous (cavernous) tissue is not developed, it is formed by the age of 8-9	Slight swelling causes a sharp obstruction of nasal breathing, which makes it difficult to suck
Paranasal sinuses	They are insufficiently developed at birth. The maxillary (maxillary), ethmoidal (latticed) and wedge-shaped sinuses are formed, but they are very small in size. The frontal sinus is missing. Full formation of sinuses — by the age of 15	Sinusitis in young children is rare
Throat	The newborn's throat is narrow. The lymphoid ring is poorly developed. After a year, the palatine tonsils go beyond the arches, the crypts in them are poorly developed	Angina in young children is rare. Often, in young children, there is an overgrowth of nasopharyngeal lymphoid tissue (adenoids), which makes nasal breathing difficult. The formation of an "adenoid face" is possible: open mouth, lack of nasal breathing, uffiness, snoring in a dream
Larynx	Funnel-shaped, narrow, cartilage is tender and pliable. A narrow lumen, rich vascularization and a tendency of the mucous membrane to edema. The vocal cords are shorter than in adults, which determines the character of the voice. Up to 3 years old, the shape of the larynx is the same in boys and girls. Then, in boys, the angle of junction of the plates of thyroid cartilage becomes sharper than in girls. With increasing—the volume of the vocal cords is lengthened (especially by the age of 10-1 2 years)	Small children have a high-pitched voice. The tendency of young children to stenosing laryngitis
Chest	In a newborn, the chest is barrel-shaped: the sagittal size is almost equal to the transverse one (Fig. 7-6). the ribs are connected to the vertebral column more horizontally (almost at a right angle). The epigastric angle is obtuse. Respiratory muscle weakness, superficial, predominantly diaphragmatic breathing in newborns and children of the first months of life. With age, the anteroposterior size decreases, and the posterior section of the thoracic cage becomes oval. Its frontal size increases, its sagittal size decreases relatively (Fig. 7-7), the curvature of the ribs increases, the epigastric angle becomes more acute. Elastic structures of the lung tissue develop, ventilation efficiency increases	High risk of pneumonia, atelectasis in newborns and young children
Mediastinum	Relatively more than adults. The upper part contains the trachea, large bronchi, arteries, veins, nerves (L. vagus, truncus sympathicus, P. larynges recurrents, etc.), thymus gland and lymph nodes. In the lower part there is a heart. The root of the lung is a component part of the mediastinum, consists of large bronchi, blood and lymphatic vessels and lymph nodes (paratracheal, tracheobronchial, bronchopulmonary, etc.). Lymph nodes of the lungs (as well as lymph nodes of other areas) have wide sinuses, rich vascularization, weak capsule development, large the number of large cellular elements	Ease of development of inflammatory processes

Middle and lower respiratory tract. *The larynx* for the birth of a child has a funnel-shaped shape, its cartilage is tender and pliable. The glottis is narrow and located high — at the level of the IV cervical vertebra (in adults- at the level of the VII cervical vertebra). The cross-sectional area of the airway under the vocal folds is on average 25 mm, and the length of the vocal folds is 4-4. 5 mm. The mucous membrane is tender, richen blood and lymphatic vessels. Elastic tissue is poorly developed. Up to 3 years of age, the shape of the larynx is the same in boys and girls. After 3 years, the angle of junction of the thyroid plates in boys becomes more acute, which becomes especially noticeable by the age of 7; by the age of 10, the larynx in boys is similar to that of an adult male.

The glottis remains narrow up to 6-7 years. True vocal folds in young children are shorter than in older ones (which makes them have a high voice); from the age of 12, the vocal folds in boys become longer than in girls. The peculiarity of the larynx structure in young children also explains the frequency of its lesions *(laryngitis)*, and they are often accompanied by difficulty breathing – *croup*.

The trachea is almost fully formed at birth. It has a funnel-shaped shape. Its upper edge is located at the level of the IV cervical vertebra (at the level of the VII vertebra in an adult). The tracheal bifurcation is higher than that of an adult. It can be roughly defined as the intersection of lines drawn from *the spinae scapulae* to the spine. The tracheal mucosa is tender and rich in blood vessels. Elastic tissue is poorly developed, and its cartilaginous framework is soft and easily narrows the lumen. With age, the trachea increases both in length and in diameter, however, compared with the growth of the body, the rate of tracheal growth lags behind, and only from puberty does the increase in its size accelerate.

The tracheal diameter changes during the respiratory cycle. Especially significantly changes the lumen of the trachea during coughing-the longitudinal and transverse dimensions are reduced by 1/3. There are many glands in the tracheal mucosa – approximately one gland per 1 mm² of the surface. Due to the secretion of glands, the tracheal surface is covered with a layer of mucuas microns thick, the mucus movement speed is 10-15 mm / min, which is ensured by the movement of cilia of the ciliated epithelium (10-35 cilia per 1 microns²).

Features of the trachea structure in children are determined by its frequent isolated lesions *(tracheitis)*, in combination with laryngeal *(laryngotracheitis)* or bronchial *(tracheobronchitis) lesions*.

The bronchi are quite well formed at the time of birth. The mucus pack shell has a rich blood supply, is covered with a thin layer of mucus that moves at a speed of 0.25-1 cm / min. In the bronchioles, the movement of mucus is slower (0.15-0.3 cm / min). The right bronchus is like a continuation of the trachea, it is shorter and somewhat wider than the left one.

Muscle and elastic fibers in children of the first year of life are still poorly developed. With age, both the length and lumen of the bronchi increase. The bronchi grow especially fast in the first year of life, then their growth slows down. At the beginning of puberty, their growth rate increases again. By the age of 12-13, the length of the main bronchi doubles, and the resistance to bronchial collapse increases with age. In children, acute bronchitis is a manifestation of a respiratory viral infection. Asthmatic bronchitis is less commonin patients with respiratory allergies. The delicate structure of the bronchial mucosa and the narrowness of their lumen also explain the relatively frequent occurrence *of bronchiolitis in young children with complete or partial obstruction syndrome*.

The weight of the lungs at birth is 50-60 g, which is 1/50 of the body weight. In the future, it increases rapidly, and especially intensively during the first 2 months of life and during puberty. It doubles by 6 months, triples by one year of life, increases almost 6 times by 4-5 years, 10 times by 12-13years, and 20 times by 20 years.

In newborns, the lung tissue is less airy and is characterized by abundant development of blood vessels and loose connective tissue in the chin of the acini. Elastic tissue is insufficiently developed, which explains the relatively easy occurrence of emphysema in various pulmonary diseases. Thus, the ratio of elastin and collagen in the lungs (dry tissue) in children under 8 months is 1 : 3.8, while in an adult-1 : 1.7. By the birth of a child, the respiratory part of the lungs (acinus, where gas exchange between air and blood occurs) is insufficiently developed.

Alveoli begin to form from the 4th6-6th week of life, and their number increases very quickly during the first year, increasing to 8 years, after which the lungs increase due to the linear size of the alveoli (Fig. 3).

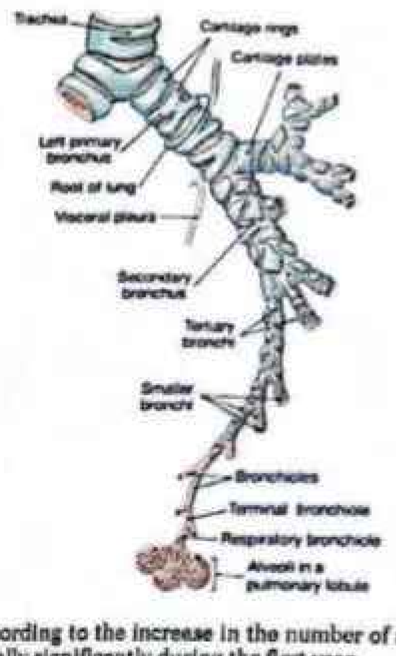


Fig 3.Bronchial tree
https://www.researchgate.net/figure/Architecture-of-the-bronchial-tree-the-trachea-divides-into-bronchi-bronchioles-and_fig16_331485670

According to the increase in the number of alveoli, the respiratory surface also increases, especially significantly during the first year.

This corresponds to the greater oxygen demand of children. By birth, the lumen of terminal bronchioles is less than 0.1 mm, by 2 years it doubles, by 4 – triples, and by 18 years it increases 5 times.

The narrowness of the bronchioles explains the frequent occurrence of lung atelectasis in young children. A. I. Strukov identified 4 periods in the development of lungs in children.

In the first period (from birth to 2 years), especially intensive development of the alveoli occurs.

In the second period (from 2 to 5 years), elastic tissue, muscle bronchi with peribronchial and lymphoid tissue included in it develop intensively. This probably explains the increase in the number of cases of prolonged pneumonia and the beginning of the formation of chronic pneumonia in children in pre-school age.

In the third period (5-7 years), the final maturation of the acinus structure occurs, which explains the more benign course of pneumonia y in preschool and school-age children.

In the IV period (7-12 years), there is an increase in the mass of mature lung tissue.

As you know, the right lung consists of three lobes: the upper, middle and lower, and the left-of two: top and bottom. The medial lobe of the right lung corresponds to the lingual lobe in the left lung. The development of individual lobes of the lung is uneven. In children 1of the 1st year of life, the upper lobe of the left lung is less developed, and the upper and middle lobes of the right lung are almost the same size. Only by the age of 2 years, the size of the individual lobes of the lung correspond to each other, as in adults.

Along with the division of the lungs into lobes, *in recent years, knowledge of the segmental structure of the lungs has become very important*, since it explains the features of the localization of lesions and is always taken into account during surgical interventions on the lungs.

As mentioned above, the structure of the lungs is formed depending on the development of the bronchi. After dividing the trachea into the right and left bronchi, each of them is divided into lobes that fit each lobe of the lung. Then the lobar bronchi are divided into segmental ones. Each segment has the form of a cone or pyramid with the vertex directed to the root of the lung.

Anatomical and functional features of the segment are determined by the presence of independent ventilation, the terminal artery andintersegmental partitions made of elastic connective tissue.The segmental bronchus with its corresponding blood vessels occupiesa certain area in the lobe of the lung. The segmental structure of the lungs is wellestablished even in newborns. There are 10 segments in the right lung and 9 in the left lung (Fig. 4).

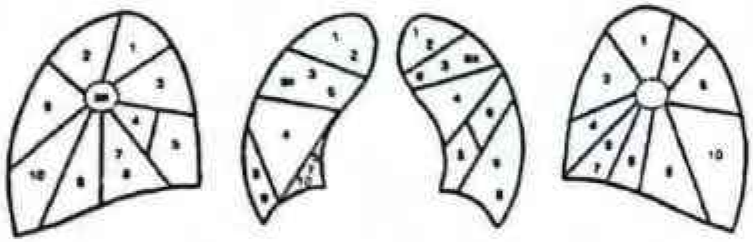


***Fig. 4.* Segmental structure of the lungs.**
https://studfile.net/preview/5210855/page:13/

The upper left and right lobes are divided into 3 segments: the upper apical (1), upper posterior (2) and upper anterior (3). Sometimes another additional segment is mentioned – the axillary, which is not considered independent.

The middle right lobe is divided into 2 segments: the inner (4), located medially, and the outer (5), located laterally. In the left lung, the middle lobe corresponds to the lingual lobe, which also consists of 2 segments – the upper lingual (4) and the lower lingual (5).

The lower lobe of the right lung is divided into 5 segments: basal-apical (6), basal-medial (7), basal-anterior (8), basal-lateral (9) and basal-posterior (10).

The lower lobe of the left lung is divided into 4 segments: basal-apical (6), basal-anterior (8), basal-lateral (9) and basal-posterior (10).

In children, the pneumonic process is most often localized in certain segments, which is due to the peculiarities of their aeration, the drainage function of their bronchi, the evacuation of secretions from them and the possibility of infection. Pneumonia is most often localized in the lower lobe, namely in the basal-apical segment (6). This segment is to a certain extent isolated from other segments of the lower lobe. His segmental bronchus departs above the other segmental bronchi and goes at a right angle straight back. This creates conditions for poor drainage, as young children usually stay in the prone position for a long time. Along with the lesion of the 6th segment, pneumonia is also often localized in the upper posterior (2) segment of the upper lobe and the basal-posterior (10) segment of the lower lobe. This explains the frequent form of so-called paravertebral pneumonia. A special place is occupied by the lesion of the middle lobe – with this localization, pneumonia is acute. There is even the term "moderate pain syndrome".

The mid-lateral (4) and middle-anterior (5) segmental bronchi are located in the area of bronchopulmonary lymph nodes; they have a relatively narrow lumen, a considerable length and depart at right angles. As a result, the bronchi are easily squeezed by enlarged lymph nodes, which suddenly leads to the shutdown of a significant respiratory surface and is the cause of severe respiratory failure.

First breath mechanism

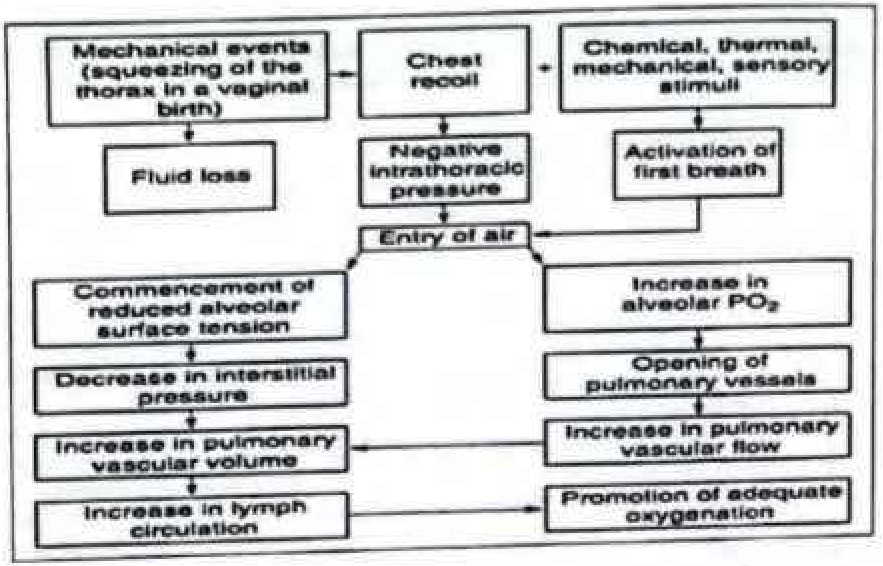
It is known that fetal respiratory movements occur at the 13th week of intrauterine development. However, they occur when the glottis is closed. During labor, the transplacental circulation is disrupted, and when the umbilical cord is clamped, the newborn is completely stopped, which causes a significant decrease in the partial oxygen pressure (P <o2), an increase in PC <o2, and a decrease in pH. In this regard, there is an impulse from the aortic and carotid artery receptors to the respiratory center, as well as a change in the corresponding parameters of the environment around the respiratory center itself. So, for example, in a healthy newborn baby, pH_{O_2} decreases from 80 to 15 mm Hg, PC_{O_2} increases from 40 to 70 mm Hg, and pH drops below 7.35. Along with this, irritation of the skin's receptors is also important. A sharp change in temperature and humidity due to the transition from the intrauterine environment to being in the atmosphere is an additional impulse for the respiratory center. Less important is probably the tactile reception when passing through the birth canal and during the reception of a newborn. The contraction of the diaphragms creates a negative pressure inside the chest, which facilitates the entry of air into the respiratory tract.More significant resistance to inhaled air is providedby the surface tension in the alveoli and the viscosity of the fluid in the lungs. Surface tension forces in the alveoli are reduced by surfactant. With normal expansion of the lung, the lung fluid is rapidly absorbedby the lymphatic vessels and blood capillaries. It is consideredthat normally the negative intrapulmonary pressure reaches 80 cm of water, and the volume of inhaled air at the first breath is more than 80 ml, which is significantly higher than the residual volume.

Respiration is regulated by the respiratory center locatedin the reticular formation of the brain stem in the region of the bottom of the IV ventricle. The breathing center consists of 3 parts: *medullary*, which starts and supports the alternation of inhalation and exhalation; *apnoetic*, which causes a prolonged inspiratory spasm (located at the level ofthe middle and lower part of the brain bridge); *pneumotactic*, which has an inhibitory effect on the apnoetic part (located at the level of the upperpart of the brain bridge).

Respiration is regulated by central and peripheral chemoreceptors, and the central chemoreceptors are the mainones in the regulation of respiration. Central chemoreceptors are more sensitive to changes in the concentration of CO_2 and pH.

Peripheral chemo-and baroreceptors, especially carotid and aortic, are sensitive to changes in oxygen and carbon dioxide content. They are functionally active by the time the baby is born.

At the same time, the pneumotactic part of the respiratory center matures only during the first year of life, which explains the pronounced arrhythmicity of breathing. Apnea is most frequent and prolonged in premature infants, and the lower the body weight, the more frequent and prolonged the apnea is. This indicates insufficient maturity of the pneumotactic part of the respiratory center. But even more important in predicting the surviva lof premature babies is the rapidly increasing increase in breathing in the first minutes of a newborn's life. This indicates a lack of development of the apnoetic part of the respiratory center (Chart 3).



Functional features of the respiratory system in children

Oxygen reserves in the body are very limited, and they last for 5-6 minutes. Providing the body with oxygen is carried out in the process of breathing. Depending on the function performed, there are 2 main parts of the lung: *the conducting part* for supplying air to the alveoli and removing it to the outside and *the respiratory part*, where gas exchange between air and blood occurs. The conducting part includes the larynx, trachea, and bronchi, i.e., the bronchial tree, and the respiratory part itself – the acini, consisting of the adductor bronchiole, alveolar passages, and alveoli. External respiration refersto the exchange of gases between atmospheric air and the blood of the capillaries of the lungs. It is carriedout by simple diffusion of gases through the alveolar-capillary membrane due to the difference in the pressure of oxygen in the inhaled (atmospheric) air and venous blood flowing through the pulmonary artery to the lungs from the right ventricle (Chart 4).

Chart 4

Partial pressure of gases in the inhaled and alveolar air, arterial and venous blood (mmHg)

Indicator	Inhaled air	Alveolar air	Arterial blood	Venous blood
PO_2	160	100	90	40
RSO_2	0	40	40	50
PN_2	600	573	573	573
PH_2O	0	47	47	47
Total pressure	760	760	750	710

The difference in oxygen pressure in the alveolar air and venous blood flowing through the pulmonary capillaries is 50 mm Hg. This ensures the transfer of oxygen to the blood through the alveolar-capillary membrane. The difference in the pressure of carbon dioxide causes its transition from venousblood to alveolar air. The effectiveness of the function of the external-respiration system is determined by three processes: ventilation of the alveolar space, adequate ventilation of the lungs by capillary blood flow (perfusion), and gas diffusion through the alveolar-capillary membrane. In comparison with adults, children, especially in the first year of life, havepronounced differences in external respiration. This is explained by the fact that in the postnatal period there is a further development of the respiratory parts of the lungs (acinuses), where gas exchange occurs. In addition, children have numerous anastomoses between the bronchial and pulmonary arteries and capillaries, which is one of the reasons for blood bypass surgery, bypassing the alveolar spaces.

Currently, the function of external respiration is evaluated according to the following groups of indicators.

1. *Pulmonary ventilation* – frequency (f), depth (Vt), minute breathing volume (V), rhythm, volume of alveolar ventilation, distribution of inhaled air.
2. *Lung volumes* – vital capacity of the lungs (VEL, VC), total lung capacity, inspiratory reserve volume (IRV), expiratory reserve volume (ERV), functional residual capacity (FRC), residual volume (RV).
3. *Breathing mechanics* – maximum ventilation of the lungs (MVL, V max), or the limit of respiration, respiration reserve, forced vital capacity of the lungs (FEV) and its ratio to VEL (Tiffno index), bronchial resistance, volume velocity of inspiration and exhalation during quiet and forced breathing.
4. *Pulmonary gas* exchange – the amount of oxygen consumption and carbon dioxide release in 1 min, the composition of alveolar air, and the oxygen utilization rate.
5. *The gas composition of arterial blood* is the partial pressure of oxygen (PO_2) and carbon dioxide (CO_2), the content of oxyhemoglobin in the blood, and the arteriovenous difference in hemoglobin and oxyhemoglobin.

The depth of respiration, or respiratory volume (RV) in children, both in absolute and relative numbers, is significantly less than in an adult (Chart 5).

Chart 5

Respiratory volume in children depending on age

Age	Respiratory volume in children, ml			
	By J. Brock		By N. A. Shalkov	
	Abs. number	Per 1 kg of body weight	Abs. number	Per 1 kg of body weight
Newborn Baby	11,5	3,5	-	-
1 month	-	-	30	6,2
4 months	25	4,8	39	6,2
6 months	36	5,0	54	6,7
1 year old	60	6,0	70	7,0
3 years old	95	6,5	114	7,4
6 years	118	6,2	156	7,9
11 years	175	5,8	254	7,8

14 years	227	5,8	300	7,8
Adults	410	6,4	-	-

This is due to two reasons. One of them, of course, is a small lung mass in children, which increases with age, and during the first 5 years mainly due to neoplasms of the alveoli. Another, no less important reason explaining shallow breathing in young children is the peculiarities of the structure of the chest (the anterior-posterior size is approximately equal to the lateral one, the ribs move away from the spine almost at right angles, which limits the excursion of the chest and changes in lung volume). The latter changes mainly due to the movement of the diaphragm. An increase in the respiratory volume at rest may indicate respiratory failure, and a decrease in it may indicate a restrictive form of respiratory failure or chest rigidity. At the same time, the oxygen demand in children is significantly higher than in adults, which depends on a more intensive metabolism. Thus, in children of the first year of life, the oxygen demand per 1 kg of body weight is approximately 7.5-8 ml / min, by 2 years it increases slightly (8.5 ml / min), by 6 years it reaches its maximum value (9.2 ml / min), and then gradually decreases (at 7 years – 7.9 ml / min, 9 years-6.8 ml / min, 10 years-6.3 ml / min, 14 years-5.2 ml / min). In an adult, itis only 4.5 ml / min per 1 kg of body weight. The shallow nature of breathing and its no rhythmicity are compensated for by a higher respiratory rate (f). So, in a newborn-40-60 breaths in 1 min, in a one – year-old-30-35, in a 5-year-old-25, in a 10-year-old-20, in an adult-16-18 breaths in 1 min. The respiration rate reflects the compensatory capabilities of the body, but in combination with a small respiratory volume, tachypnea indicates respiratory failure. Due to the higher respiratory rate, per 1 kg of body weight, the daily volume of respiration is significantly higher in children, especially at an early age, than in adults. In children under 3 years of age, the minute volume of respiration is almost 1.5 times greater than in an 11-year-old child, and more than 2times greater than in an adult (Chart 6).

Chart 6

Minute volume of breathing in children

Indicators	Newborns	3 months	6 months	1 year old	3 years old	6 years	11 years	14 years	Adults
MVB, cm	635	1100	1150	2200	2900	3200	4200	5000	6150
MVB per 1 kg of body weight	135	200	208	220	200	168	140	128	96

Observations of healthy people and children with pneumonia showed that at low temperatures (0...5° C) there is a decrease in respiration witha decrease in its depth, which is, apparently, the most economical and effective breathing for providing the body with oxygen. It is interesting to note that a warm hygienic bath causes an increasein lung ventilation by 2 times, and this increase occurs mainly due to an increase in the depth of breathing. Hence, the proposal of A. A. Kisel (an outstanding Soviet pediatrician), which he made back in 20the 20s of the last century and which became widespread in pediatrics, to widely use the treatment of pneumonia with cold fresh air, becomes quite understandable.

The vital capacity of the lungs (VCL), i.e. the amount of air (in milliliters) that is maximally exhaled after maximum inspiration (determined by a spirometer), is significantly lower in children than in adults (Chart 7).

Chart 7

Vital capacity of the lungs

Age	VCL, ml	Volumes, ml		
		respiratory	reserve exhalation	reserve breath
4 years old	1100	120	480	490
6 years	1200			
8 »	1600	170	730	730
10 »	1800			
12 »	2200	260	1000	1000
14 »	2700			
16»	3800	400	1750	1650
Adult	5000	500	1500	1500

If we compare the vital capacity of the lungs with the volume of breathing in a calm position, it turns out that children in a calm position use only about 12.5% of VEL.

Inspiratory reserve volume (IRV) – the maximum volume of air (in milliliters) that can be additionally inhaled after a calm inhalation.

For its assessment, the ratio of the IRV to the residential housing unit VCL is of great importance VCL. In children aged 6 to 15 years, the VCL ranges from 55 to 59%. A decrease in this indicator is observed in restrictive (restrictive) lesions, especially with a decrease in the elasticity of the lung tissue.

Expiratory reserve volume (ERV), – the maximum volume of air (in milliliters) that can be exhaled after a calm inhalation. Just as for the reserve volume of inspiration, ERV its ratio to VCL is important for estimating the ERV. In children aged from 6 to 15 years, the VCL is 24-29% (increases with age).

The vital capacity of the lungs decreases with diffuse lung lesions, accompanied by a decrease in the elastic extensibility of the lung tissue, with an increase in bronchial resistance or a decrease in the respiratory surface.

Forced vital capacity (FVC, FEV), or forced expiratory volume (FEV, l/s), is the amount of air that can be exhaled during forced exhalation after maximum inspiration.

Tiffno index (FEV as a percentage) – the ratio of FEV to VEL (FEV%), normally for 1 day FEV is not less than 70% of the actual VCL.

Maximum lung ventilation (MVL, Vmax), or breath limit, is the maximum amount of air (in milliliters) that can be ventilated in 1 minute. Usually, this indicator is examined within 10 seconds, as signs of hyperventilation may occur (dizziness, vomiting, fainting). MVL in children is significantly lower than in adults(Chart 8).

Chart 8

Maximum lung ventilation of children

Age, years	Average data, l / min	Age, years	Average data, l / min
6	42	11	55
7	40	12	61

8	42	13	61
9	46	14	68
10	48	15	75

For example, a 6-year-old child's breathing limit is almost 2 times less than that of an adult.6 лет предел дыхания почти в 2 раза меньше, чем у вароclf the respiration limit is known, it is not difficultto calculate the value of the respiration reserve (the value of the minute volume of respiration is subtracted from the limit). Lower vital capacity and rapidbreathing significantly reduce the reserve of respiration (Chart 9).

Chart 9

Respiratory reserve in children

Age, years	Breathing reserve, l / min	Age, years	Breathing reserve, l / min
6	38,8	11	50,4
7	36,4	12	56,3
8	38,2	13	46,2
9	41,9	14	63,1
10	43,7	15	69,6

The effectiveness of external respiration is judged by the difference in the contentof oxygen and carbon dioxide in the inhaled and exhaled air. Thus, thisdifference in children of the first year of life is only 2-2. 5%, while in adults it reaches 4-4. 5%. The exhaled air of young children-contains less carbon dioxide – 2.5%, and adults-4%.Thus, young children absorb less oxygen and emit less carbon dioxide for each breath, although gas exchange in children is more-significant than in adults (in terms of 1 kg of body weight).

Of great importance in judging the compensatory capabilities of the external respiration system is the oxygen utilization coefficient (O_2UC) – the amount of oxygen absorbed (O_2A) from 1 liter of ventilated air.

$$O_2UC = O_2A \text{ (ml / min) / MVB (l / min)}.$$

In children under 5 years of age, O_2UC is 31-33 ml / l, and at the age of 6-15 years – 40 ml/l, in adults-40 ml/l. O_{2UY} depends on the conditions of oxygen diffusion, the volumeof alveolar ventilation, on the coordination of pulmonary ventilation and circulation in the small circle.

Oxygen transport from the lungs to the tissues is carried out by blood, mainly in the form of a chemical compound with hemoglobin –oxyhemoglobin, and to a lesser extent-in a dissolved state. One gram of hemoglobin binds 1.34 ml of oxygen, so the amount of bound oxygen depends on the amount of hemoglobin. Since the hemoglobin content in newborns during the first days of life is higher than in adults, the oxygen-binding capacity of their blood is also higher. This allows the newborn to survive a critical period – the period of the formation of pulmonary

respiration. This is also facilitated by a higher content of fetal hemoglobin (HbF), which has a greater affinity for oxygen than adult hemoglobin(HBA). After the establishment of pulmonary respiration, the HbF content in the child's blood decreases rapidly. However,in hypoxia and anemia, the amount of HbF may increase again. This is like compensatory device that protects the body (especially vital organs) from hypoxia.

The ability of hemoglobin to bind oxygen is also determined by temperature, blood pH, and carbon dioxide content. As the temperature increases, pH decreases, and CO_2 increases, the binding curve shifts to the right.

The solubility of oxygen in 100 ml of blood at a PO_2=100 mm Hg is only 0.3 ml. The solubility of oxygen in the blood increases significantly with increasing pressure. Increasing the oxygen pressure to 3 atm ensures the dissolution of 6% oxygen, which is sufficient to maintain tissue respiration at rest without the participation of oxyhemoglobin. This technique (oxybarotherapy) is currently used in the clinic.

Capillary blood oxygen also diffuses into tissues due to the gradient of oxygen pressure in the blood and cells (in arterial blood, the oxygen pressure is 90 mm Hg, in cell mitochondria itis only 1 mm Hg).

Features of tissue respiration are studied much worse than other stages of respiration. However, it can be assumed that the intensity of tissue respiration in children is higher than in adults. This is indirectly confirmed by the higher activity of blood enzymes in newborns compared to adults. One of the essential features of metabolism in young children is an increase in the proportion of the anaerobic phase of metabolism in comparison with that in adults.

The partial pressure of carbon dioxide in tissues is higher than in blood plasma, due to the continuity of oxidation and release of carbon dioxide, H_2CO_3 easily enters the blood from tissues. In the blood CO_2, H_2CO_3 is found in the form of free carbonic acid bound to red blood cell proteins, and in the form of bicarbonates. At a blood pH of 7.4, the ratio of free carbonic acid to bound sodium bicarbonate ($NaNCO_3$) is always 1:20. The reaction of carbon dioxide binding in the blood with the formation of H_2CO_3, bicarbonate and, conversely, the release of carbon dioxide from compounds in the capillaries of the lungs is catalyzed by the enzyme carbonic anhydrase, the action of which is determined by the pH of the medium. In an acidic environment (i.e., in cells, venous blood), carbonic anhydrase promotes the binding of carbon dioxide, and in an alkaline environment (in the lungs), on the contrary, it decomposes and releases it from compounds.

The activity of carbonic anhydrase in premature newborns is 10%, and in full-term infants-30% of the activity in adults. Its activity slowly increases and only by the end of the first year of life reaches the norms of an adult. This explains the fact that hypercapnia (accumulation of carbon dioxide in the blood) is more common in children with various diseases (especially lung diseases).

Thus, the process of breathing in children has a number of features. They are largely determined by the anatomical structure of the respiratory organs. In addition, young children have a lower efficiency of breathing. All the described anatomical and functional features of the respiratory system create prerequisites for a more mild respiratory disorder, which leads to respiratory failure in children.

METHODS OF STUDYING THE RESPIRATORY SYSTEM IN CHILDREN

Medical history. The respiratory examination usually begins with an interview with the motheror child, which is carried out in a certain sequence. They try to find out if there is a runny nose and its nature. *Serous or mucus-serous discharge* is observed in acute respiratory viral infections, and sometimes in allergic rhinitis. Mucous or mucopurulent discharge is characteristic of measles and is observed in later periods of influenza or adenovirus diseases, as well as with sinusitis. An admixture of blood (sukrovichnoe discharge) is noted with nasal-diphtheria. *Nosebleeds* are characteristic of hemorrhagic diathesis, leukemia, hypoplastic anemis,nasal polyps, rheumatism, and are also noted in the case of features of the structure of the nasal choroid plexus (*locus Kisselbachi*). Dry runny nose with snoring breathing in infants is suspected of chronic damage to the nasal mucosa in congenital syphilis.

Cough is one of the most characteristic signs of respiratory damage. The most typical cough is whooping cough. It occurs in paroxysms(paroxysms) with reprises (long, high breaths) andis accompanied by redness of the face and vomiting. Cough paroxysms are more often observed at night. *Cough in the larynx* is usually dry, rough and barking. It is so characteristic that it makes it possible to heal the laryngeal lesion (laryngitis or croup) at a distance. *Cough with tracheitis* is rough (like in a barrel). *With bronchitis*, the cough can be both dry (at the beginning of the disease) and wet, with sputum separation. *With bronchial asthma*, sticky sputum is usually separated. *With pneumonia* in the first days of the disease, the cough is more often dry, in subsequent days it becomes wet. *When the pleura is involved in the process*, the cough becomes painful (croup pneumonia, pleurisy).

Bitonal cough — a spastic cough that has a rough maintone and a musical high second tone, occurs from irritation of the cough zone of the tracheal bifurcation by enlarged lymph nodes or mediastinal tumors and is observed in tuberculous bronchoadenitis, lymphogranulomatosis, lymphosarcoma, leukemia, mediastinal tumors (thymoma, sarcoma, etc.). *A painful dry cough* occurs in pharyngitis and nasopharyngitis.

To determine whether there is a dry or wet cough, it is necessary to monitor the child, whether he swallows sputum. *Copious discharge of mucosaporны* (purulent) with a full mouth in young children is observed when an abscess or suppurated cyst of the lungs is emptied into the bronchi. Older children have a lot of sputum in chronic pneumonia, when there are already bronchiectasis.

Sometimes it is important to change the cough during the course of the disease. So, a rare cough at the beginning of the disease is observed in acute respiratory infections. If it then becomes more frequent and wet, then this may be a sign of the development of bronchiolitis and pneumonia. For ASD, it is important to find out whether the body temperature was elevated, whether there was no chills (in young children, the equivalent of chills is vomiting).

Sometimes *with pneumonia, abdominal pain* (abdominal syndrome) is noted, which makes the child suspect appendicitis and refer the child fora consultation with a surgeon. Only a thorough examination and observation make it possible to reject the diagnosis of appendicitis and avoid surgery.

From the medical history, it is necessary to find out whether there were pre-existing lung diseases, and if so, the degree of recovery from them. This is important in the diagnosis of bronchial asthma and chronic pneumonia.

It is advisable to find out whether the child had measles and whooping cough, which are often complicated by pneumonia, the peculiarity of which is a totallesion of the bronchial walls (panbronchitis) and a significant involvement of interstitial lung tissue in the process.

Большое, а иногда и решающее значение в диагностике поражений легContact with tuberculosis patients in the family and in the apartment is of great and sometimes decisive importance in the diagnosis of lung lesions.

Inspection. During external examination, *cyanosis should be noted*, which can be permanent, local or general. The greater the respiratory insufficiency and the lower the oxygen stress, the more pronounced and widespread the cyanosis. Cyanosis of the skin, lip and tongue mucosa occurs when the arterial blood oxygen saturation decreases (95% by oxyhemoglobin). This corresponds to 30 g / l or more of reduced hemoglobin in arterial blood, which indicates a marked decrease in its partial oxygen pressure (PO_2). Cyanosis in lung lesions during crying usually increases, since when you hold your breath on exhalation, there is an even greater decrease in RO_2. In addition, pulmonary cyanosis is characterized by a certain localization (around the mouth, eyes). In small children (up to 2-3 months of age), foamy discharge can be seen in the corners of the mouth, under the tongue with bronchiolitis and pneumonia (Fig.5-6). *The occurrence of this symptom is explained by the penetration of inflammatory exudate* from the respiratory tract into the oral cavity (the oral cavity of a healthy child in the first 2-3months is relatively dry, since it does not yet have salivation).

When examining the nose, discharge (serous, mucous, mucopurulent, sukrovichny, bloody) and difficulty breathing through the nose can be noted.

Fig 5. Perioral cyanosis
https://www.grepmed.com/images/3662/clinical-cyanosis-perioral-pediatrics-newborn

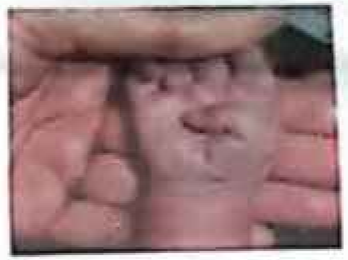


Fig 6. Cyanosis of the hands
https://www.researchgate.net/figure/_Showing-peripheral-cyanosis-over-a-palm_fig1_200461242

Nose examination technique. A nurse or mother picks up a baby wrapped in her arms. The examiner tilts the child's head back, lifts the tip of the nose and examines the entrance to the nasal cavity. If the entrance to the nasal cavity is blocked by crusts, then they are removed with a cotton swab moistened with vaseline oil. With such a thorough examination, the nature of the discharge from the nose is determined, in addition, you can see a foreign body or diphtheria plaque in the front of the nose, as well as assess the condition of the vascular plexus of the nose. Depending on the nature of the discharge serous, mucopurulent, and hemorrhagic rhinitis is distinguished. Rhinitis is most often one of the symptoms of acute respiratory viral infection (adenovirus, parainfluenza and influenza), and is observed in measles. Sukrovichnye discharge from the nose is characteristic of nasal diphtheria or a foreign body. Congenital syphilis is characterized by so-called snoring breathing.

During the examination, pay attention to голосthe child's voice, which often changes when the larynx and vocal folds are affected. *Laryngitis* is clinically manifested by a rough barking cough and a change in voice. Unlike adults, laryngitis in children is often accompanied by difficulty breathing — croup. Croup can be true or false (sublabular laryngitis). *True croup* is observed in laryngeal diphtheria, when there isa large inflammation of the vocal folds with the formation of a film. *False croup* (subclavian laryngitis) most often occurs in acute respiratory viral infections (most often in parainfluenza) and is caused by edema of the mucous membrane below the vocal folds.

There are both common symptoms of croup (barking cough, inspiratory shortness of breath), and some differences. False croup occurs, as a rule, suddenly and usually in the evening and at night. Before that, it is as if a healthy child suddenly wakes up and begins to suffocate. True croup often develops gradually (within 1-3 days). In contrast to the turn-down croup, with true croup, the voice gradually disappears *(aphonia)*. Croup requires immediate medical attention. *A rough, low voice* is one of the hallmarks of myxedema. *Nasal tint of the voice* occurs in chronic rhinitis, adenoids, pharyngeal abscess, etc. The appearance of nasal tint in pharyngeal diphtheria and encephalopathies indicates paresis of the palatine curtain. In preschool and school-age children with adenoid vegetations, the face acquires a characteristic appearance. It is pale, puffy, with a slightly open mouth, raised upper lip and upturned nose; often there is an incorrect bite.

It is characterized *by the appearance of a frequently coughing child (with whooping cough and chronic non-specific lung lesions)*. Such children have a pale, pasty face and eyelids (due to impaired lymph outflow — lymphostasis), cyanotic lip mucosa, swollen skin veins, and conjunctival and subcutaneous tissue hemorrhages.

When examining the oral cavity, it is necessary to pay attention to the *condition of the pharynx and tonsils*. In children of the first year of life, the tonsils usually do not extend beyond the anterior arches. Preschool children usually have hyperplasia of the lymphoid tissue and the tonsils extend beyond the anterior arch when examined. They are dense and do not differ in color from the mucous membrane of the pharynx.

Children often have various inflammatory processes —angina. *Angina* is divided into catarrhal, follicular, lacunar, and also specific infectious. *Catarrhal angina* during examination of the patient is manifested by its hyperemia, swelling of the arches, swelling and loosening of the tonsils. It is usually associated with acute respiratory viral infection.

In follicular angina, with hyperemia, looseness and enlargement of the tonsils, dotted or small overlays are visible on their surface, usually white in color. *With lacunar angina*, the degreeof inflammation is more pronounced, and overlays capture the lacunae. Follicular and lacunar angina is usually bacterial etiology (streptococcal, staphylococcal). *Angina in scarlet* fever differs from banal angina by sharply delimited hyperemia, and in moderate and severe forms-by necrosis of the mucous membrane (necrotic angina). *In pharyngeal diphtheria*, the tonsils usually have a dirty-gray coating with moderate pronounced hyperemia. When removing the plaque, bleeding of the mucus of the stoic membrane is noted.

The shape of the chest in children, as a rule, changes with rickets, as well as with lung diseases. In newborns, swollen breasts are noted with pneumothorax, pneumo mediastinum. In bronchial asthma, emphysematous bloating of the lungs, the chest is in the phase of maximum inspiration (barrel). With exudative pleurisy on the side of the lesion, chest bulging is noted, and with chronic pneumonia-entrapment. To establish the asymmetry of the chest, measure each semicircle of the chest with a centimeter tape.

Retraction of the intercostal space in the area of the diaphragm attachment, which is slightly noticeable during calm breathing in children under 3 months of age, is a normal phenomenon. In a child older than 4 months, it should not be noticeable when breathing calmly. Such a retraction of the compliant areas of the chest indicates either toosoft ribs (rickets), or a lesion of the respiratory tract, accompanied by inspiratory shortness of breath. Significant retraction of the intercostal space and jugular fossa in the inspiratory phase is characteristic of stenotic respiration in croup.

In a healthy child, both sides of the chest participate synchronously in breathing. With pleurisy, to a lesser extent with tuberculous bronchoadenitis, lung atelectasis, chronic pneumonia, with its mostly unilateral localization, one can notice that one of the chest cavities (on the affected side) lags behind in breathing.

To determine the mobility (excursion) of the chest, the circumference of the chest is measured with a centimeter tape, which is applied in front of the level of the nipples, in the back-at the angles of the shoulder blades. The measurement is performed at a calm position in the phase of maximum inhalation and exhalation. The difference in size shows a tour of the chest.

During the examination, pay attention to the *type of breathing*. In young children, *an abdominal type* of breathing is observed. In boys, it remains unchanged, in girls from 5 to 6 years of age, a *thoracic type* of breathing appears. *Restriction of chest excursion* is observed in acute bloating, bronchial asthma, pulmonary fibrosis, subphragmatic abscess, intercostal neuralgia.

Counting the number of breaths is best done within 1 minute when the child is asleep. In newborns and small children, you can use a soft stethoscope to count the number of breaths, the bell of which is held near the child's nose. This method makes it possible to count the number of breaths without undressing the child. Sometimes this method can be used to listen to wheezing in bronchitis, bronchiolitis and pneumonia.

The respiratory rate of children, even in a state of complete health, variesquite widely, so the detection of increased respiration (tachypnea) or its decrease (bradypnea) can only be reliable if deviations reach30-40% or more from the average values. Centile or sigma scales are rarely used in assessingthe respiratory rate. Table 8 shows the characteristics of the average values of the respiratory rate and the boundary of two sigma deviations. (Chart 10).

Chart 10

Respiratory rate in healthy children

Age, years	Respiratory rate per minute
Newborn	40-60
1 year	30-35
5—6 year	20-25
10 year	18—20
Adult	16-18

In children with respiratory damage, there *is a change inthe ratio between the respiratory rate and pulse*. In healthy children in the first year of life, one breath accounts for 3-3. 5 pulse beats, in children older than a year-4 beats per breath. With lung damage (pneumonia) these-ratios change and become 1 : 2, 1 : 3, as breathing becomes faster to a greater extent, and pulse-to a lesser extent. If a change in the ratio between pulse and respiration helps to distinguish lung damage from damage to other organs and systems, then *a change in the duration of inspiration and exhalation* seoften helps to differentiate one lung disease from another. So, *the exhalation is sharply prolonged* in bronchial asthma and pneumonia with obstruction syndrome and an asthmatic component, and *also* —the inhalation is prolongedin laryngitis, laryngospasm, croup, a foreign body, a tumor and cysts of the respiratory tract, and pulmonary fibrosis. At the same time, the power of forced inhalation or exhalation decreases in these diseases, which indicates a violation of bronchial patency.

Respiratory distress syndrome, or the syndrome of respiratory disorders (or, more correctly, the syndrome of respiratory distress), occurs more often in premature infants and is manifested by dyspnea of varying degrees, retraction of the compliant areas of the chest, increased breathing with subsequent slowing down (with the most severe degree of hypoxia), tachycardia, cyanosis. Often there *is a change in the rhythm of breathing*. *Rapid breathing* (tachypnea — more than 10% of the average age norm) in healthy children occurs with excitement, physical exercise, etc., and in patients-with extensive lesions of the respiratory system, diseases of the cardiovascular system, blood diseases (anemia), febrile diseases (depending on irritation of the respiratory center), with pain, distress syndrome.

Respiratory depression (bradypnea) is very rare in children and indicates exhaustion of the respiratory center. Usually, these serious respiratory disorders occur in comatose states (uremia), poisoning (forexample, sleeping pills), increased intracranial pressure, andin newborns — in the end stages of distress syndrome. *Large Kussmaul, Biot, and Cheyne—Stokes respiration* reflects severe degrees of respiratory distress.

When examining a child, attention should be paid *to the involvement of auxiliary muscles in breathing* (rectus abdominis, sternoclavicular-mastoid, thoracic), which indicates difficulty in breathing, i.e. shortness of breath. At the same time, young children also have inflated and strained nose wings (like a chiseled nose with a shiny skin). Dyspnea occurs in hypoxemia, hypercapnia, an excess of various under-oxidized products that accumulate in the blood and brain matter, as well as in acidosis.

There are the following **forms of shortness of breath.**

Inspiratory dyspnea is observed with obstruction of the upper respiratory tract (croup, foreign body, cysts and tumors, congenital narrowing of the larynx, trachea, bronchi, pharyngeal abscess, etc.). Difficulty breathing during inspiration is clinically manifested by retraction of the epigastric region, intercostal, supraclavicular spaces, jugular fossa, tension *of the T. sternocleidomastoideus* and other auxiliary muscles.

Expiratory dyspnea. The chest is raised up and almost does not participate in the act of breathing. The rectus abdominis muscles, on the contrary, are tense. Exhale slowly, sometimes with a whoosh. It is observed in bronchial asthma, with partial compression of the bronchi.

Shortness of breath Chic. Expiratory puffing depends on compression by tuberous infiltrates and lymph nodes of the lung root, the lower part of the trachea and bronchi, which freely pass air only when inhaled.

Mixed dyspnea – expiratory-inspiratory. It is manifested by a swollen chest and retraction of the compliant places. Mixed dyspnea is characteristic of bronchiolitis and pneumonia.

Stenotic breathing is explained by the difficult passage of air through the upper respiratory tract (croup, compression of the tumor).

Suffocation attacks – asthma. The inhalation and exhalation are loud, prolonged, and often audible at a distance. It is characteristic of bronchial asthma.

Especially significant respiratory disorders in newborns are observed in respiratory distress syndrome, which is always accompanied by severe respiratory failure. Respiratory distress syndrome is more common in premature infants.

In respiratory distress syndrome, the baby's cry at birth is weaker even absent. There is marked hypotension of the muscles, decreased reflexes, pallor or cyanosis. Attentions drawn to the moaning breath, but without stenotic respiratory noise, shallow breathing. When examining a child for clinical signs, you can get an idea of the severity of the condition (Chart 11).

Chart 11

Criteria for the severity of respiratory distress syndrome

Criteria	Degree of severity		
	0	I	II
Comparative movements of the sternum and abdomen	Synchronous services	Late sinking of the sternum, minimal protrusion of the abdomen	Breath paradoxical
Intercostal retraction	No	Moderate	Significant
Sternum retraction	*	*	*
Sinking of the chin		Observed, but the mouth	Significant,
while inhaling		remains closed	mouth open
Expiratory grunting	*	It can only be heard with a stethoscope	Heard without a stethoscope

Palpation. To palpate the chest, both palms are symmetrically applied to the studied areas. By squeezing the chest from the front to the back and from the sides, its resistance is determined (Fig. 7-8). The younger the child's age, the more malleable the chest is. With increased chest resistance, they talk about rigidity.

Figure 7-8. Determination of chest resistance: a – compression from front to back; b – compression from the sides. (propaedeutics of childhood diseases Geppe N.A., Podchernyaeva N.S. https://medicknow.com/bookstudent/propedevtika-geppe/10.php)

Palpation can reveal breast soreness. It is necessary to distinguish between superficial soreness associated with surface tissues (muscle, nerve, bone damage) and deep – pleural soreness.

Superficial soreness occurs in:

- in case of inflammatory processes in soft tissues;
- if the intercostal muscles are affected (a connection with respiratorymovements is characteristic and localization in the intercostal space is usually throughoutthe entire length);
- with damage to the ribs and sternum (with a fracture, you can additionally detect crunch – crepitation); with inflammation of the periosteum – swelling and unevenness of the corresponding area of the rib or sternum; it should be remembered that pain on palpation of these areas occurs in diseases of the blood system (leukemias, etc.);
- in diseases of the intercostal nerves (3 pain points are characteristic-at the spine, along the axillary line and at the sternum; in these places the intercostal nerves approach the surface).

Pleural pain usually increases with inhalation and exhalation, often radiates to the epigastric and subcostal regions, and weakens if the chest is squeezed (reduced lung mobility). In contrast to neuralgic ones, pleural pain decreases when the body is bent in the affected direction (with neuralgic ones, it increases).

By palpation, *the thickness of the skin fold is determined on symmetrically located areas of the breast.* To do this, take the skin fold with the index finger and thumb of both hands simultaneously. Thickening of the skin fold is observed in exudative pleurisy, especially purulent; it is less pronounced in tuberculous Broncho adenitis on the side of the wound. Thickening of the skin fold is explained by a violation of bone innervation in the projection of the internal organ (lung), which causes a change in the tropics of this surface area with the development of reactive edema, lympho-and hemostasis, with the involvement of the venous network during periprocess.

Vocal tremor (fremitus vocalis) is a sensation that occurs when hands are placed on symmetrical areas of the patient's chest on both sides, while the patient utters words that give a large vibration (containing a large number of vowels and the "p" sound, for example, "thirty-three", "forty-three", etc.). etc.).

In young children, vocal tremors are examined during the child's cry or crying. Vibrations that are detected in this process are transmitted from the vocal folds along the walls of the bronchi and bronchioles to the surface of the lungs. *Increased vocal tremor* is associated with compaction of the lung tissue (dense bodies conduct sound better) and the presence of cavities in the lungs (the distance from the glottis is shortened).

Vocal tremor is weakened when the bronchus is blocked (atelectasis is easy), when the bronchi are pushed away from the chest wall (exudate, pneumothorax,pleural tumor) (Fig. 9-14).

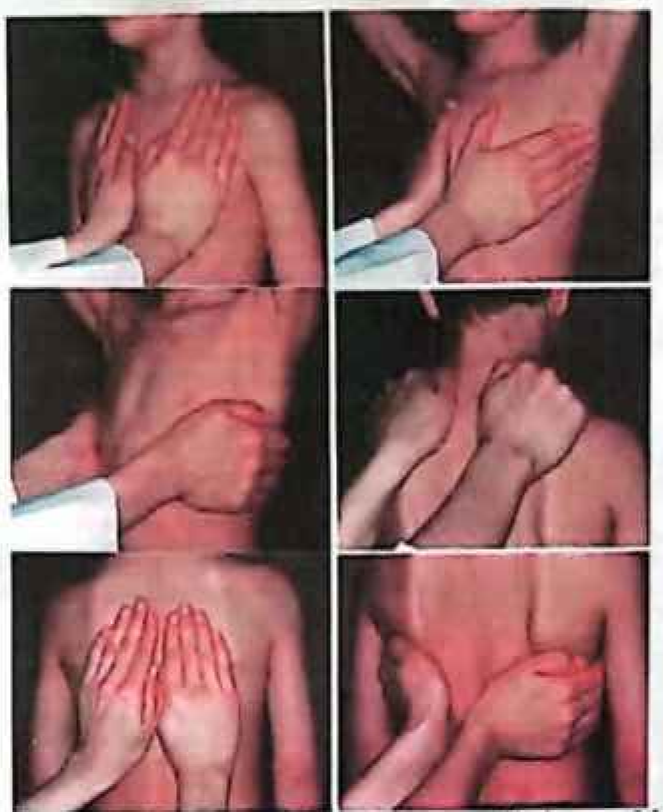


Fig. 9-14. Detection of vocal tremor in symmetrical areas of the chest (a—e) (propaedeutics of childhood diseases Geppe N.A., Podchernyaeva N.S. https://medicknow.com/bookstudent/propedevtika-geppe/10.php)

Percussion. There is a distinction between indirect and direct percussion.

Direct percussion is performed by tapping with a bent finger, more often with the middle or index finger, along the ribs or, according to the Sample method, with the index finger of the right hand when it slides off the middle finger (click method). At the same time, the sense of touch is involved in assessing the resistance of tissues. This method of percussion is most often used in the examination of young children (Fig 15-17).

Indirect percussion — finger-to-finger percussion. As a plessimeter, the phalanx of the middle finger of the left hand is used, which is tightly applied with the palm surface to the examined place. Percussion blows are delivered with the middle finger of the right hand, half-bent, notin contact with the other fingers. Percussion should be performed with weak strokes, since due to the elasticity of the chest in children and its small size, percussion concussions are too easily transmitted to remote areas, so with strong tapping, the dull sound of the limited area can be completely drowned out by the clear sound of healthy lower parts of the lung.

With percussion, the correct position of the patient (symmetrical position of both halves of the chest) becomes very important. It is necessary to hold the child so that his shoulders are at the same level and the position of the shoulder blades is the same on both sides. During back percussion of a 1-2-year-old child, N. F. Filatov suggested sitting him on a pillow placed on a table. The child's arms are bent at the elbow joints at right angles, and the forearms are placed across the abdomen so that they lie one behind the other. In this position, the mother or nurse, standing to the right of the child, holds his hands and presses them to the stomach with his right hand. The mother or nurse puts her left hand on the back of the child's head and tilts the head slightly to prevent the child from arching back, which the child always tries to do as soon as the child's back is tapped. In front of nyu, the chest surface is percutated in the supine position.

Fig. 15-17. Direct percussion of various sections of the chest (a—b). (propaedeutics of childhood diseases Geppe N.A., Podchernyaeva N.S. https://medicknow.com/bookstudent/propedevtika-geppe/10.php)

During percussion in older children, the anterior surface of the lungs is percutized in the supine position, and the posterior surface is percutized in the sitting position. The patient shouldbe on the right side of the doctor.

It should be borne in mind that when percussion in gun symmetric areas of the chest during a cry, the sound may change, which may mislead the researcher. Always start with comparative percussion, which allows you to more clearly identify the change in sound.

When percussion is performed on healthy lungs, the same pulmonary sound is not detected everywhere. On the right, it is shorter in the underlying regions due to the proximity of the liver; on the left, due to the proximity of the stomach, it has a tympanic tint (the so — called Traube space, which is delimited from above by the lower border of the heart and left lung; on the right — by the edge of the liver, on the left - by the spleen, and on the bottom-by the costal arch; when fluid accumulates in the pleural area, it disappears).

When the respiratory system is affected, there is a change in percussion sound of different intensity.

Shortening of the percussion sound is possible due to:

- reduction of lung tissue airiness — in *case of lung inflammation* (insomnia and edema of the alveoli and inter alveolar septa); *hemorrhages in the lung tissue*; with *significant* *pulmonary edema* (usually in the lower parts); with *lung scarring;* with *a decline in lung tissue* (atelectasis, compression of the lung tissue with pleural fluid, a greatly expanded heart, a tumor in the chest cavities);

- formations in the lung cavity of other, airless tissue - with *tumors*,
- formation of a cavity in the lungs and accumulation of fluid in it (sputum, pus, echinococcal cyst), provided that this cavity is more or less filled with fluid;
- filling the pleural space with exudate (exudative pleurisy) or transudate, fibrinous overlays on pleuralleaves.

The tiffanic hue of the sound appears due to:

- formation of air-containing cavities: when the lung tissue is destroyed as a result of inflammation (cavern in pulmonary tuberculosis, abscess), tumors (decay), cysts;daphragmatic hernia and pneumatization of cysts; accumulation of gas and air in the pleural cavity-pneumothorax (spontaneous, artificial);
- some relaxation of the lung tissue due to a decrease in its elastic properties (emphysema), compression of the lungs above the location of the fluid (exudative pleurisy and other forms of atelectasis);
- filling of the alveoli with air with the simultaneous presence of fluids in them during pulmonary edema, at the beginning of inflammation, and during dilution of inflammatory exudate in the alveoli.

Box sound — a loud percussion sound with a tympanic tone-appears when the elasticity of the lung tissue is weakened and its airiness is increased (emphysema of the lungs).

Cracked pot noise — a kind of intermittent rattling sound, similar to the sound when tapping on a cracked pot. The sound becomes clearer when the patient opens his mouth. It is obtained by percussion of the chest during the cry of children. In a number of diseases, it occurs in areas that communicate with the bronchi through a narrow slit.

Topographic percussion of the chest in those areas that correspond to the normal location of the lungs gives a clear (loud), full (long), rather low and non-mechanical percussion sound. This soundis separated from the sound received from the organs adjacent to the lungs.

When determining the boundaries of the lungs by topographic percussion, the finger - plessimeter is placed parallel to the desired border (ribs), and in the intervertebral region — parallel to the spine.

The upper limit of the lungs in children varies depending on age. In preschool children, it is not detected, since the tops of the lungs do not extend beyond the collarbone.

Determination of the height of standing of the apices of the lungs begins from the front. A plessimeter finger is placed over the clavicle, the distal phalanx touching the outer edge of the sternoclavicular-mastoid muscle. Percutiruyut on the finger-plesimetra, moving it up until the shortening of the sound. Normally, this area is located at a distance of 2-4 cm from the middle of the clavicle. The border is marked on the side of the plessimeter finger facing the clear sound. *Posteriorly, percussion of the apices is conducted from the spina scapulae* towards the spinous process of the VII cervical vertebra. At the first appearance of a shortened percussion sound, the percussion is stopped. Normally, the height of the apices standing behind is determined at the level of the spinous process of the VII cervical spine.

Determination of the width of the Krenig fields is determined using indirect percussion. The plessimeter finger is placed in the middle of the upper edge of the trapezius muscle. From this point, percussion is performed alternately towards the neck and shoulder until dulling. The resulting distance between the two farthest points is the width of the Krenig fields (Fig 18).

Fig. 18 Determining the width of the Krenig fields
https://www.youtube.com/watch?app=desktop&v=G7OEfGe_s

A decrease in the height of the standing tops of the lungs can be observed when they are wrinkled on the basis of tuberculosis. At the same time, the width of the Krenig fields decreases.

It is very important to know the boundary between the lobes of the lungs. The upper lobe is located on the front left, the upper and middle lobes are on the right (the border between them runs along the IV rib). On the side — on the right, all 3 lobes are determined, on the left — 2 lobes. Behind, on both sides, there are upper and lower lobes, the boundary between which runs along the line drawn along the spina scapulae to its intersection with the spine, or along the line starting from the III thoracic vertebra to the place where it intersects with the posterior axillary line and the IV rib.

In diseases, the boundaries of the lungs may change.

The lower borders of the lungs (Chart 12) are lowered due to an increase in lung volume (emphysema, acute bloating) or low diaphragm standing — with a sharp lowering of the abdominal organs and a decrease in intra-abdominal pressure, as well as with paralysis of the diaphragm.

Chart 12

Percussion boundaries of the lower edges of the lungs

Line	On the right	On the left
midclavicular line	VI rib	It forms a notch corresponding to the boundaries of the heart, departs from the chest at the height of the VI rib and descends steeply downwards
Anterior axillary	VI I rib	VI I rib
Middle axillary	VI I I—IX rib	V I I— I X rib
Posterior axillary	IX rib	IX rib
Scapular	X rib	X rib
Paravertebral	At the level of the spinous process TX,	

The lower borders of the lungs are raised:

- with a decrease in the lungs due to their wrinkling (more often on one side with chronic inflammatory processes);
- when the lungs are pushed back by pleural fluid or gas;
- when the diaphragm is raised due to an increase in intra-abdominal pressure or the diaphragm is pushed up by one or another organ or fluid (flatulence, ascites, enlarged liver or spleen, abdominal tumor).

It is necessary to examine the mobility (excursion) of the lower edge of the lungs. Percussion is used to find the lower border of the lungs along the middle submaxillary or posterior axillary line. Then the patient is asked to take a deep breath and hold it and determine the standing of the lower edge of the lung (the mark is made on the side of the finger that faces